AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

THE COLUMBIA ACCIDENT INVESTIGATION BOARD REPORT

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

SEPTEMBER 4, 2003

Serial No. 108–27

Printed for the use of the Committee on Science

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

U.S. GOVERNMENT PRINTING OFFICE

89–216PS WASHINGTON : 2004

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) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

COMMITTEE ON SCIENCE

HON. SHERWOOD L. BOEHLERT, New York, *Chairman*

LAMAR S. SMITH, Texas
CURT WELDON, Pennsylvania
DANA ROHRABACHER, California
JOE BARTON, Texas
KEN CALVERT, California
NICK SMITH, Michigan
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
GIL GUTKNECHT, Minnesota
GEORGE R. NETHERCUTT, JR., Washington
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
WAYNE T. GILCHREST, Maryland
W. TODD AKIN, Missouri
TIMOTHY V. JOHNSON, Illinois
MELISSA A. HART, Pennsylvania
JOHN SULLIVAN, Oklahoma
J. RANDY FORBES, Virginia
PHIL GINGREY, Georgia
ROB BISHOP, Utah
MICHAEL C. BURGESS, Texas
JO BONNER, Alabama
TOM FEENEY, Florida
RANDY NEUGEBAUER, Texas

RALPH M. HALL, Texas
BART GORDON, Tennessee
JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
NICK LAMPSON, Texas
JOHN B. LARSON, Connecticut
MARK UDALL, Colorado
DAVID WU, Oregon
MICHAEL M. HONDA, California
CHRIS BELL, Texas
BRAD MILLER, North Carolina
LINCOLN DAVIS, Tennessee
SHEILA JACKSON LEE, Texas
ZOE LOFGREN, California
BRAD SHERMAN, California
BRIAN BAIRD, Washington
DENNIS MOORE, Kansas
ANTHONY D. WEINER, New York
JIM MATHESON, Utah
DENNIS A. CARDOZA, California
VACANCY

CONTENTS

September 4, 2003

	Page
Witness List	2
Hearing Charter	3

Opening Statements

Statement by Representative Sherwood L. Boehlert, Chairman, Committee on Science, U.S. House of Representatives	23
Written Statement	24
Statement by Representative Ralph M. Hall, Minority Ranking Member, Committee on Science, U.S. House of Representatives	25
Written Statement	27
Statement by Representative Dana Rohrabacher, Chairman, Subcommittee on Space and Aeronautics, Committee on Science, U.S. House of Representatives	28
Written Statement	29
Statement by Representative Bart Gordon, Member, Committee on Science, U.S. House of Representatives	29
Written Statement	30
Prepared Statement by Representative Joe Barton, Member, Committee on Science, U.S. House of Representatives	31
Prepared Statement by Representative Nick Smith, Chairman, Subcommittee on Research, Committee on Science, U.S. House of Representatives	31
Prepared Statement by Representative Vernon J. Ehlers, Chairman, Subcommittee on Environment, Technology, and Standards, Committee on Science, U.S. House of Representatives	33
Prepared Statement by Representative John Sullivan, Member, Committee on Science, U.S. House of Representatives	33
Prepared Statement by Representative J. Randy Forbes, Member, Committee on Science, U.S. House of Representatives	34
Prepared Statement by Representative Jerry F. Costello, Member, Committee on Science, U.S. House of Representatives	34
Prepared Statement by Representative Eddie Bernice Johnson, Member, Committee on Science, U.S. House of Representatives	35
Prepared Statement by Representative Michael M. Honda, Member, Committee on Science, U.S. House of Representatives	35
Prepared Statement by Representative Sheila Jackson Lee, Member, Committee on Science, U.S. House of Representatives	35

Panel

Admiral Harold W. Gehman, Jr., U.S. Navy retired, Chairman of the *Columbia* Accident Investigation Board, accompanied by Board members Major General Kenneth W. Hess, Dr. James N. Hallock, and Dr. Sheila E. Widnall	
Oral Statement	37
Written Statement	39
Discussion	
Risk	43
Crew Escape	45
Shuttle Replacement	47

Page

Continuing Shuttle Operations 48
NASA's Culture and Management 48
Vision 49
International Space Station and Space Shuttle Mishap Interagency Investigation Board Charter 50
Defining Benchmarks for Progress and Past Reports 50
Schedule Pressure 51
Inaction to Previous Foam Loss 52
Reduction in Safety Procedures 52
Shuttle Servicing of Hubble 52
Schedule Pressure 53
Independent Technical Authority 55
Vision 56
Budget 58
Benchmarks of Implementation 59
Shuttle Design Compromises 60
One-year Review 61
Following Through on the Report's Recommendations 62
Workforce 62
Characteristics of a Follow-on Vehicle 64
Manned vs. Unmanned Science 66
Defining Cultural and Organizational Problems 67
The Culture of Safety 70
Accountability 73
NASA Recruiting and Retention 74
Prioritizing Space Research Within the Federal Budget 74
The Value of Research in Space 75
The Process of Defining a Vision 76
The Difference Between "Observations" and "Recommendations" in the Report 77
NASA Engineering and Safety Center 78
SFOC Board of Investigation 79
Cost Estimates and Mission Parameters of a Follow-on Vehicle 79
ISS Supply 80
Shuttle Support of ISS Construction 80
Funding as a Factor in the Accident 81
Accountability 82

Appendix 1: Answers to Post-Hearing Questions

Admiral Harold W. Gehman, Jr., U.S. Navy retired, Chairman of the *Columbia* Accident Investigation Board 86

THE COLUMBIA ACCIDENT INVESTIGATION BOARD REPORT

THURSDAY, SEPTEMBER 4, 2003

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

The Committee met, pursuant to call, at 10 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

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

Hearing on

The Columbia Accident Investigation Board Report
Thursday, September 4th, 2003
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Admiral Harold Gehman (ret.)
Chairman
Columbia Accident Investigation Board

Accompanied by the following board members

James Hallock, Ph.D.
Manager
Aviation Safety Division
Volpe National Transportation Systems Center

Major General Kenneth W. Hess
Commander
Air Force Safety Center

Sheila E. Widnall, Ph.D.
Institute Professor and Professor of Aeronautics and Astronautics and Engineering Systems
Massachusetts Institute of Technology (MIT)

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 strives to accommodate/meet the needs of those requiring special assistance. If you need special accommodation, please contact the Committee on Science in advance of the scheduled event (3 days requested) at (202) 225-6371 or FAX (202) 225-0891.

Should you need Committee materials in alternative formats, please contact the Committee as noted above.

HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The Columbia Accident Investigation Board Report

THURSDAY, SEPTEMBER 4, 2003
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, September 4th at 10:00 a.m., the Science Committee will hold a Full Committee hearing on the findings and recommendations of the *Columbia* Accident Investigation Board (CAIB). The Committee will receive testimony from retired Navy Admiral Harold Gehman, Chairman of the 13-member Board, along with three members of the Board.

2. Background

This is the first in a series of hearings the Science Committee will hold this fall on the Space Shuttle accident and related problems highlighted in the CAIB report. This hearing provides an opportunity for Admiral Gehman to present the report to the Committee and will set the stage for the follow-up hearings. The overall goal this fall is to fully understand the risks, costs, and benefits of the human space flight program, including the Space Shuttle, and to determine what actions need to be taken to reform NASA.

While the CAIB has said it intends the report to help NASA in safely getting back to human space flight, the report is hard hitting. It describes in detail the specific physical causes of the Shuttle *Columbia*'s demise and documents the failures of NASA's organization in recognizing and dealing with the dangers the Shuttle faced. The CAIB makes a number of recommendations to remedy both problems, some that NASA must meet before the Shuttle returns to flight, and others that the report suggests will take longer to implement. It is likely that Congress will ultimately be responsible for ensuring those recommendations are met.

The CAIB report also cites as contributions to the Shuttle accident NASA's reluctance to realistically assess its ability to conduct human space flight missions on a constrained budget and the lack of a national commitment to an ambitious and probably expensive vision for human space flight. The report sets the stage for a thorough public policy debate regarding the future of human space flight, the prospects for a Shuttle replacement, the appropriate balance of human and robotic missions, future priorities in space exploration, and the level of resources that should be allocated for such activities. The Committee's findings will, among other things, form the basis of a NASA reauthorization bill next year.

3. Witnesses

Admiral Harold Gehman (retired), Chairman, *Columbia* Accident Investigation Board. Formerly Co-Chairman of the Department of Defense review of the attack on the U.S.S. Cole. Before retiring, Gehman served as the NATO Supreme Allied Commander, Atlantic, Commander in Chief of the U.S. Joint Forces Command, and Vice Chief of Naval Operations for the U.S. Navy. Gehman earned a B.S. in Industrial Engineering from Penn State University and is a retired four star Admiral.

James Hallock, Ph.D., Manager, Aviation Safety Division, Volpe National Transportation Systems Center, Massachusetts. Dr. Hallock contributed to Group III of the CAIB, which focused on engineering and technical analysis of the accident and resulting debris. He has worked in the Apollo Optics Group of the MIT Instrumentation Lab and was a physicist at the NASA Electronics Research Center, where he developed a spacecraft attitude determining system. He joined the DOT Transportation Systems Center (now the Volpe Center) in 1970. Hallock received B.S., M.S. and Ph.D. degrees in Physics from the Massachusetts Institute of Technology (MIT). He is an expert in aircraft wake vortex behavior and has conducted safety analyses on air traffic control procedures, aircraft certification, and separation standards, as well as developed aviation-information and decision-support.

Major General Kenneth W. Hess, Commander, Air Force Safety Center, Kirtland Air Force Base, New Mexico, and Chief of Safety, United States Air Force, Headquarters U.S. Air Force, Washington, D.C. Major General Hess contributed to Group II of the CAIB, which scrutinized NASA training, operations, and the in-flight performance of ground crews and the Shuttle crew. Hess entered the Air Force in 1969 and has flown operationally in seven aircraft types. He has commanded three Air Force wings—the 47th Flying Training Wing, 374th Airlift Wing, and 319th Air Refueling Wing—and commanded the U.S. 3rd Air Force, RAF Mildenhall, England. Hess also has extensive staff experience at the Joint Staff and U.S. Pacific Command. He holds a B.B.A. from Texas A&M University and a M.S. in Human Relations and Management from Webster College.

Sheila E. Widnall, Ph.D., Institute Professor and Professor of Aeronautics and Astronautics and Engineering Systems, Massachusetts Institute of Technology (MIT), Massachusetts. Dr. Widnall also contributed to Group III of the CAIB, which focused on engineering and technical analysis of the accident and resulting debris. Widnall has served as Associate Provost, MIT, and as Secretary of the Air Force. She is currently Co-Chairman of the Lean Aero-space Initiative. A leading expert in fluid dynamics, Widnall received her B.S., M.S., and Ph.D. in Aeronautics and Astronautics from MIT.

4. Attachments:

- Executive Summary, *Columbia* Accident Investigation Report.
- Chapter 11, Recommendations, *Columbia* Accident Investigation Report.
- CRS Report, NASA's Space Shuttle *Columbia*, Synopsis of the CAIB Report (RS21606).
- CRS Report, NASA's Space Shuttle *Columbia*: Quick Facts and Issues for Congress (RS21408).

Attachment 1

COLUMBIA ACCIDENT INVESTIGATION BOARD REPORT

VOLUME I

AUGUST 2003

EXECUTIVE SUMMARY

The *Columbia* Accident Investigation Board's independent investigation into the February 1, 2003, loss of the Space Shuttle *Columbia* and its seven-member crew lasted nearly seven months. A staff of more than 120, along with some 400 NASA engineers, supported the Board's 13 members. Investigators examined more than 30,000 documents, conducted more than 200 formal interviews, heard testimony from dozens of expert witnesses, and reviewed more than 3,000 inputs from the general public. In addition, more than 25,000 searchers combed vast stretches of the Western United States to retrieve the spacecraft's debris. In the process, *Columbia*'s tragedy was compounded when two debris searchers with the U.S. Forest Service perished in a helicopter accident.

The Board recognized early on that the accident was probably not an anomalous, random event, but rather likely rooted to some degree in NASA's history and the human space flight program's culture. Accordingly, the Board broadened its mandate at the outset to include an investigation of a wide range of historical and organizational issues, including political and budgetary considerations, compromises, and changing priorities over the life of the Space Shuttle Program. The Board's conviction regarding the importance of these factors strengthened as the investigation progressed, with the result that this report, in its findings, conclusions, and recommendations, places as much weight on these causal factors as on the more easily understood and corrected physical cause of the accident.

The physical cause of the loss of *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam which separated from the left bipod ramp section of the External Tank at 81.7 seconds after launch, and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon panel number 8. During re-entry this breach in the Thermal Protection System allowed superheated air to penetrate through the leading edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and break-up of the Orbiter. This breakup occurred in a flight regime in which, given the current design of the Orbiter, there was no possibility for the crew to survive.

The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.

This report discusses the attributes of an organization that could more safely and reliably operate the inherently risky Space Shuttle, but does not provide a detailed organizational prescription. Among those attributes are: a robust and independent program technical authority that has complete control over specifications and requirements, and waivers to them; an independent safety assurance organization with line authority over all levels of safety oversight; and an organizational culture that reflects the best characteristics of a learning organization.

This report concludes with recommendations, some of which are specifically identified and prefaced as "before return-to-flight." These recommendations are largely related to the physical cause of the accident, and include preventing the loss of foam, improved imaging of the Space Shuttle stack from liftoff through separation of the External Tank, and on-orbit inspection and repair of the Thermal Protection System. The remaining recommendations, for the most part, stem from the Board's findings on organizational cause factors. While they are not "before return-to-flight" recommendations, they can be viewed as "continuing to fly" recommendations, as

they capture the Board's thinking on what changes are necessary to operate the Shuttle and future spacecraft safely in the mid- to long-term.

These recommendations reflect both the Board's strong support for return-to-flight at the earliest date consistent with the overriding objective of safety, and the Board's conviction that operation of the Space Shuttle, and all human space flight, is a developmental activity with high inherent.

Attachment 2

CHAPTER 11

Recommendations

It is the Board's opinion that good leadership can direct a culture to adapt to new realities. NASA's culture must change, and the Board intends the following recommendations to be steps toward effecting this change.

Recommendations have been put forth in many of the chapters. In this chapter, the recommendations are grouped by subject area with the Return-to-Flight (RTF) tasks listed first within the subject area. Each Recommendation retains its number so the reader can refer to the related section for additional details. These recommendations are not listed in priority order.

PART ONE – THE ACCIDENT

Thermal Protection System

R5.2-1 Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

R3.3-2 Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

R3.3-1 Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

R6.4-1 For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

R3.3-3 To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural sub-system damage.

R3.3-4 In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

R3.3-5 Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

R3.8-1 Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions on Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

R3.8-2 Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

Imaging

R3.4-1 Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

R3.4-2 Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

R3.4-3 Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

R6.3-2 Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight while on orbit a standard requirement. [RTF]

Orbiter Sensor Data

R3.6-1 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

R3.6-2 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both as needs change.

Wiring

R4.2-2 As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

Bolt Catchers

R4.2-1 Test and qualify the flight hardware bolt catchers. [RTF]

Closeouts

R4.2-3 Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

Micrometeoroid and Orbital Debris

R4.2-4 Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

Foreign Object Debris

R4.2-5 Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of "Foreign Object Debris" and eliminate any alternate or statistically deceptive definitions like "processing debris." [RTF]

PART TWO – WHY THE ACCIDENT OCCURRED

Scheduling

R6.2-1 Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

Training

R6.3-1 Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

Organization

R7.5-1 Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the sub-system, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in Recommendation R9.1-1.

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

R7.5-3 Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

PART THREE – A LOOK AHEAD

Organization

R9.1-1 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

Recertification

R9.2-1 Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

Closeout Photos/Drawing System

R10.3-1 Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

R10.3-2 Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including:

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

Columbia
United States

Attachment 3

Order Code RS21606
September 2, 2003

CRS Report for Congress
Received through the CRS Web

NASA's Space Shuttle Columbia: Synopsis of the Report of the Columbia Accident Investigation Board

Marcia S. Smith
Specialist in Aerospace and Telecommunications Policy
Resources, Science, and Industry Division

Summary

NASA's space shuttle *Columbia* broke apart on February 1, 2003 as it returned to Earth from a 16-day science mission. All seven astronauts aboard were killed. NASA created the *Columbia* Accident Investigation Board (CAIB), chaired by Adm. (Ret.) Harold Gehman, to investigate the accident. The Board released its report (available at [http://www.caib.us]) on August 26, 2003, concluding that the tragedy was caused by technical and organizational failures. The CAIB report included 29 recommendations, 15 of which the Board specified must be completed before the shuttle returns to flight status. This report provides a brief synopsis of the Board's conclusions, recommendations, and observations. Further information on *Columbia* and issues for Congress are available in CRS Report RS21408. This report will not be updated.

The National Aeronautics and Space Administration (NASA) launched the space shuttle *Columbia* on its STS-107 mission on January 16, 2003. On February 1, 2003, as it descended to Earth after completing a 16-day scientific research mission, *Columbia* broke apart over northeastern Texas. All seven astronauts aboard were killed. They were Commander Rick Husband; Pilot William McCool; Mission Specialists Michael P. Anderson, David M. Brown, Kalpana Chawla, and Laurel Clark; and payload specialist Ilan Ramon, an Israeli. Within hours, NASA Administrator Sean O'Keefe appointed an external group, the *Columbia* Accident Investigation Board (CAIB), to investigate the accident. Chaired by **Adm. (Ret.) Harold Gehman**, CAIB released the results of its investigation on August 26, 2003. The 248-page report is available at CAIB's Web site [http://www.caib.us]. Additional volumes are planned for publication later.

CAIB's Conclusions

The following synopsis focuses on what appear to be the major questions being asked about the CAIB's findings about the tragedy and recommendations on the future of the shuttle program. All quotations are from the CAIB report unless otherwise noted.

What Caused the *Columbia* Accident? The Board "recognized early on that the accident was probably not an anomalous, random event, but rather likely rooted to some degree in NASA's history and the human space flight program's culture." (p. 9) Therefore, it also looked at "political and budgetary considerations, compromises, and changing priorities over the life" of the shuttle program, and "places as much weight on these causal factors as on the ... physical cause...." (p. 9)

The **physical cause** was damage to *Columbia*'s left wing by a 1.7 pound piece of insulating foam that detached from the left "bipod ramp" that connects the External Tank[1] to the orbiter, and struck the orbiter's left wing 81.9 seconds after launch. The foam strike created a hole in a Reinforced Carbon-Carbon (RCC) panel on the leading edge of the wing, allowing superheated air (perhaps exceeding 5,000°F) to enter the wing during reentry. The extreme heat caused the wing to fail structurally, creating aerodynamic forces that led to the disintegration of the orbiter. (Described in detail in Chapters 2 and 3.)

Regarding **organizational causes**, the Board concluded the accident was —

> ... rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices..., organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules. (p. 9)

The Board found that there is a **"broken safety culture"** at NASA (pp. 184-189). **Schedule pressure** (pp. 131-139) related to construction of the International Space Station, **budget constraints** (pp. 102-105), and **workforce reductions** (pp. 106-110) also were factors. The Board concluded that the shuttle program "has operated in a challenging and often turbulent environment...." (p. 118) "It is to the credit of Space Shuttle managers and the Shuttle workforce that the vehicle was able to achieve its program objectives for as long as it did." (p. 119)

Should the Shuttle Continue to Fly? The Board concluded that "the present Shuttle is not inherently unsafe" but the "observations and recommendations in this report are needed to make the vehicle safe enough to operate in the coming years." (p. 208) CAIB "supports return to flight for the Space Shuttle at the earliest date consistent with an

---

[1] The Space Transportation System (STS)—the space shuttle—consists of an airplane-like Orbiter, two Solid Rocket Boosters (SRBs) on either side, and a large cylindrical External Tank that holds cryogenic fuel for the Orbiter's main engines. The SRBs detach from the orbiter 2 ½ minutes after launch when their fuel is spent, fall into the ocean, and are recovered for refurbishment and reuse. The External Tank is not reused. It is jettisoned as the Orbiter reaches Earth orbit, and disintegrates as it falls into the Indian Ocean.

overriding consideration: safety." (p. 208) NASA has a target of March/April 2004 for return to flight, and Adm. Gehman stated in an interview on PBS' The NewsHour with Jim Lehrer on August 26 that he saw no reason why NASA could not meet that schedule.

The CAIB report contains 29 recommendations (listed below)—23 technical and six organizational—of which 15 must be implemented before the shuttle returns to flight status. The others are "continuing to fly" recommendations assuming the shuttle will be used for years to come. The Board recommended that, if the shuttle is to be used beyond 2010, that it be recertified (p. 209). But the Board said it reached an "inescapable conclusion"—

> *Because of the risks inherent in the original design of the Space Shuttle, because the design was based in many aspects on now-obsolete technologies, and because the Shuttle is now an aging system but still developmental in character, it is in the nation's interest to replace the Shuttle as soon as possible as the primary means for transporting humans to and from Earth orbit.* (p. 210-211. Emphasis in original.)

Why Did NASA Decide Not to Obtain Imagery from DOD Satellites to Assess the Damage? A central question during the investigation was why NASA did not ask the Department of Defense (DOD) to image the shuttle with its high resolution ground- or space-based systems to help assess whether the orbiter had been damaged by the foam. The Board found (pp. 140-172) that three requests for imagery were made by NASA engineers but through incorrect channels, plus there were several "missed opportunities"when managers could have pursued the issue. One request did reach the appropriate DOD personnel, but NASA canceled the request 90 minutes later. The Board concluded that the likely sequence of events was that the chair of STS-107's Mission Management Team (MMT), after informally learning that there had been a "request" for imagery, called three other MMT members and determined that none knew of a "requirement" for imagery. CAIB cited a flawed analysis of the extent to which the orbiter might have been damaged by the foam that was too readily accepted by program managers, a low level of concern by program managers, a lack of clear communication, a lack of effective leadership, and a failure of the role of safety personnel as reasons why the imagery was not obtained. Whether such images would, in fact, have shown the damage remains unclear, but the Board recommended that such images now be taken on all shuttle missions.

Could the Crew Have Been Saved? The Board concluded that the crew died from "blunt trauma and hypoxia" (lack of oxygen) after the crew cabin separated from the rest of the disintegrating shuttle and, itself, disintegrated; there was no explosion. (p. 77) The Board asked NASA to evaluate two options for returning the crew safely if the degree of damage had been understood early in the mission: repairing the damage on-orbit, or rescuing the crew with another shuttle mission. The repair option "while logistically viable....relied on so many uncertainties that NASA rated this option 'high risk.'" (p. 173) The rescue option "was considered challenging but feasible." (p. 174)

What Are the "Echoes" of *Challenger*? Former shuttle astronaut Sally Ride served on the Rogers Commission that investigated the January 1986 *Challenger* accident, which claimed the lives of seven astronauts, and on CAIB. During the *Columbia* investigation, she said she heard "echoes" of *Challenger* as it became clear that the accident resulted from NASA failing to recognize that a technical failure (bipod ramp foam shedding) that had occurred on previous shuttle flights could have safety-of-flight implications even if the earlier missions were completed successfully. In the case of

Challenger, it was erosion of seals (O-rings) between segments of the Solid Rocket Booster, which had been noted on previous missions. Some engineers warned NASA not to launch *Challenger* that day because unusually cold weather could have weakened the resiliency of the O-rings. They were overruled. CAIB concluded that "both accidents were 'failures of foresight'" and the parallels between them demonstrate that: "the causes of the institutional failure responsible for *Challenger* have not been fixed"; "if these persistent, systemic flaws are not resolved, the scene is set for another accident"; and that while individuals must be accountable for their actions, "NASA's problems cannot be solved simply by retirements, resignations, or transferring personnel." (p. 195)

CAIB's Recommendations and Observations

CAIB's 29 recommendations are compiled in Chapter 11 of its report. Adm. Gehman stated at the Board's August 26 press conference that there is no hierarchy in the recommendations—all have equal weight. The Board also made 27 "observations" in Chapter 10. Following are abbreviated versions of the recommendations—separated into those that must be implemented prior to Return to Flight, and those that are "continuing to fly" recommendations—and observations. Some have been combined for brevity.

Return to Flight (RTF) Recommendations. CAIB recommends that NASA:

- initiate an aggressive program to eliminate all External Tank foam shedding;
- initiate a program to increase the orbiter's ability to sustain minor debris damage;
- develop and implement a comprehensive inspection plan to assess the structural integrity of the RCC panels, supporting structure, and attaching hardware;
- develop a practical capability to inspect and effect emergency repairs to the orbiter's thermal protection system (TPS) both when near the International Space Station and when operating away from it, and accomplish an on-orbit TPS inspection;
- upgrade the ability to image the shuttle during its ascent to orbit;
- obtain and downlink high resolution images of the External Tank after it separates from the orbiter, and of certain orbiter thermal protection systems;
- ensure that on-orbit imaging of each shuttle flight by Department of Defense satellites is a standard requirement;
- test and qualify "bolt catchers" used on the shuttle;
- require that at least two employees attend final closeouts and intertank area hand-spraying procedures when applying foam to the External Tank;
- require NASA and its contractors to use the industry-standard definition of "foreign object debris";
- adopt and maintain a shuttle flight schedule that is consistent with available resources;
- implement an expanded training program for the Mission Management Team;
- prepare a detailed plan for creating an independent Technical Engineering Authority, independent safety program, and reorganized space shuttle integration office; and
- develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings.

Continuing to Fly Recommendations. The Board recommends that NASA:

- increase the orbiter's ability to reenter the atmosphere with minor leading edge damage to the extent possible;

- develop a better database to understand the characteristics of Reinforced Carbon-Carbon (RCC) by destructive testing and evaluation;
- improve the maintenance of launch pad structures to minimize leaching of zinc primer onto RCC;
- obtain sufficient RCC panel spares so maintenance decisions are not subject to external pressures relating to schedules, costs, or other considerations;
- develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts;
- maintain and update the Modular Auxiliary Data System (MADS) on each orbiter to include current sensor and data acquisition technologies, and redesign the MADS so they can be reconfigured during flight;
- develop a state-of-the-art means to inspect orbiter wiring;
- operate the shuttle with the same degree of safety for micrometeoroid and orbital debris as is used in the space station program, and change guidelines to requirements;
- establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, which should be funded directly from NASA Headquarters and have no connection to or responsibility for schedule or program cost;
- give direct line authority over the entire shuttle safety organization to the Headquarters Office of Safety and Mission Assurance, which should be independently resourced;
- reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter;
- develop and conduct a vehicle recertification prior to operating the shuttle beyond 2010 and include recertification requirements in the Shuttle Life Extension Program; and
- provide adequate resources for a long-term program to upgrade shuttle engineering drawings.

Observations. Chapter 10 lists 27 observations—"significant issues that are potentially serious matters that should be addressed ... because they fall into the category of 'weak signals' that could be indications of future problems." Therefore, NASA should:

- develop and implement a public risk acceptability policy for launch and reentry of space vehicles and unmanned aircraft;
- develop and implement a plan to mitigate the risk that shuttle flights pose to the general public;
- study the *Columbia* debris to facilitate realistic estimates of the risk to the public during orbiter reentry;
- incorporate knowledge gained from *Columbia* in requirements for future crewed vehicles in assessing the feasibility of vehicles that could ensure crew survival even if the vehicle is destroyed;
- perform an independent review of the Kennedy Space Center (KSC) Quality Planning Requirements Document to address the quality assurance program and its administration, consolidate KSC's Quality Assurance programs under one Mission Assurance Office that reports to the Center Director, require quality assurance managers to work with NASA and perhaps DOD to develop training programs, and examine which areas of ISO 9000/9001 truly apply to a 20-year old research and development system like the space shuttle;
- use statistical sampling for Quality and Engineering review of work documents for the next shuttle flight (STS-114);

- implement United Space Alliance's (USA's) suggestions for process improvement;
- create an oversight process to statistically sample the work performed by USA technicians to ensure process control, compliance, and consistency;
- make every effort to achieve greater stability, consistency, and predictability in Orbiter Major Modification planning, scheduling, and work standards;
- better understand workforce and infrastructure requirements, match them against capabilities, and take actions to avoid exceeding thresholds;
- continue to work with the Air Force on aging systems, service life extension, planning and scheduling, workforce management, training, and quality assurance;
- determine how the shuttle program office will meet the challenges of inspecting and maintaining an aging shuttle fleet;
- include non-destructive analysis of the potential impacts on structural integrity when evaluating corrosion damage, make long-term corrosion detection a funding priority, develop non-destructive inspections to find hidden corrosion, and establish orbiter-specific corrosion rates for orbiter-specific environments;
- do not use Teflon and Molybdenum Disulfide in the carrier panel bolt assembly;
- mitigate galvanic coupling between aluminum and steel alloys;
- review the use of Room Temperature Vulcanizing 560 and Koropon;
- assure the continued presence of compressive stresses in A-286 bolts in their acceptance and qualification procedures;
- consider a redesign of the "hold-down" bolt system;
- reinstate a safety factor of 1.4 for the solid rocket booster attachment rings;
- assess whether upgrading to digital test equipment will provide the reliability and accuracy needed to maintain the shuttle through 2020; and
- implement an agency-wide strategy for leadership and management training that provides a more consistent and integrated approach to career development.

General Deal's Supplemental Views

Air Force Brig. Gen. Duane Deal, a CAIB member, wrote a "supplement" that is scheduled to be published in Volume II as Appendix D. Some of the views in the supplement were reported by the media on August 27. CAIB supplied a copy of the document to CRS, emphasizing that it represents supplemental, not dissenting, views.

Gen. Deal expressed concern that NASA may not fully implement the CAIB's recommendations, and particularly its observations. "History shows that NASA often ignores strong recommendations; without a culture change, it is overly optimistic to believe NASA will tackle something relegated to an 'observation' when it has a record of ignoring recommendations." He said the supplement is written from the perspective of someone "who fears the [CAIB] report has bypassed some items that could prevent 'the next accident' from occurring—the 'next' O-ring or the 'next' bipod ramp." He believes the observations should have been characterized as "'strong signals' that are indications of present and future problems" rather than "weak signals" that could indicate future problems. Among the areas he listed as needing further attention are: Quality Assurance (unresponsive management, staffing levels, grade levels, inspector qualifications, employee training, providing necessary tools, government inspections, and quality program surveillance); Orbiter Corrosion; Solid Rocket Booster External Tank Attach Ring; Crew Survivability; Shiftwork and Overtime; security of Redesigned Solid Rocket Motors when they are shipped from the manufacturer; and security at NASA's Michoud Assembly Facility where the External Tanks are assembled.

Attachment 4

Order Code RS21408
Updated October 6, 2003

CRS Report for Congress

Received through the CRS Web

NASA's Space Shuttle Columbia: Quick Facts and Issues for Congress

Marcia S. Smith
Specialist in Aerospace and Telecommunications Policy
Resources, Science, and Industry Division

Summary

On February 1, 2003, NASA's Space Shuttle *Columbia* broke apart while returning to Earth from a 16-day science mission in orbit. All seven astronauts—six Americans and one Israeli—were killed. An investigation board issued its report on the accident on August 26, 2003, which is available at [http://www.caib.us]. A synopsis is provided in CRS Report RS21606. This report provides quick facts about *Columbia*, an overview of the investigation board's report, and a brief discussion of issues for Congress. More information on the space shuttle is available in CRS Issue Brief IB93062, CRS Report RS21411, and CRS Report RS21419. This report is updated regularly.

The Loss of the Space Shuttle *Columbia*

The space shuttle *Columbia* was launched on its STS-107 mission on January 16, 2003. After completing a 16-day scientific research mission, *Columbia* started its descent to Earth on the morning of February 1, 2003. As it descended from orbit, approximately 16 minutes before its scheduled landing at Kennedy Space Center, FL, *Columbia* broke apart over northeastern Texas. All seven astronauts aboard were killed. They were Commander Rick Husband; Pilot William McCool; Mission Specialists Michael P. Anderson, David M. Brown, Kalpana Chawla, and Laurel Clark; and payload specialist Ilan Ramon, an Israeli. The last communication with *Columbia* was at about 09:00 EST. The shuttle was at an altitude of 207,135 feet, traveling at a speed of Mach 18.3 (about 13,000 miles per hour).

NASA Administrator Sean O'Keefe immediately appointed an internal "Mishap Investigation Board," (MIB) and also an external group, the "*Columbia* Accident Investigation Board" (CAIB), to investigate the accident. MIB was replaced by the NASA Accident Investigation Team (NAIT) on March 21, 2003. Much of the information NASA is releasing to the public can be obtained at [http://www.nasa.gov/columbia/]. The CAIB is discussed below. It has its own Web site [http://www.caib.us].

The Space Shuttle *Columbia* and the STS-107 Mission

The Space Transportation System (STS)—the space shuttle—consists of an airplane-like orbiter, two Solid Rocket Boosters (SRBs) on either side, and a large cylindrical External Tank that holds the fuel for the orbiter's main engines. The SRBs detach from the orbiter 2 ½ minutes after launch when their fuel is spent, fall into the ocean, and are recovered for refurbishment and reuse. The External Tank is not reused. It is jettisoned as the orbiter reaches Earth orbit, and disintegrates as it falls into the Indian Ocean.

Columbia was one of four flightworthy reusable space shuttle orbiters in NASA's fleet. The others are *Discovery*, *Atlantis*, and *Endeavour*. A fifth orbiter, *Challenger*, was lost in a 1986 accident. Another orbiter, *Enterprise*, was used for approach and landing tests in the 1970s and was not designed to travel in space. *Enterprise* now belongs to the Smithsonian's National Air and Space Museum.

Columbia was the first spaceflight-worthy orbiter built for NASA by Rockwell International (the space division of Rockwell, which built the orbiters, was later bought by Boeing). It was used for the very first shuttle flight on April 12, 1981. The STS-107 mission was *Columbia*'s 28th flight. Although *Columbia* was the oldest orbiter, *Discovery* has been used for more flights (30). NASA has conducted a total of 113 shuttle launches to date. Orbiters are periodically taken out of service for maintenance and overhaul. *Columbia* last underwent such an "orbiter major modification" (OMM) period in 1999-2001. STS-107 was *Columbia*'s second flight after the OMM. It was a scientific research mission that, unlike most current shuttle launches, was not related to the International Space Station (ISS) program (see CRS Issue Brief IB93017). The crew conducted a research program involving 59 separate investigations. Some of the research required analysis of specimens and data sets after the shuttle returned to Earth, and most were destroyed along with the crew and orbiter. Other data, however, were transmitted to ground-based researchers during the flight, and a few specimens were retrieved among the debris, so some of the research survived. Quantifying the amount is difficult.

Previous Spaceflight-Related Crew Fatalities

The United States has suffered two other spaceflight-related accidents that caused astronaut fatalities. On January 27, 1967, the crew of the first Apollo mission—Virgil "Gus" Grissom, Edward White, and Roger Chaffee—died when electrical arcing in spacecraft wiring caused a fire in their Apollo command module during a pre-launch test. Apollo flights resumed after 21 months. On January 28, 1986, the space shuttle *Challenger* (STS 51-L) exploded 73 seconds after launch, killing all seven astronauts aboard: Francis "Dick" Scobee, Michael Smith, Judith Resnik, Ellison Onizuka, Ronald McNair, Gregory Jarvis (a payload specialist from Hughes Aircraft), and schoolteacher Christa McAuliffe. A presidentially-created commission, chaired by former Secretary of State William Rogers, determined that cold weather at the launch site caused a rubber "O-ring" in one of the SRBs to fail, allowing gases to escape, resulting in a catastrophic explosion. The shuttle system was grounded for 32 months.

Four Soviet cosmonauts also died during spaceflights. Cosmonaut Vladimir Komarov died during the first Soyuz flight on April 24, 1967. The spacecraft's parachutes did not function properly and it struck the ground with great force, killing

Colonel Komarov. Soviet human spaceflights were suspended for 18 months. Three cosmonauts died on Soyuz 11 on June 29, 1971 when an improperly sealed valve allowed the spacecraft's atmosphere to vent into space. The cosmonauts—Georgiy Dobrovolskiy, Vladislav Volkov, and Viktor Patsayev—were not wearing spacesuits, and were asphyxiated. There were no Soviet human spaceflights for 27 months.

The *Columbia* Accident Investigation Board (CAIB)

NASA Administrator O'Keefe established the *Columbia* Accident Investigation Board (CAIB) within hours of the tragedy, and transitioned responsibility for the investigation to it on February 6. Chaired by **Adm. (Ret.) Harold Gehman**, former NATO Supreme Allied Commander, Atlantic, CAIB had 12 other members (see [http://www.caib.us]). All were appointed by Mr. O'Keefe, although some were added to the initial roster upon the recommendation of Adm. Gehman. NASA revised the Board's charter three times to clarify its independence from NASA, primarily in response to congressional concerns. However, the CAIB was created by NASA, includes NASA representatives, and the Board members were appointed by the NASA Administrator, so concerns about its independence remain. CAIB released the results of its investigation on August 26, 2003. The report is available at its Web site. Additional volumes are planned for publication later. Board member Brig. Gen. Duane Deal wrote a 10-page "supplement" to the report that will be published in Vol. 2. It provides additional recommendations and viewpoints that Gen. Deal felt important to convey.

The Cause of the Accident. The Board concluded that the tragedy was caused by both technical and organizational failures. The technical cause was damage to *Columbia*'s left wing by a 1.7 pound piece of insulating foam that separated from the External Tank's left "bipod ramp" and struck the orbiter's left wing 81.9 seconds after launch. The foam strike created a hole in a Reinforced Carbon-Carbon (RCC) panel on the leading edge of the wing, allowing superheated air (perhaps exceeding 5,000°F) to enter the wing during reentry. The extreme heat caused the wing to fail structurally, creating aerodynamic forces that led to the disintegration of the orbiter. Organizationally, the Board pointed to detrimental cultural traits and organizational practices that developed over the institutional history of the program. Adm. Gehman cited a loss of "checks and balances" in the program's management that should have led to a recognition of the danger posed by "foam shedding" from the External Tank, which had occurred on previous shuttle missions. The Board also cited long term budget constraints as a factor.

CAIB's Recommendations. The CAIB made 29 recommendations, five of which were issued prior to the report's release. Of those 29, 23 are technical and six are organizational. CRS Report RS21606 provides a synopsis of them. Of the 29 recommendations, the Board specified 15 that must be completed before the shuttle returns to flight status, including that NASA should:

- develop and implement a comprehensive inspection plan to assess the structural integrity of the RCC panels, supporting structure, and attaching hardware;
- ensure that on-orbit imaging of each shuttle flight by Department of Defense satellites is a standard requirement;
- develop a practical capability to inspect and effect emergency repairs to the orbiter's thermal protection system both when near the International Space Station and when operating away from it;

- augment the ability to image the shuttle during its ascent to orbit;
- obtain and downlink high resolution images of the External Tank after it separates from the orbiter, and of certain orbiter thermal protection systems;
- initiate an aggressive program to eliminate all External Tank foam shedding;
- initiate a program to increase the orbiter's ability to sustain minor debris damage;
- test and qualify "bolt catchers" used on the shuttle;
- adopt and maintain a shuttle flight schedule that is consistent with available resources;
- implement an expanded training program for the Mission Management Team; and
- prepare a plan for creating an independent Technical Engineering Authority, independent safety program, and reorganized space shuttle integration office.

Issues for Congress

Congressional hearings are focusing not only on the shuttle program, but more broadly on the nation's human spaceflight goals and implications for NASA's budget. Among the many questions likely to be addressed are the following.

Future of the Shuttle and the U.S. Human Spaceflight Program. A fundamental question is whether the benefits of human spaceflight are worth its risks and costs. CAIB hopes that the *Columbia* tragedy stimulates a national debate about future goals for the U.S. human spaceflight program. As the public and policy makers consider what goals, if any, are sufficiently compelling to warrant exposing crews to the risks inherent in human spaceflight, and the expenditures needed to achieve them, debate is likely to focus on whether the nation should commit itself to a goal of sending humans back to the Moon or to Mars, or to rely more heavily on robotic spacecraft to explore the solar system. In the near-term, decisions will be needed about the future of the existing human spaceflight program. Several options are available, each with its own pros and cons, which are discussed in CRS testimony to the Senate Commerce Committee, April 2, 2003, at [http://commerce.senate.gov] (click on the PDF version of the testimony):

- Terminate the U.S. human spaceflight program, including the space shuttle, U.S. participation in the International Space Station (ISS) program, and plans to develop an Orbital Space Plane.
- Terminate the shuttle and Orbital Space Plane programs, but continue participation in the ISS program, relying on Russian vehicles for taking U.S. astronauts to and from space when possible.
- Terminate the shuttle program, but continue participation in the ISS program and continue to develop the Orbital Space Plane or another replacement for the shuttle.
- Continue the shuttle program, but with fewer missions—perhaps limiting it to space station visits—and as few crew as possible.
- Resume the human spaceflight program, including shuttle flights, as planned.

Based on past experience and current polls, many expect the last option to be chosen. Therefore, debate may focus on how to reduce the risk of an accident, and increase the likelihood of crew survivability if an accident occurs. A USA Today/CNN/Gallup poll found that 43% of those polled were willing to accept one fatal shuttle accident every 100 missions, 19% every 50 missions, 7% every 20 missions, 6% every 10 missions, and 17% none (USA Today, August 19, 2003, A 1). Those numbers suggest that a large percentage

of the public is willing to accept the risks inherent in human spaceflight, but within limits. Questions that may arise include:

- Should NASA invest more money in developing crew escape systems to help assure the crew's survival if an accident occurs?
- What would be required to modify the shuttle to operate autonomously, or with fewer crew?
- Should efforts to develop a vehicle to replace or complement the shuttle—such as the Orbital Space Plane now being designed—be accelerated? Is the nation willing to invest the resources needed to develop a new vehicle during a time of record budget deficits and substantial budget demands for other national priorities?

Timing of "Return to Flight". Assuming that the decision is made to continue the shuttle program, the question arises as to when it will be ready to return to flight status. NASA established a "Return to Flight" (RTF) team soon after the tragedy to ensure the agency was ready to resume flights at the earliest opportunity. NASA officials had targeted March/April 2004 for RTF, but currently think that September/October 2004 is more likely. NASA officials refer to a "sense of urgency" to resume shuttle launches, but insist the RTF process will be deliberate and cautious. CAIB said NASA should return to flight at "the earliest date consistent with the overriding objective of safety" and separated its recommendations into those that must be completed before RTF, and others that are "continuing to fly" recommendations if the shuttle is to be used for years to come. Although the Board cited both technical and organizational failures as causes of the accident, it concluded that many of the organizational changes would take a long time to fix and need not delay RTF. The urgency to return to flight apparently stems from a desire to proceed expeditiously with construction of the International Space Station. Questions that may arise include:

- To what extent should space station construction drive the schedule for returning the shuttle to flight status? Russian Soyuz and Progress spacecraft can be used to rotate crews and resupply the station as long as funds are available to construct them. If funds are not available, the station could be destaffed, although there is concern that a technical malfunction could imperil the station if it could not be solved remotely by sending commands from the ground. Schedule delays also would increase the program's costs. Those concerns would have to be weighed against the repercussions if the shuttle returns to flight too hurriedly and suffers a major failure.
- Could schedule pressure cause NASA to take shortcuts in fixing the shuttle? The CAIB report cites space station schedule pressure as a factor in the *Columbia* accident. How will a similar result be avoided now?

Causes of the *Columbia* Accident. The CAIB report details technical and organizational failures, and budgetary constraints, that led to the accident. Questions on which Congress may focus include:

- To what extent was the accident caused by inadequate funding? What funding will be required in the future to ensure that the shuttle is as safe as possible? Is the nation willing to invest those resources?
- Why did NASA and its contractors not consider foam striking the shuttle to be a safety-of-flight concern? What other technical issues exist with the shuttle today that similarly may not be sufficiently appreciated?

- What "cultural" changes are needed at the agency to ensure that future shuttle launches do not involve unnecessary risk? Some personnel already have been removed from their positions; are other personnel changes needed to ensure the agency and the shuttle program have the leadership necessary to effect such changes?

Oversight of NASA's Response to CAIB. Questions are arising about what group should oversee NASA's compliance with the CAIB recommendations. NASA created a task group chaired by two former astronauts—Thomas Stafford and Richard Covey— to assess NASA's implementation of the CAIB recommendations "as they relate to the safety and operational readiness of STS-114," the next shuttle flight (see[http://www.nasa.gov/news/highlights/returntoflight.html]). Col. Covey has stated that the group plans to complete its work one month before RTF, and its charter does not include addressing many of the organizational and cultural issues raised by the CAIB report. Questions that may arise include:

- Is the NASA-created Stafford/Covey Task Group the best mechanism for overseeing NASA's compliance regarding technical fixes, or should an independent committee, separate from NASA, be established, as was done following the *Challenger* accident? In that case, the Rogers Commission directed that the National Research Council oversee NASA's redesign of the solid rocket boosters.
- What group should oversee NASA's compliance with the other CAIB recommendations, such as needed organizational and cultural changes? Should CAIB be reconvened periodically? Adm. Gehman told the House Science Committee that the group agreed to reconvene in one year if asked. Should another group be created, and, if so, by whom—Congress, the White House, or NASA? (H.R. 3219 would create a panel of the National Academies of Science and Engineering to provide that oversight.)

Budget Implications. Mr. O'Keefe states that he does not know how much it will cost to fix the shuttle. Congress is currently considering NASA's FY2004 budget request as part of the VA-HUD-IA appropriations bill (H.R. 2861/S. 1584). That request, formulated prior to the tragedy, includes $3.968 billion for the shuttle program. For FY2003, Congress approved NASA's full request for the shuttle and added $50 million for the *Columbia* investigation and remedial actions (see CRS Report RL31347). Another $50 million was included in the FY2004 Legislative Branch Appropriations act (P.L. 108-83). NASA estimates that, in FY2003, it will need $152.5 million for Recovery and Investigation, and $40 million for initial activities related to Return to Flight (NASA notified Congress in September that it plans to take $40 million from its space science and aerospace technology activities to cover that cost). NASA officials have said they expect savings of $30 million in FY2003 because not as many shuttle missions were launched as expected, and that additional savings from "underexecuting" the program may be achieved. At the same time, costs for the space station program may increase because of schedule delays, and NASA wants to accelerate development of the Orbital Space Plane (OSP, discussed in CRS Issue Brief IB93017). Thus the budget implications in FY2004 and beyond could be significant.

Chairman BOEHLERT. The hearing will come to order. I want to welcome everyone here for the first of what will be an extensive series of hearings on the future of the Shuttle program, and of the manned space flight programs, in general. This is a pivotal moment in NASA's history, and this committee intends to lead the way in examining the issues that will enable Congress and the White House to chart NASA's future. Perhaps I should say in "confronting the issues" because moving forward will require asking tough questions and facing up to tough choices.

We will be better able to do that because of the extraordinary work that has been done by Admiral Gehman and the entire membership and staff of the *Columbia* Accident Investigation Board. The Board members have been inspiring models: independent, focused, inquiring, tough, candid, and accessible. The Board report has to be the starting point for setting NASA's future course.

If the Shuttle is to return to flight, then, at a minimum, every single one of the CAIB's return-to-flight recommendations must be implemented. That includes the recommendation that NASA have a detailed plan for addressing the organizational and cultural deficiencies the CAIB has so convincingly described. Indeed, Mr. Hall and I wrote to Admiral Gehman back in the early summer suggesting just that sort of recommendation to help ensure that NASA would act on the central recommendations concerning organization and culture.

I think all of us need to face up to the rather disheartening picture of NASA that has been so painstakingly drawn by the CAIB. If we fail to do so, it is readily apparent that we will just have to go through this same and sad exercise again. NASA's experience may be the ultimate proof of Santayana's famous observation about those who fail to learn from the past being doomed to repeat it.

The sad fact is that the loss of the *Columbia* and her crew was preventable. This is not even close to being a case in which the problems could only be seen in hindsight. We need to clearly identify and root out each of the systemic and individual failures that led to this accident. The CAIB report is a blueprint for doing so. The memory of the *Columbia* crew compels us to do no less.

I have to say that I am concerned about some of the ways NASA has been approaching the return-to-flight thus far. I admire Administrator O'Keefe and I am pleased he has embraced the CAIB report with his words. But deeds are what count. And I am concerned that NASA may already be rushing to meet unrealistic launch dates instead of examining this report closely and moving deliberately.

I am also concerned that NASA has been trumpeting changes in its safety organization that do not appear to address any of the problems that have been persuasively identified in the Board's report. Delay is not the goal, but if safety is to improve, NASA must not be judging itself by how quickly it can send the Shuttle back into orbit.

And undue haste is ill advised for another reason, too. We, as a Committee, and as a nation, need some time to consider our overall space policy.

We need to make fundamental decisions about the future of the Shuttle program and of the manned space flight program. We need

to get, perhaps for the first time, accurate cost estimates of what it will cost to run the Space Shuttle and other manned programs safely and accurate descriptions of what they will be able to accomplish. I, for one, am not willing to write NASA a blank check for the Shuttle program.

We also need to have a better appraisal of what the risks are of operating the Space Shuttle, because even after implementing the CAIB recommendations, the Shuttle will continue to be a risky vehicle, and I am not willing to see the Shuttle fly without regard to the level of risk.

Finally, we need to better define NASA's overarching human space flight vision: something that has been lacking for more than a generation. That won't be easy, and it can only be done after hearings that will enable us to make a clear-eyed appraisal of the costs, benefits, and risks of different options.

So I approach today's hearing soberly because of the tragedy that has brought us here and the daunting tasks that lie ahead. But I also approach today with eagerness, because we have a rare chance to reshape our nation's space program, and we will be able to benefit from the outstanding work of Admiral Gehman and his team. I look forward to hearing from them.

Mr. Hall.

[The prepared statement of Mr. Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD BOEHLERT

I want to welcome everyone here for the first of what will be an extensive series of hearings on the future of the Shuttle program, and of the manned space flight programs, in general. This is a pivotal moment in NASA's history, and this committee intends to lead the way in examining the issues that will enable Congress and the White House to chart NASA's future. Perhaps I should say in "confronting the issues" because moving forward will require asking tough questions and facing up to tough choices.

We will be better able to do that because of the extraordinary work that has been done by Admiral Gehman and the entire membership and staff of the *Columbia* Accident Investigation Board (CAIB). The Board members have been inspiring models—independent, focused, inquiring, tough, candid and accessible. The CAIB report has to be the starting point for setting NASA's future.

If the Shuttle is to return to flight, then, at a minimum, every one of the CAIB's return-to-flight recommendations must be implemented. That includes the recommendation that NASA have a detailed plan for addressing the organizational and cultural deficiencies the CAIB has so convincingly described. Indeed, Mr. Hall and I wrote to Admiral Gehman back in July suggesting just that sort of recommendation to help ensure that NASA would act on the central recommendations concerning organization and culture.

I think all of us need to face up to the rather disheartening picture of NASA that has been so painstakingly drawn by the CAIB. If we fail to do so, it's readily apparent that we will just have to go through this same sad exercise again. NASA's experience may be the ultimate proof of Santayana's famous observation about those who fail to learn from the past being doomed to repeat it.

The sad fact is that the loss of the *Columbia* and her crew was preventable. This is not even close to being a case in which the problems could only be seen in hindsight. We need to clearly identify and root out each of the systemic and individual failures that led to this accident. The CAIB report is a blueprint for doing so. The memory of the *Columbia* crew compels us to do no less.

I have to say that I am concerned about some of the ways NASA has been approaching the return-to-flight thus far. I admire Administrator O'Keefe and I'm pleased he has embraced the CAIB report with his words. But deeds are what will count. And I'm concerned that NASA may already be rushing to meet unrealistic launch dates instead of examining this report closely and moving deliberately.

I'm also concerned that NASA has been trumpeting changes in its safety organization that do not appear to address any of the problems that have been persuasively

identified in the CAIB report. Delay is not the goal, but if safety is to improve, NASA must not be judging itself by how quickly it can send the Shuttle back into orbit.

And undue haste is ill-advised for another reason, too. We, as a committee, and as a nation, need some time to consider our overall space policy.

We need to make fundamental decisions about the future of the Shuttle program and of the manned space flight program. We need to get, perhaps for the first time, accurate cost estimates of what it will cost to run the Space Shuttle and other manned programs safely and accurate descriptions of what they will be able to accomplish. I, for one, am not willing to write NASA a blank check for the Shuttle program.

We also need to have a better appraisal of what the risks are of operating the Space Shuttle—because even after implementing the CAIB recommendations, the Shuttle will continue to be a risky vehicle—and I am not willing to see the Shuttle fly without regard to the level of risk.

Finally, we need to better define NASA's overarching human space flight vision—something that has been lacking for more than a generation. That won't be easy, and it can only be done after hearings that will enable us to make a clear-eyed appraisal of the costs, benefits and risks of different options.

So I approach today's hearing soberly because of the tragedy that has brought us here and the daunting tasks that lie ahead. But I also approach today with eagerness because we have a rare chance to reshape our nation's space program, and we will be able to benefit from the outstanding work of Admiral Gehman and his team. I look forward to hearing from them.

Mr. Hall.

Mr. HALL. Chairman, thank you for a good opening statement, and I think it is a statement that we all need to keep and to refer back to as we proceed and as we adhere to and recognize the findings of the Admiral and his colleagues. So I say to you, Admiral, again, good morning. And thanks for your openness. Thanks for your being available to anyone who wanted to talk to you about anything. And thanks for the work you have done, you and all of your colleagues. And thanks for the work we will be expecting you to do and the oversight we will expect of you in the days that are—lie ahead. The Nation owes a great debt of gratitude to all of you and to your staff for your very dedicated service. I am grateful to you, and I think every Member up here is.

When you began your work seven months ago, it was not at all clear that we would ever unravel the physical cause of the accident. And there will be some who are not totally satisfied with the findings, but I think you have a lot of backup material there and—that they can refer to, and I just—indeed, your report, I think, makes it very clear that a series of reviews over the years, since the *Challenger,* had uncovered some of the same sorts of problems that you found during your investigation. This committee needs to get your best assessment of why these problems have continued to occur and what will be required to keep them from causing another accident. Your answers will help me shape legislation that I am developing. It will help others of us shape legislation that we are developing to provide for continued oversight. And the end of the two-year period, the first really important two-year period, we don't want this thing just to dwindle away like it did after the *Challenger.* We want to keep it before people and keep the goal in sight, and that goal in sight should be safety, safety, safety. If real estate people say location, location, location, I think the American people today are calling for safety.

I know that there are a lot that want to know who is at fault for the *Columbia* accident. Maybe they wanted names and things like that, but—and that is understandable, but your report makes

it clear that the conditions that ultimately led to the accident were not just a result of a few individual actions. I personally am not as interested in assigning the blame as I am to working to fix the problems identified by your investigation. We are going to need your help in determining the best way to proceed from here on out.

In that regard, I am very interested in your recommendations for returning the Shuttle fleet to flight. This committee needs to know why you included the items you did, and equally important, why some potential tasks were not included in your recommendations.

Mr. Chairman, the *Columbia* Accident Investigation Board has performed a very important service. Now it is up to Congress, I think, in cooperation with the White House and in cooperation with the NASA Administrator to make this report work to seek and find and figure out every area of safety that we can to consider issues that are beyond the Board's charter. And namely, we need to decide on some concrete goals for the human space flight program and be willing to commit the resources necessary to meet those goals.

There will be those who will say that we should walk away from human space flight as a result of this accident. It has been said. I disagree. The question is not whether we should have a human space flight program. The real question is how to make that program as safe and productive as possible. My view is that we should complete the International Space Station as originally planned so that it can be a productive research facility. We need to fix the Shuttle, and as part of that effort, take a serious look at how best to protect the crews that are going to be flying the Shuttle for the next 10 to 20 years.

Finally, we need to get some concrete goals for human exploration beyond the Space Station. Establishment of human exploration goals would ensure that we make the appropriate investments in our space program, would revitalize the NASA workforce and would serve as a source of inspiration for both the NASA workforce and the American people.

With respect to crew safety, I would note that just a month ago, the House of Representatives unanimously approved an amendment that I offered up that many of us on this committee had offered up at the Committee level here. We all agreed on safety, we just couldn't agree exactly on how it was to be done, so my amendment simply said to launch out onto a program for safety, a study as to how to get that safety and who ought to do it, not to assess blame, but to be grateful to those that made the program great that put these people, magnificent men and women, into the air and brought them back safely so many, many, many times. I think we are going to continue to rely on the Shuttle for a lot of years to service the Space Station. We need to do everything we can to ensure that if this Shuttle comes under threat in the future the crew is given every possible opportunity to survive.

I didn't send up that amendment to cause any problems or to nudge anybody, but I sent it up simply to say to the world that we are interested in safety, we care about safety, and we are going to launch a program designating and designing how we can make it safe. And if we don't do that, we may not have the Shuttle as safe as it should be, if we should have another tragedy in the next five

years or eight years or six years or six months or 10 months, but we better be on our way. And we better have a program to show the American people that we are trying to make it safe for the men and women who will man the Shuttle. We have to do that. That is our goal. That is my goal. And if we don't have that well underway or completed when we have another tragedy, we can forget about the space program. I don't want to do that.

I yield back my time, Mr. Chairman.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Good morning. I'd like to welcome Admiral Gehman and his colleagues from the *Columbia* Accident Investigation Board to today's hearing. The Nation owes a debt of gratitude to all of the Board members and staff for your dedicated service.

When you began your work seven months ago, it was not at all clear that we would ever unravel the physical cause of the accident. It is a tribute to your efforts that we can now be highly confident that a foam strike did in fact lead to the loss of the Space Shuttle *Columbia* and its crew.

At the same time, your report makes a persuasive case that other factors made an equal contribution to the Shuttle accident. It is painful reading, because the Board essentially has concluded that NASA never really learned the lessons of the Space Shuttle *Challenger* accident more than 17 years ago. Indeed the CAIB report makes it clear that a series of reviews over the years since *Challenger* had uncovered the same sorts of problems that you found during your investigation. This committee needs to get your best assessment of why those problems have continued to occur, and what will be required to keep them from causing another accident. Your answers will help me shape legislation that I am developing to provide for continued oversight of the implementation of the Gehman recommendations.

I know that there are some who want to know who was at fault for the *Columbia* accident. That is understandable. However, your report makes it clear that the conditions that ultimately led to the accident were not just the result of a few individuals' actions. I personally am not as interested in assigning blame as I am in working to fix the problems identified by your investigation. We are going to need your help in determining the best way to proceed from here on out.

In that regard, I am very interested in your recommendations for returning the Shuttle fleet to flight. This committee needs to know why you included the items you did, and equally importantly, why some potential tasks were *not* included in your recommendations.

Mr. Chairman, the *Columbia* Accident Investigation Board has performed an important service. However, it is now up to Congress—in coordination with the White House—to consider issues that are beyond the Board's charter. Namely, we need to decide on some concrete goals for the human space flight program and be willing to commit the resources necessary to meet those goals.

There will be those who say that we should walk away from human space flight as a result of this accident. I disagree. The question is not whether we should have a human space flight program—the real question is how to make that program as safe and productive as possible. My view is that we should complete the International Space Station as originally planned so that it can be a productive research facility. We need to fix the Shuttle, and as part of that effort take a serious look at how best to protect the crews that will be flying the Shuttle for the next 10 to 20 years. Finally, we need to set some concrete goals for human exploration beyond the Space Station. Establishment of human exploration goals would ensure that we make the appropriate investments in our space program, would revitalize the NASA workforce, and would serve as a source of inspiration for both the NASA workforce and the American public.

With respect to crew safety, I would note that just a month ago, the House of Representatives unanimously approved my amendment providing adequate funds for NASA to at least begin assessing Space Shuttle crew rescues options seriously. If we lose another Shuttle and its crew, the impact on the space flight program will be disastrous. We are going to continue to rely on the Shuttle for many years to service the Space Station, and we need to do everything possible to ensure that if the Shuttle comes under threat in the future, the crew is given every possible opportunity to survive.

Mr. Chairman, I will close by again expressing my appreciation for the Board's efforts.

Chairman BOEHLERT. Thank you very much, Mr. Hall.

Mr. Rohrabacher.

Mr. ROHRABACHER. First of all, I would like to thank Ralph Hall and our Democratic colleagues for the bipartisan spirit that we have had in this committee since this tragedy. This could be a very tumultuous time for us all, but we have worked together and we have kept politics out of it, and we have all been trying our best, as just demonstrated by Ralph Hall's wonderful statement, and so we appreciate that and all the work you have done.

I would also like to thank Chairman Boehlert for his leadership and Chairman Boehlert for his good judgment during this very vexing time. It is—now it is our time to pick up this job. And Admiral Gehman and his crew have done a terrific job, a wonderful job. Now it is time for us to do our job. It is our work—actually, you might say our work actually begins today.

Today's hearing is the first step in understanding, on this end of the hearing anyway, what went wrong with the Space Shuttle *Columbia*, what went wrong with NASA, and what choices we have in the future, what type of vision we must have in order to achieve the goals that we set as part of that vision.

We are greatly indebted to Admiral Gehman and the whole *Columbia* Accident Investigation Board for what they have done and for a terrific and an outstanding job. Their work will be an invaluable resource for us as we now move forward to solve the problems at NASA and to set a course for NASA in the future.

A key element of NASA's success in the past was a clear national objective and purpose when it came to our space program. Mercury, Gemini, Apollo, all were involved, of course, with beating the Russians to the moon and all of that was something that Americans understood, all of us in—as American citizens, of people in the government, people in the Legislative Branch, people in NASA, we all knew what that goal was and the vision. We were behind it, and we were part of the team. Our civil space program today suffers from a lack of strategic vision and a lack of broader national goals.

Putting America's space program back on track means more than fixing a flawed piece of Shuttle technology. In fact, the Shuttle itself remains a major question mark as we go through the findings of the Gehman report. For the last 30 years, NASA may well have been on the wrong path when it comes to the Shuttle. The Shuttle has failed miserably to meet its original goals, and our reliance on such a complex, high-risk technology has drained billions of dollars from our Treasury and billions of dollars from other space programs. And it has regrettably cost us too much money and cost too many lives.

Now there have been successes in the Shuttle program as well. I was part of the Reagan Administration when the first Shuttle landed, and I know how important the Shuttle was to inspiring the American people at a time when we had our—when our national spirits needed inspiring. And who can say what type of a contribution that made, seeing that Shuttle land and knowing it was probably one of the most magnificent engineering feats in all of human history. That did inspire us. And how many billions of dollars were added to our economy? Hundreds of billions by that inspiration. And that has to be put into the equation as well.

Yet when focusing on the loss of our bravest astronauts and our brave astronauts, we must want to make sure that we look at human space travel in the future that we do, as Ralph has just stated, our utmost to ensure that we are protecting those astronauts and those people's lives in the line as well. But with that in mind, we should not close the door on human space travel. The astronauts who have given their lives would not want us to turn around, would not want us to be earthbound because lives were lost. They knew the risks they were taking, and that is why they are unique among American heroes today, and we honor them in this hearing and we honor them by moving forward. It is a risky venture to move forward into space with human beings, but I would submit today that it is worth the risk.

We have the rare opportunity to help NASA today. And with Admiral Gehman's help and with his team's help to break the bureaucratic malaise that has gripped the NASA bureaucracy for too long. Our space program should be about expanding American freedom into a new frontier and to carry all of humankind to new heights into the heavens above and to a better life here on this planet. It is not the time to turn around; it is the time to move forward and do what is right to finish the Space Station and to move forward with new technologies that will carry us to greater heights.

Mr. Chairman, thank you for your leadership, and I look forward to working with you in the weeks ahead.

[The prepared statement of Mr. Rohrabacher follows:]

PREPARED STATEMENT OF REPRESENTATIVE DANA ROHRABACHER

I'd like to thank Chairman Boehlert for his leadership in calling this important hearing. Today's hearing is the first step in understanding what went wrong with the Space Shuttle, what went wrong with NASA, and what choices we have as we strive to set a new vision for our space program. We are greatly indebted to Admiral Gehman and the *Columbia* Accident Investigation Board for their dedicated service and their outstanding report. Their work will be an invaluable source to us as we grapple with the problems at NASA.

A key element of NASA's success in the past was a clear national objective and purpose. Mercury, Gemini, and Apollo were about beating the Russians to the Moon and beating the Russians in the Cold War. Unfortunately today, our civil space program suffers from a lack of strategic vision and a lack of any connection to such broader national goals.

For the last 30 years, I believe, NASA has been on the wrong path with the Space Shuttle. The Shuttle has failed miserably to meet any of its original goals. Our reliance on such a complex and high-risk technology has drained billions of dollars from our treasury and has regrettably cost too many lives.

We should not close the door on human space travel, however. It is a risky venture, but worth the risks. We have the rare opportunity to help NASA break the bureaucratic malaise that has gripped it for so long. Our space program should be about expanding American freedom into a new frontier.

Mr. Chairman, I believe your leadership and this committee will help frame this critical debate.

Chairman BOEHLERT. Thank you very much, Mr. Rohrabacher.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman. I will be brief, because I think that you did an excellent job in laying out our charge before this committee. And I think that if we will follow your outline, we will all be well served. And let me also say that I think we all should be grateful to Mr. Hall's tenacious efforts before, and I am sure they are going to be continuing to bring us back to flight, but also in a safe manner. And I look forward to working with my

friend from California as our Committee works to oversee the progress of this report.

So Admiral Gehman, let me join everyone in welcoming you and certainly your Board here—or the members of the Board that came today, and more importantly, I want to thank you for seven long, I am sure, months. You—they were longer for you than for a lot of folks. You have done a good job. Excuse me.

Admiral Gehman, you—your report warrants a thorough public hearing, and this hearing will be an important initial step in that regard. And as I reviewed the report, I found that there were a number of things that were troubling to me. And let me mention just a few. I am troubled that NASA failed to heed early reviews that identified many of the same problems that you described in your Board's report. I am troubled by your finding that NASA's safety system has repeatedly fallen short of the mark. I am troubled by your conclusion that, in your words, "years of workforce reduction and outsourcing have cowed from NASA's workforce the layers of experience and hands-on systems knowledge that once provided a capacity for safety oversight." I am troubled by your report's finding that the pressure by NASA's headquarters to meet an artificial Space Station Core Complete milestone may have unduly influenced Shuttle Manager's decisions. And I am worried that we have seen echoes of that pressure in some of the headquarters' pronouncements on the timetable for Shuttle return-to-flight.

So Admiral Gehman, fixing the problems identified by your report will take time and money. We should not kid ourselves in that regard. And I would like to get your views on how expensive and how time-consuming that effort is likely to be. When NASA submits its proposed budgets for fixing the problems, we need to know whether they are going to be realistic. And I would also like to get your views on what benchmarks this committee should be seeking for NASA to determine whether or not they are complying with your report's finding.

We have got a lot to cover today. I am anxious to hear what you have to say. And once again, thank you, and all of you, for being here with us.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good morning. I want to join my colleagues in welcoming Admiral Gehman to this hearing. I also want to add my thanks for the hard work all of the Board members did over the last seven months in investigating the causes of the *Columbia* accident. Your report warrants a thorough public airing, and this hearing will be an important initial step in that regard.

Admiral Gehman, your report ranges over a number of important issues. As I reviewed your report, I found much that was troubling to me. Let me mention just a few items:

- I am troubled that NASA failed to heed earlier reviews that had identified many of the same problems you describe in your Board's report.
- I am troubled by your finding that NASA's safety system has repeatedly fallen short of the mark.
- I am troubled by your conclusion that *"yeas of workforce reductions and outsourcing have culled from NASA's workforce the layers of experience and hands-on systems knowledge that once provided a capacity fog safety oversight."*

- I am very troubled by your Board's finding that pressure by NASA Headquarters to meet an artificial Space Station "Core Complete" milestone may have unduly influenced Shuttle managers' decisions.
- And I worry that we've seen echoes of that pressure in some of the Headquarters pronouncements on the timetable for Shuttle return-to-flight.

Admiral Gehman, fixing the problems identified in your report will take time and money—we should not kid ourselves in that regard. I'd like to get your views on how expensive and how time-consuming that effort is likely to be. When NASA submits its proposed budgets for fixing the problems, we need to know whether they are realistic. I'd also like to get your views on what "benchmarks" this committee should be seeking from NASA to determine whether or not they are complying with your report's findings.

Well, we have a great deal to cover today. I again want to welcome you to today's hearing, and I look forward to your testimony.

Chairman BOEHLERT. I want to thank all of my colleagues for their opening statements and all of the Members will have leave to insert their opening statements in the record at this juncture.

[The prepared statement of Mr. Barton follows:]

PREPARED STATEMENT OF REPRESENTATIVE JOE BARTON

Thank you, Mr. Chairman, for holding this important hearing. I also want to thank Admiral Gehman and his colleagues of the *Columbia* Accident Investigation Board (CAIB) for accomplishing the daunting task of investing the accident. We are here today to learn more about the causes of the accident, both physical, and intangible, such as the organizational culture at NASA.

The crew of the *Columbia* risked their lives in pursuit of knowledge that might improve the quality of life for all mankind. I am very supportive of NASA and realize that if we are to learn about the mysteries of this universe, space exploration must continue. However, in exploring space, we should not unnecessarily risk lives. The CAIB report mentioned the need to create a new vehicle for manned spaced flights. It also cautioned against falling into the trap of trying to do too many things with one vehicle. I fully echo this view. I am hesitant to send seven more astronauts on a vehicle that is unsafe. To that end, we need to move toward building a newer and safer space vehicle—whether that is a new Space Shuttle, or an Orbital Space Plane. The current fleet of Space Shuttles can be improved, but they cannot be made 100 percent safe. We cannot allow manned space flights on a continuing basis until safer vehicles are developed.

I also hope that we, as a Congress and also the Nation as a whole, take this time to develop the goals of our space program. In the 1960s, President Kennedy laid down a broad agenda for our nation to become the first to walk on the moon. The *Columbia* accident has given us the opportunity to regain that national enthusiasm and spirit toward the space program. I will continue to work with my Science Committee colleagues to investigate the best possible steps through which to move the program forward.

[The prepared statement of Mr. Smith of Michigan follows:]

PREPARED STATEMENT OF REPRESENTATIVE NICK SMITH

I want to thank Chairman Boehlert for holding this hearing to review the findings and recommendations of the *Columbia* Accident Investigation Board (CAIB). I'd also like to thank the witnesses for appearing here today, and for the tremendous work that they provided in preparing this report. Admiral Gehman and his team should be commended for delivering a thorough report that will be important to this committee as we move forward.

I understand that the CAIB was charged with assessing what caused the accident and give recommendations for changes that need to be made at NASA to better assure safety. The Board determined that the accident was caused by a piece of insulating foam that damaged the left wing of the *Columbia*, eventually leading to a thermal breakdown of the wing and breakup of the orbiter. The Board also concluded that bureaucratic pressures and cultural problems within NASA likely contributed to the circumstances that led to the accident. This morning we begin the process of learning more about NASA's internal workings and what went wrong in the days, months and years leading up to February 1, with the aim to guide Congress and the Administration through important crossroads.

Since the successful Soviet launch of Sputnik in 1957, our country's space program has been an integral part of our national sense of identity. Space exploration has captured the imagination of the American public while generating a wealth of scientific discovery. I remember the pride and awe that I felt when Neil Armstrong took his first steps on the moon. Other missions, like in 1998 when the Sojourner Rover landed on Mars and sent back color pictures of the landscape, have continued to fuel our fascination with space exploration.

Unfortunately, the space program has also been associated with a number of national tragedies, such as in 1967, when *Apollo 1* exploded on the launch pad, in 1986, when the Space Shuttle *Challenger* was lost shortly after takeoff, and again last February, when the Space Shuttle *Columbia* broke up during the final stages of re-entry into the Earth's atmosphere. It has taken this latest disaster to focus needed scrutiny on the state of our country's space program.

Americans want to know how the *Columbia* accident happened, but they also want to know the cost-benefit of manned space flight. The CAIB report is very thorough in assessing what caused the *Columbia* breakup and how NASA's management structure and safety procedures contributed to this. It goes on to recommend certain changes that should be made in order to continue human space flight. The report does not address the basic question of whether the cost and priority now given to manned space flight is justified.

One of the important decisions that needs to be made is what balance should be struck between funding for manned and unmanned space flight. As Chairman of the Research Subcommittee, I am interested in a more quantitative evaluation of the value of science research performed on both types of space flight, as well as on the International Space Station (ISS). Advancements in nanotechnology, miniaturization, and robotics will eventually accommodate most outer space research and exploration. Sending humans into space may be necessary in order to continue important life-science research. However, most functions of space flight can be accomplished without the cost and danger of involving astronauts.

I have often questioned witnesses on the justification for manned space flight because I am concerned that the costs are high and the benefits too few compared to unmanned flight or for that matter spending those dollars on research through the National Science Foundation or National Institutes of Health. With limited dollars for research in tight budgetary times, it is imperative that Congress direct funding toward investments that give us the greatest scientific return that hopefully can result in economic returns!

The *Washington Post* has reported that the International Space Station, if completed, is expected to cost $17 billion over budget. In addition, the three-person crew spends a majority of their time simply doing maintenance as opposed to doing actual research—an effort the *Wall Street Journal* appropriately referred to as "the modern equivalent of a New Deal program to keep spacemen busy digging holes and filling them in again until we can find some more productive goal." While manned Shuttles do provide us with some useful scientific information, the major objective of many missions is simply to re-supply the Space Station. At this time of tight budgets in the U.S. and with a growing reluctance in other contributing countries, these costs may have been given a higher priority than is justified. With NASA already spending nearly half of its $15 billion budget on human space flight, serious consideration should be given to the continuing viability of the Shuttle program and ISS.

In contrast, unmanned space missions have provided us with extremely useful and interesting information, and at a much lower cost. For instance, according to the "Bulletin of the Atomic Scientists," the Galileo project discovered and analyzed oceans and volcanoes on Jupiter's moons, and sent back information on the planet's weather patterns at a cost of $1.35 billion over 14 years. The Mars Pathfinder mission, which operated three times longer than its original planned lifetime, cost $270 million, provided our scientists with more than 16,000 images from Mars, 15 chemical analyses of rocks, and large amounts of useful information on Martian winds and weather. The Kepler space telescope, which will cost an estimated $286 million and is expected to be operational by 2006, will be able to observe nearly 100,000 stars and any planets in orbit around them. This will allow us to estimate how many Earth-like planets capable of sustaining life exist in the universe.

I fear the exercise of debating all potential changes to NASA will be futile if we first do not closely scrutinize the costs and benefits of our space science efforts, particularly with regard to manned versus unmanned exploration.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

I want to express my thanks to Admiral Gehman and the entire *Columbia* Accident Investigation Board for producing an excellent and thorough report. The Admiral and the Board have taken the lead in rigorously determining not only the technical cause of the accident, but also in outlining underlying cultural and organizational factors which contributed to the loss of the orbiter. The Board has identified the need for changes at NASA; it is now Congress' task to make sure those changes take place.

Most importantly, Congress must lead the Nation in determining whether, and to what extent, we should continue human space exploration. If we continue with human exploration of space, we must have a clear vision and mission, and be willing to pay the price of human space exploration—which will not be cheap.

We could decide to simply maintain the status quo in human space exploration, with missions to the International Space Station and low earth orbit exploration as has been done by the Space Shuttle. The Shuttle could be recertified and refurbished for this purpose in the near-term for relatively limited costs.

However, to continue human space exploration over the long haul, we must admit that, though the Space Shuttle has served us well, it is aging and has outlived its usefulness. A new vehicle will be needed. The replacement vehicle should be safer, more efficient, cost less to operate, and have shorter turn-around times than the Shuttle if the vehicle is reusable. These are achievable goals with modern technologies; however, we must bear in mind that development and initial deployment of the vehicle will be expensive. However, if the vehicle is designed well enough, we may actually save money in the long-term compared to the expensive maintenance cost of the Shuttle.

If we consider going even further into space, for example, a manned flight to Mars and back, the cost and the risk to personnel greatly increases. While landing a robot on Mars costs about $150 million, a manned mission would cost 1,000 times that amount, approximately $150 billion. Crew safety is also a significant issue. Personally, I do not believe we should attempt a human expedition to Mars until our technological capabilities have improved. In particular, we need better propulsion systems and light life support systems for a mission to be viable.

Furthermore, we need to remember that, although the American people are enamored by the glamour of space travel, the basic mission of NASA is scientific. Dollar for dollar, far more scientific knowledge is gained from unmanned missions than missions involving human space flight. The current unmanned exploration of Mars has yielded significant results at relatively low cost and the Hubble Space Telescope has provided scientists with a better understanding of our universe than we will ever get from the International Space Station—at a small fraction of the cost.

I look forward to a vigorous debate on these issues and a stronger, revitalized NASA.

[The prepared statement of Mr. Sullivan follows:]

PREPARED STATEMENT OF REPRESENTATIVE JOHN SULLIVAN

Thank you Mr. Chairman, I appreciate your calling this hearing today on the findings and recommendations of the *Columbia* Accident Investigation Board. As a Member of the Space and Aeronautics Subcommittee on the House Science Committee, I consider it an honor to be a part of this investigation and I appreciate Admiral Gehman and his board for their tireless work on behalf of our nation and for coming to testify here today.

The *Columbia* Accident Investigation Board has provided this committee with an excellent blueprint to start the long-term investigation into the organizational and technical factors that led to the loss of the *Columbia.* Today we will learn exactly what went wrong with the *Columbia* when she disappeared into the heavens on February 1, 2003, and review remedies to thwart future safety risk with human space flight.

Our hearing today is one of many that will undoubtedly raise difficult questions with regard to the costs and benefits of human space flight and what actions need to be taken to reform NASA to return our Space Shuttle fleet to operational status. Ultimately, this committee will be charged with making decisions on the level of financial resources that will be allocated to human space flight in NASA's reauthorization next year.

The loss of the Space Shuttle *Columbia* affected our entire nation. This hearing is undoubtedly one of many that will determine the structure of NASA and the future of human space flight. As a nation of explorers, I view this hearing as an oppor-

tunity to plot the course for NASA's future and revitalize our priorities for manned space exploration.

[The prepared statement of Mr. Forbes follows:]

PREPARED STATEMENT OF REPRESENTATIVE J. RANDY FORBES

Thank you, Mr. Chairman. Admiral Gehman, Dr. Hallock, Major General Hess, and Dr. Windall, I would like to thank you and all members of the *Columbia* Accident Investigation Board for their hard work in completing this comprehensive report, and for appearing before the Committee today.

America's space program is a symbol of our success as a scientifically and technologically advanced nation. However, tragedies like the Space Shuttle *Challenger* and *Columbia* make some think twice about whether it is worth continuing to send humans into space. The crew of the *Columbia* took this important scientific assignment knowing the risks involved, but recognized that this mission was not only a service to the Nation, but to all of humanity. With that said, it is chilling to read the *Columbia* Accident Investigation Board (CAIB) report and learn that this accident could have been prevented. There is no excuse for poor management to lead to the untimely deaths of these brave explorers.

NASA needs to take these recommendations to heart and fix the problems that could lead to another Shuttle tragedy. We must now look at this disaster as an opportunity to rebuild our space program to the finest in the world. As the Committee proceeds with its hearings on the Space Shuttle accident and related problems highlighted in the CAIB report, it is my hope that we can redefine the objectives of the space program to find solutions to the failed organizational structure at NASA.

We have a long road ahead of us in getting our space program back on track.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank Admiral Harold Gehman for appearing before our committee to present the *Columbia* Accident Investigation Board report to the Committee.

In discussing the *Columbia* accident, we must remember to honor the seven astronauts, their vision and their legacy. Space Shuttle flights are what many people consider a routine event; however, each mission has an extremely high risk. Both our nation and our world benefit enormously from each mission.

These seven extraordinary men and women aboard the Space Shuttle *Columbia* gave their lives for the pursuit of science and discovery. We are fortunate to have an astronaut corps comprised of highly trained men and women who regularly bear this risk. Their strong passion for space exploration has immeasurably benefited our nation and the world. We will never forget the dedication and sacrifice of the crew of the *Columbia.*

Today's hearing serves as an opportunity to fully understand the risks, costs, and benefits of the human space flight program, including the Space Shuttle, and to determine what reforms need to be made at NASA. The report describes that a foam strike during launch caused the Shuttle to break apart during re-entry; however, NASA's inconsistent safety culture was equally responsible for this disaster.

The report describes a Shuttle program that failed to learn the lessons from the 1986 *Challenger* accident, the first Shuttle disaster. In the case of the *Challenger,* and it seems now with *Columbia,* safety requirements were ignored because of schedule pressures, budget constraints, and workforce reductions.

NASA presented Space Shuttle safety upgrades to Congress in its FY 2001 budget. These upgrades were designed to keep the Shuttle flying safely and efficiently to 2012 and beyond. However, the Space Flight Leadership Council accepted the upgrades only "as long as they were financially feasible" (CAIB, 188). The safety upgrade initiative had a short lifespan because of conflicting dates and the assumption that upgrades would be a waste of money if the Shuttle were to be retired in the near future. In the FY 2003 budget request, NASA submitted a request that reduced spending on safety upgrades by 34 percent. Proposed safety upgrades continued to be either not approved or deferred.

I am interested in the cost-cutting of the Shuttle safety upgrades and the continued budget constraints of NASA. NASA's concept of mission safety appears rather meaningless if it is funding a safety upgrade in order to fly safely and then canceling it for budgetary concerns.

NASA continues to be our gateway to the universe. It is through NASA's efforts that we will understand our planet, our solar system and beyond. Our investigation

and journey into space will continue; however, the agency governing such exploration will be forever changed.

I welcome Admiral Gehman and look forward to his testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. I would like to thank you for calling this all important hearing today, and I would also like to thank Admiral Gehman for agreeing to appear here today to answer our questions on this most important investigation into the February 1 Space Shuttle *Columbia* disaster.

Today we are here to discuss the *Columbia* Accident Investigation Board (CAIB) report. It is imperative that we conduct this investigation because the space exploration research program has been one of the most successful research programs in the history of this country. To protect the safety and integrity of the future of this country's space program, we must learn from the mistakes of the past. The report from this investigation will allow us to see what went wrong and how to prevent it from happening again.

It was over 40 years ago that this nation's leaders in human space travel were given the foresight to recognize the importance of space research. We owe those leaders some homage for their foresight, and I am hoping that we will then have the foresight to continue this type of research.

Human space exploration is inherently risky. Distance, speed and an environment that cannot support human life combine to make human space flights particularly precarious.

That is why it is so essential that we put forth a concerted effort to protect the safety of our astronauts.

Although we have lost a very precious group of national heroes, many lives have also been saved because of the lessons we have learned. This most unfortunate and tragic loss of five men and two women, representing a mosaic of races and nationalities, will be mourned and these great American heroes will not be forgotten.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

I thank the Chairman and Ranking Member for holding this important hearing, and I thank the members of the *Columbia* Accident Investigation Board for their hard work on this difficult matter.

In preparing its report, the *Columbia* Accident Investigation Board received unsolicited comments from individuals at NASA who were becoming concerned that safety might be compromised as a result of pressure to hold firm to the launch date of February 19, 2004 for Node 2. Those individuals attributed that date to Administrator O'Keefe.

The report concludes that "the environment of the countdown to Node 2 and the importance of maintaining the schedule may have begun to influence managers' decisions, including those made about the STS–112 foam strike," and that during *Columbia*'s last flight, "Shuttle Program managers were concerned with the foam strike's possible effect on the launch schedule."

The report is also somewhat vague on budgetary numbers, but it does note that the Administration's FY 2003 budget request for Shuttle upgrades was a 34 percent cut from the FY 2002 planned cut. This by itself seems quite significant, but in fact the cut to Shuttle safety upgrades was even greater because for the FY 2003 budget, OMB required both Shuttle safety upgrades and Shuttle infrastructure revitalization projects out of the same pot of money.

I look forward to hearing Admiral Gehman's thoughts on the impact of schedule pressure and funding cuts in Shuttle safety upgrades on the safety lapses that the Board found contributed to the *Columbia* accident.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Mr. Chairman,

Thank you for moving so swiftly and convening this important hearing. I would also like to commend Ranking Member Hall, as well as the Chair and Ranking Member Gordon of the Space Subcommittee for their leadership, and tireless work since the tragedy of February 1st to ensure that Congress and NASA and Admiral

Gehman's team are all on the same page—working together to find the best way to get NASA's vital mission back on track. And, I would like to offer my sincere appreciation and commendation to Admiral Gehman and his excellent team at the *Columbia* Accident Investigation Board for their hard work, tenacity, creativity, dedication, and openness in service to this nation.

We are at a crossroads in the ongoing history of human space exploration. February 1st was a dark moment for people around the world who dream of pushing the envelope of human existence. We now have a solid report before us that can serve as a roadmap for the future of American space exploration, and we need to start looking to the future because this mission is vital to our growth as an economy, and as a society. But first I would like to look back one more time on what we have lost—seven of humankind's greatest heroes, and for those of us from Houston—friends and neighbors: Colonel Rick Husband, Lieutenant Colonel Michael Anderson, Commander Laurel Clark, Captain David Brown, Commander William McCool, Dr. Kapana Chawla, and Colonel Ilan Ramon. Those seven courageous explorers paid the ultimate price to improve our understanding of the universe, to advance our medical and engineering sciences, to keep the United States economy on the cutting edge of technology, and to inspire young and old alike.

Mr. Chairman, I, with my colleague from Houston Congressman Nick Lampson, have introduced H.R. 525, which would posthumously award the seven members of the *Columbia* crew with the Congressional Gold Medal. It would also require the Secretary of the Treasury to make bronze duplicates of that medal available for sale to the public, to serve as an enduring reminder of the sacrifice of those brave pioneers and to pay for the cost of producing the Gold Medals. The bill now has 135 co-sponsors. I hope to see that bill go forward this year, and we continue to focus on the *Columbia,* what it meant to us, and what it means to our future.

Again, Admiral Gehman, I would like to commend you and your team for putting out this outstanding piece of work. I admit that a couple of days into February, with debris from the *Columbia* scattered across the Southwest—I had doubts as to whether we would ever know what caused this tragedy. But, with some great technical expertise and modern day sleuthing, you have put together a very compelling story of how the *Columbia* went down. That will be enormously valuable as we move forward.

Obviously, the most frustrating thing for all of us is realizing just how many opportunities there had been over the days, months, even years before the crash, to prevent this loss. Knowing that there were people at NASA—and not just some interns with naïve notions—but experienced engineers, who had recognized the dangers, and tried to take prudent steps to get images that may have averted disaster; these experts were ignored. That is truly painful to think about. Page 169 of the report gives great insight into the broken culture of safety at NASA that impeded the flow of critical information from engineers up to program managers. I quote: "Further, when asked by investigators why they were not more vocal about their concerns, Debris Assessment Team members opined that by raising contrary points of view about Shuttle mission safety, they would be singled out for possible ridicule by their peers."

That reaffirms to me that strong whistleblower protections do not just protect workers. They protect lines of communication and dialog that prevent waste, fraud, and abuse, and, in this case, might have saved lives. I will be working this year on legislation that will enhance whistleblower protections for the NASA workforce, to make sure that critical information is never lost due to intimidation or fear.

The report gives clear recommendations for NASA, concerning technical and management changes, but there is still much work ahead to decide how Congress, and this committee in particular, should respond to this disaster. The report makes it clear that cuts in budget and workforce at NASA over the past decade had detrimental effects on the safety of the NASA mission. I believe that in this committee, on this side of the aisle, we have been consistent in calling for increasing resources for NASA programs. We have been calling for a clear mission from the NASA Administrator, that would enable us to make appropriate allocations for research, development, and upgrades when needed for the Shuttle. And this has not just been about one Administrator, or one Administration, this has been a consistent push for at least the four-plus terms that I have been here. It is time that we all realize that the NASA mission is valuable, and is worth the investment, and cannot be done on the cheap. Admiral Gehman has stated in the report that budget cuts hampered safety. Today I would like to push him a bit harder to determine what kind of budget increases might be necessary to get safety programs where they need to be.

Another important area that I feel needs further exploration by this committee, and advisement from the Admiral, is the subject of accountability. I respect and commend Administrator O'Keefe for taking responsibility for what happened on his

watch. However, this report makes it clear that multiple middle-to-high level managers made seriously flawed decisions that jeopardized the mission and ultimately cost lives. I am from Houston, and the people I am talking about are probably my neighbors. I am not interested in pointing fingers just for the sake of it. However, if holding people accountable will set an example and make future NASA managers more diligent, and make the program safer, perhaps this committee should consider a specific inquiry for that purpose. Also, I wonder if we owe it to the families of the fallen crew of the *Columbia,* and those of the *Challenger,* who were promised 15 years ago that the "culture" would change.

A final issue that I believe demands our attention is: What about the International Space Station? Has it been immune to the management problems that are described for the Shuttle mission? Of course, a space mission is at most risk during take-off and re-entry—so I hope that the Space Station is stable and safe right now—but we have two fine astronauts manning the Station now. I would like to know if there is any reason to think that they might be in danger or that the Space Station have its own "falling foam" that has been disregarded and might need attention? It seems that this could be an even more urgent issue than the Shuttle, since we already have people at risk.

We have a lot of work ahead: management issues, budget issues, technical issues, safety issues, and making sure that the NASA mission and vision match their potential. This report is an excellent foundation to work from. I look forward to the discussion.

Chairman BOEHLERT. And now it is important that we get to our distinguished witness—witnesses. And before anything, I want to say, once again to Admiral Gehman and to all of the members of the Board, how sincere we are in expression—expressing our appreciation for your thoroughness, for the scope, and for the independence you have demonstrated. You have done a great service, not just for the program or for the Congress, but for the Nation, and we thank you for that.

With that, let me present Admiral Harold Gehman and the members of the *Columbia* Accident Investigation Board. And Admiral Gehman, you may wish to introduce your colleagues individually.

STATEMENT OF ADMIRAL HAROLD W. GEHMAN, CHAIRMAN, COLUMBIA ACCIDENT INVESTIGATION BOARD; ACCOMPANIED BY JAMES HALLOCK, PH.D., MANAGER, AVIATION SAFETY DIVISION, VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER; MAJOR GENERAL KENNETH W. HESS, COMMANDER, AIR FORCE SAFETY CENTER; AND, SHEILA E. WIDNALL, PH.D., INSTITUTE PROFESSOR AND PROFESSOR OF AERONAUTICS AND ASTRONAUTICS AND ENGINEERING SYSTEMS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Admiral GEHMAN. Thank you, Mr. Chairman, Mr. Hall, the distinguished Members of this committee. Thank you very much for the compliments. And on behalf of the Board, I accept those kind words for the Board members who are not here. I will introduce my colleagues here, and then I would ask the Chairman to allow me to introduce my opening statement into the record. And I will just say a few words, and we can get right to the questions.

Chairman BOEHLERT. Without objection, so ordered.

Admiral GEHMAN. Thank you, sir. Beside me, to my left, is Dr. Jim Hallock. Dr. Hallock is the manager of the Department of Transportation's Volpe National Transportation Systems Center from Massachusetts. Beside him is Major General Ken Hess, the Commander of the Air Force Safety Center and the Chief of Safety of the U.S. Air Force. And beside Ken Hess is Dr. Sheila Widnall,

the Institute Professor and Professor of Aeronautics and Astronautics and Engineering Systems at the Massachusetts Institute of Technology and previous Secretary of the Air Force.

I know that all of the Members of this committee feel as the Board does, that the tragic loss that this nation suffered on 1 February 2003 is a price that we paid that is so dear that it demands that we all do our part to ensure that an accident like this never happens again. I want to thank this committee and the leadership of this committee for helping this Board get over a rough start the first couple of weeks, the first couple of months to enable us to be at a position where we are right now that we are discussing the merits of our report and not the process by which this Board was founded. We can talk about that, too. But we could not have gotten to this position had it not been for the guidance, cooperation, and mentorship of both Branches of the Congress, and we appreciate it very much.

Before I begin, Mr. Chairman, I would like to offer my thanks to my 12 colleagues on the Board who gave up seven months of their lives to produce this report. Approximately 120 full-time investigators and the thousands of NASA engineers and employees who helped us with this, not to mention the nearly 30,000 volunteers who walked shoulder to shoulder across the State of Texas picking up 84,000 pieces of debris, which turned out to be instrumental in our reconstruction and forensic work. And to all of those unnamed and unsung heroes, we owe a great debt.

Let me just make a couple of points. I committed, a long time ago, to this committee and to the public, that our report would attempt to put this accident into context. And by context, there—I mean any one of several contexts. There is the context of the history of the human space flight program. There is a context of the budget process. There is a context of management and leadership. There is a context of all of the previous reviews and investigations that NASA has gone through and whether or not they learned. And then there is the context, as has been mentioned this morning, of what is exactly our nation's vision of what we want to do in space, and how does the Shuttle program fit into it.

Obviously, the first thing we had to do was determine the physical cause of this accident. We did. The foam did it. For those of you on this committee who may not be intimately familiar with the foam, I would like to introduce you to it.

This is an actual piece of foam. This is the left bipod ramp. The little black line here indicates approximately where it fractured. So this part of it here came off. And this is about the right size. This is the right size. And this is about what it weighs. And so this is the party of the first part here. This is what it looks like, in case somebody is not familiar with it. The Board was very deliberate in how we chose our words about saying that the foam did it. We didn't say "most likely." We didn't say "all evidence supports." We didn't say "it was the conclusion of the Board." We said, "The foam did it." And we are quite content with that, and we are quite sure of it. And we would be delighted to discuss that, if you want to talk about it some more.

If the foam did it, the Board was then interested in answering the following question: if the foam caused this accident, was this

a legitimate surprise, an anomalous event that had never happened before? Or if not, was this something that happened before and why wasn't it fixed? What was the process by which NASA went through attempts to understand and fix why it happened? Of course, as has been reported in the press, it was not a surprise anomalous event. This thing has happened before. And when we got into a deep comprehensive analysis of how the Shuttle program handles unknowns and risks and surprises and how they conduct research and development to understand what is happening and how they learn as an institution, we were not very pleased with what we found. And that statement takes about 150 pages in our report to document.

Being concerned, then, with what we found, we then took two simultaneous paths to come to a set of recommendations. The first path was a path of academic and theoretical review of how to handle high-risk, high-technology institutions. How do you handle risky activity safely? The second path was a review of what we call "best business practices" or "best safety practices." And that is the review of institutions in the United States that actually handle risky enterprises and do a good job of it and what could we learn from those enterprises.

From these two reviews, we took what you might call a sampling or a recipe or a cookbook of the characteristics that we thought applied to NASA. We then took that template, applied it to NASA, and we are not very pleased with what we found. We then concluded our report with what we considered to be concrete, specific, actual recommendations to fix these management problems that we believe would go a long way toward making the operation of the Shuttle more safe in the future.

Let me just close by saying one word about accountability. The Board does not believe that accountable persons can hide behind the excuse of bad management or culture or any other subterfuge. There is a role for personal accountability. And in our report, we think that the report is full of evidence of personal performance. But it is up to either the Administrator of NASA or this committee if you decide to hold people accountable for their actions. The Board decided long ago, announced publicly, and we have—and I will defend, very strongly, the position that we took that it is not our job to sit in judgment over other people. However, all of the performance factors that you may be interested in are in the report. They are all in there. And if you or the Administrator of NASA feels that some accountability is required, we did our job, we laid it out for you, and we don't think that that constitutes dodging the issue of accountability.

Thank you very much, Mr. Chairman. And my panel and I of colleagues here are delighted to be here and ready to answer all of your questions.

[The prepared statement of Admiral Gehman follows:]

PREPARED STATEMENT OF ADMIRAL HAROLD W. GEHMAN, JR.

Good Morning Mr. Chairman, Congressman Hall, distinguished Members of the Committee.

I know Members of this committee feel as we on the Board do: that the price this nation paid on February 1, 2003 was so dear, it demands we do our part to ensure an accident like this never happens again.

It is an honor to appear today before the House Committee on Science. I thank you for inviting me to pay tribute to the legacy of Rick Husband, Willy McCool, Mike Anderson, Dave Brown, K.C. Chawla, Laurel Clark, and Ilan Ramon in presenting the findings of the investigation into the tragic loss of the Space Shuttle *Columbia.*

Before I begin, I would like to commend the efforts of my 12 fellow Board members, 120 investigation staff members, 400 NASA engineers, and more than 25,000 debris searchers who have contributed immensely to the investigation.

Today I will provide the Committee with the final conclusions of the Board with respect to the following three areas:

- The physical cause of the accident
- The organizational characteristics of NASA that contributed to the accident
- Recommendations the Board has made in regards to the Space Shuttle Program

I. Physical Cause

The Board has determined that the physical cause of the loss of *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing. The breach was initiated by a piece of insulating foam that separated from the left bipod ramp of the External Tank and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon (RCC) panel 8 at 81.9 seconds after launch. During entry, this breach in the Thermal Protection System allowed superheated air to penetrate through the leading-edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and breakup of the orbiter.

Entry data demonstrated that the flaw in the left wing was extant prior to entry. The flight events are well documented, and establish that progressive destruction occurred as the orbiter entered the atmosphere. Superheated air damaged the structure of the wing first, leading to the abnormal aerodynamic forces that caused the eventual breakup. Once the orbiter began entry, there was no possibility of recovery.

The Board reached this conclusion after extensive analysis of five lines of evidence:

- The aerodynamic scenario
- The thermodynamic scenario
- The detailed system timeline from telemetry and recovered on-board recorder
- The videographic and photographic scenario
- Debris reconstruction and forensics.

Additionally, the Board conducted foam impact tests in order to determine that this potential cause was indeed plausible. The tests proved this, and much more. The tests demonstrated that External Tank foam shed during launch could create considerable damage to the RCC panels and the tests also added to the body of knowledge regarding RCC strength. The foam impact testing ends for all time the common belief within NASA that foam strikes are just a flight turnaround issue, and also serves as a dramatic stimulus to change some people's attitudes about what we really "know." Furthermore, it demonstrates the Board's finding that the characterization of the Space Shuttle as operational rather than experimental was flawed. The direct result of this mindset was the lack of testing on such matters as the cause of foam shedding, the force of foam projectiles, and the strength of the RCC panels to withstand such debris strikes.

II. Organizational Causes

Mr. Chairman, the Board believes very strongly that complex systems almost always fail in complex ways. Most accident investigations fail to dig deeply enough into the causes beyond identifying the actual physical cause of the accident; for example, the part that failed and the person in the chain of command responsible for that failure. While this ensures that the failed part receives due attention and most likely will not fail again, such a narrow definition of causation usually does not lead to the fixes that prevent future accidents.

Our investigation into the loss of the *Columbia* was designed to get to the heart of the accident, and reveal the characteristics of NASA that allowed the accident to occur. As everyone knows, NASA is an outstanding organization, with highly skilled and motivated people and a long history of amazing accomplishments. However, there are long-standing management issues that led to the *Columbia* disaster.

The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle Program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed upon national vision for human space flight.

Cultural traits and organizational practices detrimental to safety were allowed to develop including:

- Reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements)
- Organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion
- Lack of integrated management across program elements
- The evolution of an informal chain of command and decision-making processes that operated outside the organization's rules

The Board believes that these factors are just as much to blame as the foam. We began an analysis of how high reliability organizations handle risky enterprises, creating a template for us to use to examine management and culture at the Space Shuttle Program. The Board has concluded that the Space Shuttle Program does not have the characteristics of a high reliability organization. Furthermore, history and previous studies demonstrate that NASA, as a whole, does not "learn" well.

The results of our very intrusive investigation into the Space Shuttle Program demonstrate clearly that gradually and over a period of many years, the original system of checks and balances has atrophied. Instead of using a system of checks and balances provided by independent engineering and safety organizations, the Shuttle Program placed all responsibility and authority for schedule, manifest, cost, budgeting, personnel assignments, technical specifications and the waivers to those specifications and safety in one office. That action created an office that could make programmatic trades to achieve whatever goals were set for it by a higher authority. For example, if meeting the schedule were priority number one, the program could trade safety upgrades against schedule. We find this to be an excellent system if one's goal is to know whom to blame if something goes wrong, but NOT an excellent system if one's goal is to maximize safety.

III. Recommendations

The Board does not believe that the Space Shuttle is inherently unsafe, and we were under no pressure to say that it was safe. However, there are things that must be done to make it more safe than it is and many of these things must be accomplished before return-to-flight. Furthermore, if the Shuttle is to continue flying past the next few years, there are even more safety requirements necessary. Our recommendations and observations also constitute an attempt to find items that might be dangers in the future.

There are three types of recommendations in the report. The 15 Short-Term recommendations outline the fixes needed for return-to-flight. The 14 Mid-Term recommendations refer to the needs for continuing to fly for the next three to 12 years. The Long-Term recommendations discuss the considerations that must be made for continuing to fly the Space Shuttle beyond 12 years, including recommendations for replacing the Shuttle.

In addition to the cultural and organizational considerations that NASA must address, there are several recommendations that stand out. One of these is the call for NASA to take an integrated approach to the issue of the danger posed by debris by combining steps to reduce debris creation in the first place, an overall toughening of the orbiter, both in the RCC components and the other parts of the Thermal Protection System, including the tiles, and developing a capability for on-orbit inspection and repair. The Board studied scores of other findings of significance with respect to how exactly to prevent the next accident. Among the numerous recommendations is the need for better engineering drawings, better safety and quality assurance programs, and improved documentation. Additionally, there are specific ways to improve the orbiter maintenance down period without sacrificing safety, as well as recommendations on what to look for on bolt fractures, holdpost anomalies, Solid Rocket Booster attach rings, test equipment and training needs.

Conclusion

Mr. Chairman, at the beginning of this investigation, I promised a final report that places this accident in context, rendering the complete picture of how the loss of the *Columbia* fits into the complicated mosaic of budget trends, the myriad pre-

vious external reviews of NASA and the Shuttle Program, the implementation of Rogers Commission recommendations, changing Administrations and changing priorities, previous declarations of estimates of risk, work force trends, management issues and several other factors. We have done this to the best of our ability and I believe we have succeeded.

It is our intent that this report be the basis for an important public policy debate that needs to follow. We must establish the Nation's vision for human space flight, and determine how willing we are to resource that vision. From these decisions will flow the debate on how urgent it is to replace the Shuttle and what the balance should be between robotic and human space flight, as well as many other pressing questions on the future of human space flight. Let the debate begin.

Thank you Mr. Chairman. This concludes my prepared remarks and I look forward to your questions.

Columbia Accident Investigation Board Selected Biographies

Adm. Harold W. Gehman Jr., U.S. Navy retired, completed more than 35 years of active duty in October 2000. His last assignment was as NATO's Supreme Allied Commander, Atlantic, and as the Commander in Chief of the U.S. Joint Forces Command, one of the five U.S. Unified Commands. Immediately after retiring, Gehman served as Co-Chairman of the Department of Defense review of the terrorist attack on the USS Cole. Gehman graduated from Pennsylvania State University with a Bachelor of Science degree in Industrial Engineering and a commission in the Navy from the Naval ROTC program. He served at all levels of leadership and command and was promoted to four-star admiral in 1996. He became the 29th Vice Chief of Naval Operations in September 1996. As Vice Chief he was a member of the Joint Chiefs of Staff, formulated the Navy's $70 billion budget, and developed and implemented policies governing the Navy's 375,000 personnel.

Maj. Gen. Kenneth W. Hess is the Air Force Chief of Safety, Headquarters U.S. Air Force, Washington, and Commander, Air Force Safety Center, Kirtland Air Force Base, N.M. Hess entered the Air Force in 1969 through Officer Training School at Lackland Air Force Base, Texas, and has extensive staff experience at Headquarters U.S. Air Force, the Joint Staff and U.S. Pacific Command. He has commanded three Air Force wings: 47th Flying Training Wing, 374th Airlift Wing and 319th Air Refueling Wing. Prior to assuming his current position, Hess was Commander of 3rd Air Force, Royal Air Force Base, Mildenhall, England. He is a command pilot with more than 4,200 hours in various aircraft.

Dr. James Hallock is Manager of the Aviation Safety Division at the Department of Transportation's Volpe Center. He received BS, MS and Ph.D. degrees in Physics from the Massachusetts Institute of Technology and authored or co-authored two patents and more than 135 papers and reports. He worked in the Apollo Optics Group of the MIT Instrumentation Lab (now the Draper Lab) from 1963 to 1966, dealing with the selection of Earth landmarks for updating guidance computers on Apollo and the potential effects of solar flare radiation on Apollo's optical systems. From 1966 to 1970, he was a physicist at the NASA Electronics Research Center and did research in modern optics (holography and spatial filtering) and developed a spacecraft attitude determining system. In 1970 he joined the DOT Transportation Systems Center (now the Volpe Center) and studied aircraft wake vortices, developed aviation safety systems, and conducted many detailed safety studies.

Dr. Sheila Widnall, Professor of Aeronautics and Astronautics and Engineering Systems. Massachusetts Institute of Technology (MIT), Cambridge. She has served as Associate Provost, MIT, and as Secretary of the Air Force. As Secretary of the Air Force, Dr. Widnall was responsible for all affairs of the Department of the Air Force. Dr. Widnall was also responsible for research and development and other activities prescribed by the President or the Secretary of Defense. Since returning to MIT, she has been active in the Lean Aerospace Initiative, with special emphasis on the space and policy focus teams. Her research activities in fluid dynamics have included the following: boundary layer stability, unsteady hydrodynamic loads on fully wetted and supercavitating hydrofoils of finite span, unsteady lifting-surface theory, unsteady air forces on oscillating cylinders in subsonic and supersonic flow, unsteady leading-edge vortex separation from slender delta wings, tip-vortex aerodynamics, helicopter noise, aerodynamics of high-speed ground transportation vehicles, vortex stability, aircraft-wake studies, turbulence, and transition.

DISCUSSION

RISK

Chairman BOEHLERT. Thank you very much, Admiral Gehman.

The report states that the Board believes that the Shuttle is not inherently unsafe, but it also says repeatedly that the Shuttle is inherently risky and should be treated as experimental. And parenthetically, let me say, I couldn't agree more that it should be treated as experimental when, in the view of most, it was treated as operational. How do you reconcile those two statements? I assume that we'll likely lose the Shuttle if the vehicle is flying another 10 to 20 years. At what point does something become so risky that it becomes inherently unsafe? Did the Board ever receive any convincing risk analysis from NASA for the Shuttle program?

Admiral GEHMAN. Mr. Chairman, we chose those words very, very carefully. We very carefully used the sentence with two negatives in it. We—the statement that the Shuttle is not inherently unsafe was chosen to allow us to send the signal that we didn't think it's safe. It is not safe. It is risky. And we didn't think it is unsafe. If we thought it was unsafe, we would have recommended that we suspend flying operations. We would have said that. The Board was under no pressure to allow NASA to continue to fly this thing. The Board completely divorced itself from cost and schedule and International Space Station requirements. And we do believe that with proper management and proper skill and a good, elegant management scheme that the Shuttle can be operated reasonably safely. But as you said, it can not—it is a risky enterprise and always will be. It always will be risky.

Chairman BOEHLERT. What level of risk is that?

Admiral GEHMAN. We—I am going to let my colleagues in on this one, because we have actually seen numbers. My own view is that the numbers have little or no validity. And numbers along the lines of the probability of a failure in a mission of one in 200 are kind of the most commonly accepted numbers. I am going to let—these people have also seen other numbers. And then I will—I have a comment I would like to make. Does the gentleman want to say something?

Chairman BOEHLERT. Dr. Hallock.

Dr. HALLOCK. Yes, there are a number—a lot of numbers that float around that we have been looking at. NASA has done a job in the sense of trying to look at the various things that could affect the Shuttle. For example, the number that Admiral Gehman just mentioned, the one in 200, is the chance of actually having a problem due to a micrometeorite or an orbital debris strike and actually cause loss of crew and vehicle. So the numbers are large. But there are many other types of things that they can run into that can be a problem, too, most of which have been looked at. But once again, it is the compounding of all of these numbers that become important.

Yes, it is a risky venture, but, you know, we have a lot of other risky ventures that we are involved with. In fact, sitting next to an Admiral, I think immediately of submarines that go into an environment that is, you know, much like the space environment.

When you are well underwater, you are in a place where it is not very easy to escape from to get back to the Earth.

Major General HESS. Yes, I obviously agree with the Admiral and Dr. Hallock on this issue. And in the course of our seven months, I think we became fairly intimate with the fact that truly quantifying the risks in numeric terms for the Shuttle is, I think, a little bit like dreaming. I don't think you could actually do it. You can't quantify the risk of the human factor interfaces and all of the different layers that are involved in making management and technical decisions as well as the work that is ongoing everyday with the Shuttle. So you can probably estimate, but the error band is fairly wide. And so hanging our hat on a number is—after our study, nothing I would do with the Shuttle. And I am always reminded that, yes, the technology is risky and the uncertainty that is involved always causes you to question whether or not it is safe or unsafe to fly, but the difficulties in—that we have encountered in both *Challenger* and *Columbia* were of the human management decision style, not the technology itself. So I think the risk, in the context, is manageable, but it takes some elegant operations to do that.

Chairman BOEHLERT. Dr. Widnall, do you wish to add any?

Dr. WIDNALL. Sure, I will add a little bit. I think—I would certainly agree with my colleagues. And the phrase that I would use about trying to put numerical values on risk is that it is perhaps necessary but not sufficient. If you look at the risk of the Shuttle, you can divide it into two parts. There is the physical characteristics or the hardware. You can sort of analyze and dig deep into how the hardware was qualified, what depth of engineering analysis was used, you know, how safe do we feel the actual operation of the hardware is. But I think obviously more important are the organizational issues. And for me, the issue of how one decides to waive a requirement, how one decides to treat an anomaly and continue flying, the depth of engineering analysis that was applied to the various systems to, in some sense, certify them. I think these are very important issues, and they are not quantifiable.

Chairman BOEHLERT. Thank you. Thank you very much for outstanding answers.

Admiral GEHMAN. Mr. Chairman, may—I wanted to add something.

Chairman BOEHLERT. After they spoke.

Admiral GEHMAN. To get to your issue, though, it is a lesser—at least it was a lesser to me, that when you ask to—the answer to your question depends on who you ask. For example, NASA has a number. They actually have a calculated number for each mission. And if you go, for example, to the U.S. Air Force, which operates the eastern range where they launch it, and you ask them what their risk number is, you find it to be much larger—much different than NASA's number. It is very interesting. And in the case of the *Challenger* investigation, the famous Dr. Feynman quote at the end, he tried to address this question, too. And he kind of said that, you know, kind of the best he could determine was 99 percent, one out of 100, which is, of course, much higher than NASA's. So the answer to your question depends on who you ask. And if you

ask an independent agency, you get a number which is more risky than if you ask NASA.

Thank you, sir.

Chairman BOEHLERT. Thank you very much.

Mr. Hall?

Mr. HALL. Mr. Chairman, thank you.

Admiral, of course, I want to get back to safety. I want to visit with you and the other three of you there. And the word "risk" and "risky" and "risk assessment" and "risk containment" and all of that have been voiced, and of course, proper words for this situation and for this report. And how many times have I heard these brave men and women astronauts referred to as the Columbuses and the Magellans of space. And I often wonder how many ships were lost at seas and how many crews were before Columbus or Magellan or Amerigo Vespucci or whoever it was that hit this shore first, how many we lost and how much risk they were assessing and a different risk.

But I think we need to think in terms of we do have a risk, and we can—and we get the last guess at how to fix it, how to fix that risk. I know that even prior to the *Challenger* and prior to *Columbia*, I know that the President, after the *Challenger,* thought we had assessed the risk and had attended to it and had addressed it. I know the Congress thought we had. I know the NASA Administrator, whoever it was at that time, thought we had. But obviously they thought we had a safe Shuttle. And now, complying with your recommendations, we are going to think that we are making it safe, and we are going to think we have addressed the risk. Now we were wrong twice. We can't afford to be wrong again. And I think that now is the time to start the journey toward doing something about it if we are wrong again, that we haven't assessed the risk, that we haven't pushed back any risk. I don't suppose it is possible to say it is absolutely, without any question, risk-free. There is no way to do that. I wish we could.

CREW ESCAPE

But we can certainly—in case we are wrong, we can have a way for those that are aboard that vehicle to survive. Now we have asked for that before. I know that we have asked for it for at least 10 years since the last loss. And each time, we have been told that we can't have a vehicle aboard the vehicle. I think the gentleman from California has addressed that a lot of times. And the answer we always got was, "Well, the weight. It is a weight problem." And "It is a money problem." And it is both of those problems. But now, before we send anybody else up, even though we think we have addressed the risks, we have touched every base that we can humanly touch, we need to touch one more base and have them have a way out in case we are wrong again.

So with that, Admiral, let me say your report contains some "observations" about crew escape systems for the Shuttle. And it mentions the fact that the Aerospace Safety Advisory Panel's 2002 report recommended that the NASA consider upgrading the Shuttle to include crew escape systems in view of the Shuttle's proposed life extension. And that makes sense. That should have been done. Yet your report does not actually make a recommendation one way

or the other, that I can see, about adding a crew escape system for the Space Shuttle. Now you know that a lot of us feel very strongly that this is an area that NASA needs to address if this decision is made to fly the Shuttle for an extended period.

Without asking the question of why we sent this particular Shuttle, why we sent the oldest one we had, why we sent the one that couldn't dock at the Space Station, why we sent the one that wouldn't have available the telescope. All of those things are assuming blame to somebody. I am not interested in that. I am interested in causation. I am interested in doing something about it, if we are wrong, again, on our risk assessment. So we owe it to them to give them a fighting chance. The loss of another Shuttle would not—should not inevitably, absolutely mean the loss of the crew.

So let me just ask you directly, if NASA plans to fly the Shuttle past 2010, should NASA be required to develop escape systems for the crews that will be flying those Shuttle missions? That is a good yes answer, isn't it?

Admiral GEHMAN. As long as you say they should consider, the answer is yes. In my opinion, the answer is yes. The Board did not do an in-depth study of that issue, so I am not speaking for the Board here, but we did. We looked at that issue a little bit, and as long as it is couched in the terms of should they consider it, the answer, in my opinion, is yes.

Mr. HALL. Dr. Hallock, do you have anything to add to that?

Dr. HALLOCK. Well, I agree with that in the sense that one needs to always look at possible ways to be able to allow the crew to survive.

Mr. HALL. We don't need to just look at them. We need to do something about them. We need to get underway with it.

Dr. HALLOCK. I agree.

Mr. HALL. I can find people that are more intelligent than those of us in Congress, so all we have to do is come up with the money. But finding those of you out there who are givers and are giving your time here today, have given your life to what you are doing. We need you to come up with a way for those people to get out of there if something happens. You can be catapulted out of an F–16 or whatever. I can't understand why, with all of the modern technology and all of the intelligence and the genius we have here, a lady with MIT and the General that has given his life to this country, Dr. Hallock that has studied all of your life and been smarter than almost everybody else that you knew or you were around. Surely to God you can come up with some way to get people out of there if they say, "Hey, the damn thing is knocking. There is a rod knocking in it. Let us get out of here." Dr. Widnall.

Dr. WIDNALL. Sure, I guess maybe what I need to do is define the word "consider", because I think if one were—if one proceeds down that road, and I think it is a good idea, it would take a really in-depth engineering analysis and a consideration of, perhaps, design options and a calculation of what this would actually be, what would its characteristics be, and in fact, would it make the Shuttle, as a vehicle, more risky or less risky. And that is the calculation that has to be done.

Mr. HALL. Sure, weight and structure——

Dr. WIDNALL. Weight, strength——

Mr. HALL. Sure.

Dr. WIDNALL [continuing]. Materials. Let me just mention as a——

Mr. HALL. Jack Kennedy had the start of all of those things before——

Dr. WIDNALL. Sure.

Mr. HALL [continuing]. He ever launched the first one.

Dr. WIDNALL. Yeah. Let me just indicate the particularly demanding environment that the Shuttle saw when it reentered. Reentering at mach 25, at those altitudes, those kinds of temperatures 10,000 to 3,000 degrees Fahrenheit, there are few materials that will withstand those kinds of temperatures. And so it is a very challenging engineering problem. But that would be my definition of the word "consider."

Mr. HALL. Well, we knew the velocity of the foam that you shot into that trial wing. We knew the speed at that time. We knew all of those things before the *Columbia* loss. We knew that could happen. Why can't we use that—why can't we use our genius to come up with a vehicle that will save these people if we are wrong about attending to the risk assessment? Why can't we do that?

Dr. WIDNALL. It is perfectly reasonable to start down that road.

Mr. HALL. And it—don't—wouldn't you be very uncomfortable if you left here today and didn't believe that we were going to start down that road, whether we get down that road or not, that we are underway trying to get down to that road and that we are lucky enough and have enough support from up above that we don't have a tragedy before we get to the end of the road of finding that answer?

Dr. WIDNALL. I think it is——

Mr. HALL. We better dang well be underway hadn't we—if we have another tragedy.

Dr. WIDNALL. Yeah, it is a completely reasonable path to take.

Mr. HALL. Because I am going to support the NASA Administrator. I am going to work with him from this point forward. I am going to try to comply with the Admiral's recommendations. I am going to work with everybody on this committee, but I want us to be underway to find a way in case we are wrong and we are not successful at doing what we think we are doing about risk that we can get them out, if it happens.

I yield back my time.

Chairman BOEHLERT. Thank you very much.

The Chair of the Subcommittee on Space and Aeronautics, Mr. Rohrabacher.

SHUTTLE REPLACEMENT

Mr. ROHRABACHER. Thank you very much. And with due respect to Mr. Hall, I would like to sort of take this from the other side of the coin. Is—Admiral Gehman, isn't your finding that we should be trying to minimize our reliance on the Shuttle rather than trying to invest more into the Shuttle and—so it could be used more in the future?

Admiral GEHMAN. Yes, sir. Our recommendations are a series of recommendations to make the present operations of the Shuttle more safe, but our recommendation is to replace the vehicle as soon

as possible. And in our editorializing in chapter nine, we specified, to get back to Mr. Hall's point, that whatever it is that we replace the Shuttle with that the concept of the operations should be to separate the crew from the cargo, because as long as you keep the crew and the cargo together, you have to suboptimize human safety. And that—and therein is the dilemma.

CONTINUING SHUTTLE OPERATIONS

Mr. ROHRABACHER. So we should do our best to phase out the Shuttle and go to a new system rather than trying to bolster the capabilities of the Shuttle?

Admiral GEHMAN. The Board wrote that the Board was surprised and disappointed to find ourselves here at 2003 without a replacement vehicle, even on the drawing board.

Mr. ROHRABACHER. In terms of what we have to do and what the Shuttle is necessary for in the future, Space Station is certainly something that will not be completed without the Shuttle. And even to make the type of safety upgrades that we are talking about today will take a certain length of time that would go well into Station's life span. Is it—do you have any recommendation at all in terms of whether the Shuttle should be used to complete the Space Station, given its current risks?

Admiral GEHMAN. The Board report, I believe, speaks very clearly to the subject of operating the Shuttle at what we call the midterm, that is like two to 15 years or two to 10 years. And in there, we specify very clearly, I believe, that the present management scheme is not adequate to operate the Shuttle safely. Technically, hardware-wise, as long as you take care of the Shuttle and as long as you aggressively investigate every single waiver and every single anomaly, we believe the Shuttle can be operated for another 10 years with a degree of safety.

NASA'S CULTURE AND MANAGEMENT

Mr. ROHRABACHER. So if we change the—one of the central findings, if we come to grips with one of the central findings of your Commission, which is the culture or attitude of what was going on safety-wise at NASA, that that might, in itself, enable us to reach a safety threshold in which the Shuttle could be used to complete the work on Station?

Admiral GEHMAN. That is correct. Are there any other Board members who want to—but that is the central core of our recommendation. And that is that the present management scheme tends to hide or overlook or not react to those little tiny signals that something is going wrong. And it is those little tiny signals, like foam coming off and things like that, that you have to go after aggressively. And we can't predict what the next thing to go wrong with the Shuttle is, but we do know that the present management scheme is not good enough to catch it.

Chairman BOEHLERT. Mr. Rohrabacher, just let me intervene, if I may, and it won't be taken out of your time. But little tiny signals, Shuttle after Shuttle, debris, foam comes off, assumed that, since it came off, they assume too much that it was going to be the size of the previous foam and no larger. And isn't the basic thrust

of your whole report that too much was assumed and they weren't skeptical enough?

Admiral GEHMAN. Absolutely correct. And they didn't have the resources to have a robust research and development department. And they—and the engineers were all funded from the Shuttle programs, so, you know, they are not going to tell their boss that he is in trouble and et cetera, et cetera. But yes. Yes, sir. You are exactly right.

Chairman BOEHLERT. Thank you.

Mr. Rohrabacher?

Mr. ROHRABACHER. That, of course, is the difference between being proactive and being reactive. And in fact, I think your report suggests that the NASA attitude went beyond being reactive. It was actually blasé toward some of these signs that Chairman Boehlert has just pointed out.

Let us go to that attitude now, as soon as we get done with these beeps and buzzes. Did your Commission find that this lack of energy or this blasé attitude or bad culture, whatever we want to call it, that this was part of the NASA culture in the past during the Apollo programs and other programs, or was this something that has just sort of evolved into place in these last 10 to 15 years?

Admiral GEHMAN. We spent a lot of pages trying to answer that question, Mr. Rohrabacher. And it is our conclusion that it appears to us that, as you study history and you study the previous reviews of NASA management, and you know, NASA is never not being reviewed by somebody, so there are a lot of data points out there, that it seems to ebb and flow. After a big tragedy, like *Apollo* or *Challenger,* they take a whole lot of management actions to make the program more safe and make it more sensitive to engineering problems. And then, over the years, forces begin to act on NASA. And some of these forces are external forces, by the way. Some of these forces are budget pressure or schedule pressure put on by both ends of Pennsylvania Avenue. And NASA then starts to—it starts to migrate or morph its management scheme to be more effective, more efficient, more cost-effective. And we specifically found, for example, that—in this particular case that we were looking at so carefully, the Space Shuttle program, the Space Shuttle program management actually had been squeezed to the point where the Program Manager had so much authority, so much responsibility, and so much authority that he could trade schedule against safety upgrades. He could trade costs against research and development. And we found this to be unhealthy.

VISION

Mr. ROHRABACHER. One last thrust here, and that is this attitude and this evolution in the wrong direction, that does have something to do with a lack of vision and a lack of goals of the whole space program, does it not? We have a saying on top of us here that says, "Where there is no vision, the people perish." And let us note where there—when there is no vision, astronauts perish. And is that not what we are talking about here?

Admiral GEHMAN. We noted in our report that a lack of an agreed national vision causes NASA to have an unclear set of criteria on how to make decisions.

Mr. ROHRABACHER. And leads to that attitude?

Admiral GEHMAN. It absolutely does.

Mr. ROHRABACHER. Okay. Thank you very much.

Chairman BOEHLERT. Thank you very much.

Mr. Gordon?

Mr. GORDON. Thank you, Mr. Chairman. And Chairman Rohrabacher, I hope that you will continue this effort to try to find that vision. I think it is very important.

INTERNATIONAL SPACE STATION AND SPACE SHUTTLE MISHAP INTERAGENCY INVESTIGATION BOARD CHARTER

A couple quick questions, because, as you know, we are caught in here with the bells. As you are well aware, Admiral Gehman, you had to make a variety of changes to the original charter that was set out in this Contingency Plan to develop a Commission that you felt comfortable with. As I understand it, we revert back to that original charter now if there is some problem in the future. Would it be fair to say that this committee ought to review—reviewing that original charter and making some changes so that if there is another occasion that we will be better prepared early on?

Admiral GEHMAN. To my knowledge, the NASA Contingency Plan, which created this board, is still in existence and the words haven't been changed. And if you feel that those—that Contingency Plan is not right, yes, it should be reviewed.

Mr. GORDON. Well, you obviously did, because you asked for it to be changed——

Admiral GEHMAN. That is correct.

Mr. GORDON [continuing]. A variety of times.

Admiral GEHMAN. That is correct. Um-hum.

DEFINING BENCHMARKS FOR PROGRESS AND PAST REPORTS

Mr. GORDON. Okay. Now, as you have said on a variety of occasions outside the specifics of the foam, a lot of what your work was was rehashing the McDonald report. And if NASA had done a better job of following the McDonald report, we may or may not be here, but we would be in a better situation. I think it is very important, as our Chairman pointed out earlier, that, you know, when the crowds diminish and you are gone home, that at least this committee doesn't lose its enthusiasm for oversight and for setting up benchmarks.

And again, as the Chairman said, that is more than just good will, it is the deeds. So I will—what I am going to—because I think we can't get it all done today, but I am going to write you and ask that you lay out your thoughts on how—what kind of benchmarks, what type of processes that we need to set up to see that these things are followed, as we had hoped the McDonald would be. And you can do it more extensively later in that letter, but I will let you go ahead now. And if you would like to give this committee advice as to what kind of benchmarks we need to set up. And if you would help us, also, talk a little bit about what kind of rough dollar figures that we need to be looking for.

Admiral GEHMAN. The Board agreed with me that we would not be doing a thorough job if we did not study history. And we studied

history, the history of NASA and the history of the investigations—previous investigations of NASA, including what we found in retrospect to be a very, very good report done just three years ago by Harry McDonald. But also, we went back to the Rogers report and the Norm Augustine report and the Kraft report. And all of these reports, which we carefully documented, you might say we found nothing new. NASA has been told over and over again that they are—that a number of the things they are doing increase the risks to the Shuttle. They are—I think your question, though, is really an excellent one and that is two years from now or three years from now or four years from now, how do we ensure ourselves that the follow-up—that the progress is there and that the follow-up is there and that this natural migration of these good traits back to bad traits doesn't occur again, like it has happened in the past. And the Board has discussed this a little bit, and we would be delighted to dialogue with you on how you get at that, because I think that is the central question.

Mr. GORDON. And you are going to be around a little longer. You will have staff a little bit longer. And if you—I will send a letter of request and would welcome your advice as to how we can follow up on that.

There are lots more, Mr. Chairman, but I guess we better go.

Chairman BOEHLERT. Well, I think we can get in one more round. We have eight minutes to go, so we will go to Mr. Smith of Texas, and then we will take a brief pause. We have two votes. We will get right back. This is very important.

Mr. SMITH OF TEXAS. Thank you, Mr. Chairman.

Admiral Gehman, let me get directly to my questions. The first is that the report raised a concern about greater priority being given to scheduling demands than safety. Who or what pushed these scheduling—put these scheduling pressures on the individuals involved?

SCHEDULE PRESSURE

Admiral GEHMAN. The—we believe that we got right to the bottom of that in our report. And when you ask senior managers at NASA to a person, 100 percent of them deny that there was any schedule pressure. And then when you go down and talk to the worker bees, the project people who are actually working on the Shuttle program, to a person, they say that there was enormous schedule pressure. So schedules, of course, are not bad things. I mean, everybody uses schedules as a management tool.

Mr. SMITH OF TEXAS. Do you think the pressures were more internal than external?

Admiral GEHMAN. I think that there was a great difference of opinion between the senior managers and the junior people. And of course, any time you have got the senior managers working on one set of script and the other people working on another one, you have got a dangerous situation.

Mr. SMITH OF TEXAS. They are conflicting responses to——

Admiral GEHMAN. Complete miscommunications as to what the truth was.

INACTION TO PREVIOUS FOAM LOSS

Mr. SMITH OF TEXAS. Admiral Gehman, none of the external advisory groups voiced concerns about the foam despite the fact, as we know, that foam has been falling off consistently. What significance do you attach to the fact that none of those concerns were raised?

Admiral GEHMAN. Thank you, sir. And by the way, that, of course, struck the Board right in the forehead like a two-by-four that these wonderful previous panels, including Rogers, missed the significance of the foam coming off. If we are so brilliant that we can see that foam is a hazard to the Shuttle, why didn't all of these other people see it?

Mr. SMITH OF TEXAS. Exactly.

Admiral GEHMAN. And the way we answered that was that these—we have to set up a management scheme that can detect this kind of stuff, not—knowing that it is very hard to detect. And the management scheme that we put in place would be one in which waivers or exceptions or violations to the specifications would be reviewed by a group of people who have no interest in cost and schedule. That is the only way we can see to safely get things like foam and—oh, by the way, the Board felt it very important that we come up with others, by the way. We think it is kind of a cheap shot to take a—to criticize NASA for missing the foam, so we said, "Okay. If you are so smart, tell me what the other ones are." And we came up with half a dozen other ones that are very dangerous in which they decided to waive. I know, and my panel members, I know, for example, Dr. Widnall would like to—might want to comment on the testing of bolt catchers and things like that. So you know, there are others. So the answer to your question is this independent technical review authority.

REDUCTION IN SAFETY PROCEDURES

Mr. SMITH OF TEXAS. And a couple more questions real quickly, Admiral. You expressed concern in the report about the drastic reductions in government inspectors and the mandatory points of inspection, which actually started in the early 1990's. Was this intended to shift greater responsibility to the contractor or was it to meet budgetary constraints?

Admiral GEHMAN. It was both. It was—they assumed—their belief was——

Mr. SMITH OF TEXAS. Neither of which was good.

Admiral GEHMAN. Neither of which was good.

Mr. SMITH OF TEXAS. Okay.

Admiral GEHMAN. They assumed that the maintenance and preparation for launch of the Shuttle, they had done it so many times, they thought it was a routine operation and could be contracted.

SHUTTLE SERVICING OF HUBBLE

Mr. SMITH OF TEXAS. Lastly, Admiral Gehman, if the Shuttle flies again, and we hope that it does, is there any reason why it would be limited only to servicing the Space Station? Is there any reason why it couldn't continue to service other science missions, including the Hubble?

Admiral GEHMAN. No, there is no reason except that the on-orbit inspection repair capability, which we recommended, would be different for the two missions.

Mr. SMITH OF TEXAS. All right. Thank you. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you. Just let me make an observation. Waivers are something we are going to get into in greater depth a little bit later on. There are over 3,200 waivers that have been granted. Over 1,000 of them hadn't been reviewed in more than a decade, so that is something you rightly emphasized and that is something we should focus on. But before that focus, we have to take leave for a few minutes to go respond to the call of the House. We should be back within 15 minutes. If you have—if you would like coffee or—I can't give you a break to go sailing, Admiral, but we can give you a—we will try to—the staff will try to accommodate anything you might want, if you want——

[Recess.]

SCHEDULE PRESSURE

Chairman BOEHLERT. Let us resume. Mr. Costello?

Mr. COSTELLO. Mr. Chairman, thank you. Admiral, you answered a question earlier posed to you by my colleague, Lamar Smith, and I would like to follow up on that. On pages 116 through 118 and later in your report, you refer to the schedule pressure, the pressure that was put on NASA employees by the schedule that was adopted by the Administrator. And I would like to ask a few questions concerning the pressures that may have been added because of the schedule. And one is you apparently, according to your report, the Board's report, you very carefully evaluated the impact that the schedule pressure may have had on Shuttle safety. And specifically, the Administrator seems to have laid out a management goal of completing node two of the International Space Station by February 19, 2004.

And my question is, from reading the report, is that most of the NASA program people believed that that was an unrealistic goal. They also believed that if they didn't meet these arbitrary goals that something bad was going to happen to them. And I wonder if you might comment what you found regarding the schedule pressure and how that impacted safety.

Admiral GEHMAN. We did find that schedule pressure, undue schedule pressure, excessive schedule pressure, was at work on the workforce in NASA, even though as I indicated in my previous answer, the senior management will deny that. But we did find it present in the workforce. And as the illustrations in our report indicate, we also were concerned that some of the measures that NASA was taking to stay on schedule appear to be cutting into the safety margin, such things as working on weekends, conducting safety checks in parallel instead of series. They are all listed in those charts in there. They all appear to be a—they all appear to support our basic hypothesis that bad traits and bad engineering habits had crept into the NASA organization. We don't think—we don't say in our report, and I don't think the Board feels that schedule pressure caused this accident. That is not what we are suggesting.

Mr. COSTELLO. The—you talk repeatedly in the report about the communication failures at NASA concerning the *Columbia* disaster. And you know, it is surprising to me that the Administrator and top management never seem to hear from the people in the program level that the schedule, the Core Complete goal needed to be adjusted or changed. Did you find any evidence at all of discussions that may have taken place concerning the goal complete—Core Complete goal among the top managers or any consideration of how it impacted safety of the Shuttle? I know the top management said that they never heard, but in your investigation, did——

Admiral GEHMAN. Yes. I will let General Hess answer that. He is the expert on that area.

Major General HESS. Thanks. I think in our investigation of it, and it is documented in some of the charts in the report, we know that the International Space Station managers, as well as the Shuttle managers, were briefing the number of days of slack in the schedule. And the briefing charts were, in the last venue, I think, in December of 2002 indicated to the leadership that they were projecting as much as a 45-day late, last line on the chart says, but we are going to hold to the February date. And so I think that the discussion was there that they were telling the NASA leadership that their best estimates were that they were going to be behind, but they were still sticking to the date.

Now how far the conversations went beyond the briefing chart, I don't think we know, but when we get back and look at the circumstantial evidence, how it unfolded with regards to decisions made on STS–113 and then on-orbit decisions were made with this particular mishap, it looks like it all came together to influence decisions.

Mr. COSTELLO. General, a follow-up question, if I can. Do you have any concerns that the return-to-flight goal laid out by the Administrator may produce some of the same pressures?

Major General HESS. Well, obviously I would have concerns if NASA doesn't have a realistic timeline decided. I think that, perhaps giving them some credit here, the initial estimates about when they wanted to return to flight were done before the full value of the report was laid out before them so they could actually see the recommendations and how long it was going to take them to get from where they are currently to actually the return-to-flight decision. And certainly some of the key return-to-flight recommendations will establish a timeline that may not have been apparent when the schedule set. So I think that they have every opportunity to fix the schedule that will be realistic.

Chairman BOEHLERT. Thank you very much.

Let me ask you, Admiral, before I go to Mr. Calvert, NASA has indicated the return-to-flight report will be out next Monday, I think, the 8th, or Tuesday. Will you be in a position to give a sort of an instant evaluation of that plan?

Admiral GEHMAN. I, obviously—I am going to retain a small staff, because we have more work to do, and we are at your disposal to do whatever you want to do. I would say that Mr. O'Keefe indicated in testimony yesterday that the return-to-flight schedule is events-driven, not calendar-driven. So he said we return to flight when we are ready, not—and not on a date.

Chairman BOEHLERT. And you are due to be testifying before the Committee with Mr. O'Keefe on the 10th——

Admiral GEHMAN. That is correct.

Chairman BOEHLERT [continuing]. And so I am sure you will have some choice words on that.

Mr. Calvert.

INDEPENDENT TECHNICAL AUTHORITY

Mr. CALVERT. Thank you, Mr. Chairman. And thank you for having this hearing and the hearings we are going to have in the future. And I want to thank Admiral Gehman and certainly the Investigation Board for all of their hard work, and we certainly appreciate that.

I would like to spend a little bit of time on the issue that was brought up during your testimony, Admiral, and that is the role of independence. I am interested in learning more about the Board's suggestion that the responsibility and authority for decisions involving technical requirements and safety should rest with an Independent Technical Authority. And I agree with you. I agree with the conclusion and the relating recommendation. NASA needs to utilize independent assessment capabilities that will serve them throughout the life cycle of the space system and human space generally. And as you know, Admiral, in your career in the United States Navy, some of the oldest and best assessment—independent assessment work came from the Navy's painful experience from World War II with torpedo fuses, which was well-documented and the Navy learned their lesson and it created something that was just in my District, the NAVSEA Corona, which I represent, which trace back to that original problem. Within your recommendation that NASA stand up on an independent assessment capability, is there room, encouragement, direction for NASA to use the experience—that kind of experience and to follow agencies like DOD to establish that authority?

Admiral GEHMAN. I thank you for the question. And the answer is that—the answer to that question gets right to the core of our recommendation. We tried to devise a practical, workable recommendation that would fix as many of the problems in one—at one time as we possibly could. And the traits and the unhappy characteristics that we saw in the ignoring of engineering advice, the e-mail story about the images, all—many, many of these ills, we thought could be fixed with one management fix. And that management fix is to take the ownership of the level one specifications and requirements and all waivers to them, and the Chairman had mentioned how many, 3,000 and some odd waivers we are flying with right now, invest them in a technical engineering organization, which is divorced, isolated from cost and schedule pressure. And this is done other places. We have found other places where it is done. You mentioned NAVSEA Corona, which does not only the—now it does missile—it does all kinds of analysis of weapons' effectiveness. And they are completely independent from the guy who has to shell the money out. And so you get an independent assessment. We find that to be a very attractive methodology for fixing a number of problems.

Mr. CALVERT. And when you say independent of NASA, would they have a separate budget? Would NASA still control their budget? Would you kind of expand on how that organization will work and how its—and the relationship with the Shuttle Program Manager?

Admiral GEHMAN. It is not our intent that they will be independent from NASA. It is our intent that they be independent from the Shuttle program. Now they would still be within NASA, as we viewed it. We were very careful in our report, and we discussed among ourselves, at great length, the issue of not specifying in any great detail how this organization should be set up. Since we are not going to be around to micromanage it or be around to make the fine-tuning that are necessary to any management change, we decided instead to specific in great—with great detail and great directness how this organization should work, what its function should be, but not drawing the wiring diagram. So this organization would be within NASA, but it would be independent of the Shuttle program.

Mr. CALVERT. I understand. Dr. Hallock, General Hess, Dr. Widnall, any other comments on that, on the independent technical board?

Dr. WIDNALL. Yes, I might make a comment. I think this, as the Admiral has indicated, is an extremely important recommendation. And from my way of thinking, what we have given NASA is a template or, as a scientist, I might say we have given them a set of boundary conditions. I believe very strongly that it is in the working out that will take place within the agency of how this will work, what processes will be used, how the interaction and interfaces between the Shuttle program and independent technical agency, how that will all work I believe will go a long way toward challenging the basic culture of NASA, because it will challenge some of their basic assumptions about, you know, what is true, what is fact, what is analysis, how do you make decisions. So I look to it to have a really good effect on the agency, the working out of the details within the template.

Mr. CALVERT. Thank you. Thank you, Mr. Chairman.

Chairman BOEHLERT. Mr. Lampson.

Mr. LAMPSON. Thank you, Mr. Chairman.

VISION

Well, Admiral Gehman, I want to join with my colleagues who have passed commendations on to you and the other Board members and your staff are—the work that you have done on this report. I, too, remember back when—I guess in February when Administrator O'Keefe said, "We may never know the answer." I think that we can feel confident that you have, indeed, determined the physical cause of this accident.

I read your report to say that NASA must see significant reform, the agency must develop a vision for the future, and that the Administration and Congress must provide NASA with adequate funding levels. And I see that as a new mantra for us. Let us do what my Senator said the other—yesterday when she said, "Let us throw out faster, better, cheaper in the garbage can. Let us start looking at reform, vision, and funding and perhaps we can have

some different successes." It seems clear from your report in the area of reform that NASA and the space community are comprised of an enormously talented and dedicated group of men and women who are capable of making the cultural changes that your report indicates. How, specifically, do we continue to support their important efforts as NASA continues their return-to-flight process and institutionalizes the changes that will support and sustain safe operations over the long run?

Admiral GEHMAN. That is a tall question, Mr. Lampson, but I will give you a couple of answers to that. First of all, it isn't NASA that needs a vision. It is the country that needs a vision. NASA has got lots of visions, but visions without resources are just dreams. We need an agreed vision, and then NASA can execute that. The reforms that we call for in our report can not be instituted by the Administrator of NASA alone. He is going to have to have your help. For example, this independent technical review authority that we just discussed will have a manpower bill associated with it. These are people that are going to have to be hired, and they are going to have to be paid. They are going to have to have career paths et cetera, et cetera. So they are going to—the Administrator is going to have to come up here and get your assistance on this.

Some of the other reforms are going to require your assistance, too, because they are not solely within the purview of the Administrator of NASA. The funding business—the Board, in order that we weren't affected by cost and funding, we kind of isolated ourselves from costs, and we don't know exactly what it is going to cost to return to flight. I would say that our experience of working this problem for better—just under seven months, indicates that none of the things we have recommended are terrifically expensive. I mean, they aren't showstoppers. But some of the things that we recommended for the midterm, for example, this completely independent new technical review authority, an independent safety organization with line authority over safety means more people, more government people. And some of the other recommendations, having to do with the oversight of the contract needs more government employees. So he is going to have to come up here and explain to you how he is going to go about it, and you are going to have to help him.

Mr. LAMPSON. You made the comment about vision, and in the report, you also said "lack of agreed national vision for human space flight." Would you expand on that finding for just a few seconds, please?

Admiral GEHMAN. Well, we attempted to find everything that we possibly could that contributed to bad habits and bad traits and bad management at NASA. And there were a lot of things that contributed a little tiny bit and some things that contributed largely. This was a contributor. It—for lack of an agreed national vision, you don't know how many years to amortize investment in infrastructure. It is hard to argue budgets before Congress if you don't have an agreed vision to where you are going. You don't know when to replace equipment. We saw, in some of their technical laboratories, 1960-era oscilloscopes and things like that, analog meters when everybody is using digital meters, you know. And there are basic infrastructure decisions and basic investment decisions,

which NASA has a hard time arguing or justifying because we don't have a complete agreement on how long is a Shuttle going to be around, what is it going to be used for in the future. And so it is very difficult for them to make investment kinds of choices.

Mr. LAMPSON. Thank you very much.

I would like to ask, and I am not going to, because my time is about to run out. I would like to ask, at some point in time, for your advice on—and the Board's advice on how to recognize in the future when a lack of resources has pushed a program into an unsafe condition. And there might be something that you may want to think about and at a future opportunity that we will have—but let me take my last couple of seconds and close, if I may. I do believe that we should give NASA the funding that it needs, but first, the agency must make necessary reforms and establish a vision. Your report calls on the White House and on Congress and NASA to honor the memory of *Columbia*'s crew by reflecting on the Nation's future in space. And I couldn't agree more. And now that your report has been released, this Administration must provide Congress and the American people with a vision and a concrete set of goals for the Nation's human space flight program after the International Space Station. And I am hopeful that the agency will establish a phased series of goals over the next 20 years, including human visits to the Earth-Sun libation points, Earth-orbit crossing asteroids, as we have been reading about, deployment of a human-tended research and habitation facility on the moon, and human expeditions to the surface of—and moons of Mars. And I attempted to push such legislation, push NASA into the direction of my Space Exploration Act legislation that I introduced in the last Congress. I am going to do that again, Mr. Chairman, next week, and I invite all of our colleagues on this panel to please take a look, please make advice or suggestions to me as to how to make it the kind of legislation that would fit into our discussion today.

And again, I thank you, Admiral Gehman. I yield back my time.

BUDGET

Chairman BOEHLERT. Thank you very much, Mr. Lampson.

I would note a particular passage in the report on page 209, "NASA has usually failed to receive budgetary support consistent with its ambitions." I would suggest that probably that would apply to any agency of the Federal Government. And I am glad we are focusing so much attention on vision, because we have to have a shared vision. It has to be at the Executive Branch and the Legislative Branch, and we—and the American people signing on to that vision.

But further, and I would report on page 105 of the report, we are talking about budget reductions. We are all part of this process. But let me just read a couple of things here. "Reductions have been requested by NASA during the final stages of budget deliberations. After its budget was passed by Congress, NASA further reduced the Shuttle budget in the agency's operating plan, the plan by which NASA actually allocates its appropriated budget during the fiscal year to react to changing program needs. These released funds were allocated to other activities, both within the human

space flight program and in other parts of the agency." And then it goes on to enumerate all of the changes that were made.

Of course we haven't provided NASA, or any other agency, with every dollar they have requested. And we have to be very mindful of our special responsibilities. But when it is pointed out that we don't provide the budget to—consistent with an agency's ambitions, I would suggest that the agency better adjust its ambitions, and we better sign on to what we agree on is the vision for a program for the rest of the budget year and beyond.

With that, I go to Mr. Gutknecht, the Vice Chair.

Mr. GUTKNECHT. Thank you, Mr. Chairman.

BENCHMARKS OF IMPLEMENTATION

And again, I thank all of you for what you have done. And I think your answers today have been very candid, and we appreciate that more than you can imagine.

I—yesterday, the Administrator, Mr. O'Keefe, testified before the Senate Commerce Committee. And he indicated unequivocally that he understood the message and would implement the recommendations of your report. But you know, success leaves clues, and good management requires setting benchmarks and finding, you know, as we go forward how are we doing in terms of implementing that. And if you were sitting on this side of these desks, what would you look for in terms of benchmarks so that we could actually have a better confidence that they really are implementing the plan, at least as you outline in your report? Any particular things we should look for in the next six months to——

Admiral GEHMAN. I will take a—I will mention a couple things, and I think I am going to ask Dr. Widnall, who has some comments about oversight and review and things like that. First and foremost, of course, is the Stafford-Covey—well, the first and foremost is the waiting for the NASA return-to-flight plan. We have to get it, and we have to look at it. Second of all I think very prudently, we have a very illustrious large panel, the Stafford-Covey Return-To-Flight Review Group, which is going to provide an opinion, an evaluation not of our report, but they are going to provide an evaluation of the adequacy of NASA's response to it. And I think that that is a very, very good step. But the real core of our recommendations are recommendations which are—need to be implemented a year from now, two years from now, and three years from now. And I think that the question remains open in my mind as to how to follow up on that effectively. And setting benchmarks is a good way to do it. There are other ways to do it. And I think that Dr. Widnall wanted to make a comment about the efficacy of some kind of a review panel, which might measure those things.

So if you will allow me, I will recognize Dr. Widnall.

Mr. GUTKNECHT. Please.

Dr. WIDNALL. Okay. Well, let me make a couple remarks. First of all, I do believe that our recommendation that in the return-to-flight, the—NASA should come forward with a plan on reorganization was actually inspired. It is one of those things that happens when a group of people get together and, you know, talk deeply about an issue. And I think it really was an inspired idea. From my point of view, the organization that we have recommended, the

Independent Technical Authority and the safety organization, have specific attributes, and you could almost check them off. We leave it to NASA to do the details to figure out where in the organization it housed, who it reports to, and all of that. And the—but the processes, the fact of its independence is a specific attribute that can be measured. And there is no fudging up of that. So I think that is identifiable.

As to the issue of oversight, I think there has been a tendency to simply recommend an oversight committee. I think there is a big difference between oversight inside an organization and oversight outside of an organization. I have not been a fan of standing outside oversight committees, because I think, with time, they tend to atrophy. They lose, you know, the urgency. They have an initial charter. They have an initial mission, and they set out on that mission, but then over time, it kind of dwindles away. So I am concerned about establishing yet another "outside advisory committee." I am much more in favor of what I would call the sense of urgency, short-time committee, such as we, ourselves, were. We were a short-time committee, seven months. We had a sense of urgency about what we were doing. We were willing to work real hard for a short period of time.

So those are some of the trade-offs that you might think about as you look into the issue of how can you get adequate oversight for some of the details that need to be followed up on. I do believe that safety is a technical discipline. So you will need comments from people who, basically, are safety disciplinarians and people who have had experience at these kind of very intense investigations, such as our Board. But the question of follow and oversight is a challenging question. And I know that you will be giving a great deal of thought to this as you proceed.

SHUTTLE DESIGN COMPROMISES

Mr. GUTKNECHT. And speaking of urgency, and I know we all have to run and vote, but I couldn't let you go without at least mentioning, and perhaps you could respond briefly, Homer Hickham wrote a fairly blunt piece in the *Wall Street Journal* the other day. And he titled the piece, "NASA's Vietnam." And in it, he says, and if I could just read this into the record. He says, "Take a look at the Shuttle's stack and see what you see: a fragile space plane sitting on the back of a huge propellant tank between two massive solid rocket boosters. The Shuttle has to sit right in the middle of all of this turmoil of launch, because we once believed that it would be cheaper to bring back those engines and rebuild them rather than to build new ones. That has proved not to be the case, far from it. But it has left the crew sitting in the most vulnerable position possible in terms of design." Would any of you like to talk about it, because essentially what he says is that the whole design is a flawed strategy and that we have to get serious about coming up with a whole new way of launching a returnable vehicle? Would anybody like to comment? And I apologize, because our time is short, and we don't have enough time to discuss it in length, but——

Admiral GEHMAN. We have felt so strongly about this, and we devoted the whole first chapter in our report to the issue of the com-

promises that were made when they built this thing. And because we felt that the compromises—the original design compromises left us with what we have got. I mean, it is—what we have got is what we have got. And it is a compromised vehicle. Now it is an engineering marvel, but I know, as an aerodynamisist and Dr. Hallock also is a physicist, we all constantly scratch our heads as to why you have three 400,000 horsepower engines on a glider. And why do you put them into orbit? And we know the answer. I mean, we know the answer, but in retrospect, it is an interesting question. But in—to make a long story short, we agree with you, and that is why we devoted a whole chapter to the issue of the design compromises that were originally made when the original—when this Shuttle was originally built.

Mr. GUTKNECHT. And that is why you essentially recommend that as soon as possible, this vehicle be replaced.

Chairman BOEHLERT. Thank you. The gentleman's time is expired.

Now we have another vote, but we will dash over, and I promise you faithfully we will dash right back. And Mr. Wu will be first up. We will see who dashes the fastest.

[Recess.]

ONE-YEAR REVIEW

Chairman BOEHLERT. Let me bring up a subject that you might not want me to bring up. But Admiral Gehman, you indicated that you are not going to be micromanaging and fine-tuning everything, but we do need, and we have got our special oversight responsibilities. We have to be vigorous with them, and I can assure you we will be. And I understand, Dr. Widnall, you said about all of these external panels, appointing new panels. You are not quite certain they always do the job that they intend to do, but at the risk of offending you, this is a compliment to you, we need some help in evaluating the plan and would the panel be receptive to, sort of, a one-year review? Now I don't know how practical that is, because you are constituted under the authority of NASA. Maybe you could be reconstituted under the authority of the Congress, but I think you provide an invaluable service to the Nation. You have expertise. You have brought an awful lot to the table for us to consume and digest. And I would like some help in the process. And I am wondering if you would be receptive to, sort of, a one-year look back, an evaluation, not micromanaging, not fine-tuning, evaluating how NASA has responded to what you have proposed, what the Administrator says he embraces, which we are applauding. Admiral, would you care to comment on that?

Admiral GEHMAN. Yes, sir. I consulted my colleagues about that, and I am authorized to say, on their behalf, that if it is requested by the Congress, we would do that.

Chairman BOEHLERT. Thank you very much. And I appreciate that. And I can almost assure you that it will be requested by the Congress.

Now if Mr. Wu isn't back but—Dr. Widnall, did you wish to offer some supplementary comments for the record?

Dr. WIDNALL. Let me make two. Let me second what Admiral Gehman said. And I see it—one of its virtues as providing some

continuity, and in some sense, that is a force multiplier for the time that we all put in on this. And so I think it actually gratifies us, because we will feel that our work is even more effective if we do provide this kind of continuity, so it is certainly something that I welcome.

FOLLOWING THROUGH ON THE REPORT'S RECOMMENDATIONS

Chairman BOEHLERT. I have been in Congress 21 years. I started out at the lowest level on the first tier as a junior member. And over these years, I have seen a lot of reports. They are issued. They are produced by dedicated Americans who bring special expertise to the table, and more often than not, they gather dust on the shelf. The Rogers report was—there was immediacy in responding to some of the recommendations, then the atrophy set in, as you have referred to. We are going to follow through on this thing. We have got to be vigorous. And we just can't look to NASA and say, "All right. Now the problem has been identified. You know how to fix it. Fix it." We have got to be part of the solution. And so we have to look ourselves in the mirror and say, "Are we as vigorous as we should be in connection with our oversight responsibilities?"

And so Mr. Wu is not back yet. We will——

Dr. WIDNALL. Well, the second point I wanted to make, which was really the point that you called on me for, was just, as we finished the last round of questions, was really just to point out the time scales involved in these sorts of endeavors in the space field. I mean, when you talk about let us find a replacement Shuttle, you know, you are talking ten years. You are talking a very high level of technology. It also goes back to the issue that I discussed with Mr. Hall. You know, what is the word "consider." The word "consider" means to do an in-depth engineering analysis of what are the possibilities, what are the trade-offs, what are the options. And that certainly is a process that needs to go forward as we think about replacing the Shuttle, new concepts for manned space vehicles, how do we service the Space Station. All of these things require an in-depth engineering analysis. And the time scale involved is certainly measured in years, certainly up to ten years before one would have a new generation of vehicles.

So that was really the only point I wanted to make.

Chairman BOEHLERT. Thank you very much.

And I see our distinguished colleague, Mr. Wu, is back. Mr. Wu is recognized for five minutes.

Mr. WU. Thank you very much, Mr. Chairman.

Admiral Gehman, always good to see you and members of your Board, although one always wishes under other circumstances. Like others, I want to commend you for finding the physical cause of this tragedy at the RCC panel 8 and also for identifying some of the organizational and, one might say, cultural factors in NASA that have contributed to this set of tragedies.

WORKFORCE

I want to encourage the panel here to look forward a bit and focus on something related to the cultural and organizational

issues that you identified, but not exactly those. And that is the recruitment and retention of the best and brightest, especially young people, but people of all ages. In my experience, as I have gotten older, everybody else has gotten younger in various organizations. My teachers have gotten a lot younger, in my eyes. As I visited NASA sites, and this is with great respect to NASA personnel, they seem older than I remember them when I saw them on television when I was a young person watching the Apollo program and the Gemini program and so on. And I know older folks, whether it is at NASA or on the Board or in Congress can make great contributions, but back in the 1960's, there were, you know—NASA was—especially as Chairman of various committees. There were few places to go. And NASA was probably the place to go if you were really into technology and really hot to go. It was not only technologically and scientifically the most exciting place to go, but it was also part of this competition with the Soviet Union that made it a part of our national purpose.

You know, today, the Cold War is over. We were the first the moon. And in addition to that, we have all of these private companies and other places where folks in technology can be drawn off to, whether it is by higher salaries or nimbleness of movement—adeptness of movement in the organization, what are some of the things that can be done to help NASA recruit and retain people? And some of the negative factors that are there, some of the positive things that can be built in for the future. And I would just like to engage the panel to discuss that.

Admiral GEHMAN. Absolutely. And the panel has discussed it. And I know, as an educator, Dr. Widnall has an opinion about that, as do my other colleagues. I, very briefly, will say—list three things. First and foremost is a mission. And it is not—a good mission, a good recognized mission, which excites people, will overcome low government salaries and a whole bunch of other things. The second place is you have to have a really great place to work. And that—I am talking about the work attitude, the climate at work, and all of that kind of stuff. And I think NASA is a good place to work. It can be made better because of some of the traits that we have talked about.

And the last one would be I would like to see NASA reduce the number of times that they give the top really good jobs to outsiders. NASA, too often in my mind, takes the top, really best jobs, and gives them and recruits outsiders rather than moving people up from within. They like to hire Admirals and Generals for Center Directors and things like that instead of taking the best NASA people and make them Center Directors and things like that, even though I like Admirals and Generals. I really think that if you are a career NASA employee and you want to get a—and you want to rise to the top and then you see the top jobs going to outsiders, you just have to scratch your head. As part of that, in the Space Flight Operations Contract, the SFOC, a lot of very high level positions, which I thought ought to be government positions, are now contractor positions. And once again, these are top level positions, which have been contracted out to really competent people, but what it is instills in the workforce is that you work for the government for 15 or 18 years, and then if you really want to go into the

top jobs, you have to go over to the contractor side to get to the top job. I found—I find all three of these things that could make the place a much better place to work.

And as an educator and a close student of this, I know that Dr. Widnall may want to comment on it.

Dr. WIDNALL. Yeah. I knew this was coming. No. And as an educator, as an aerospace educator, I know that there is something about aerospace that evokes the passion of young people. There is no question about it. There is hardly any other field to which people are drawn because of the real excitement of the field. There is no question about that.

As an aerospace educator, I feel that it is my responsibility to take that passion and turn it into an appreciation for responsible engineering. And I think that that is a challenge. I do think it is no longer the case that NASA is the only place to go. I mean, this committee knows more than any other Committee about the broad range of science and technology that our nation is advancing: work in the biological sciences, work in the computer sciences and miniaturization, new materials. Science and technology are advancing across a broad front. Space is exciting, but it is not the only exciting thing that we, as a Nation, are doing.

So what I think is that we have to learn to operate in a much more complex environment where young people, in fact, do have a range of options, a range of exciting things to do. And I think we have to ensure that across a broad range of disciplines. And I think it will feed directly into our science and technological strength as a Nation. Young people are excited by the development of new capabilities. And to the extent that NASA moves forward with a vision, a national vision for space and the development of new capabilities, I think young people will naturally be drawn to NASA as a place for employment.

Mr. WU. I have a burning follow-up question, but I know better, Mr. Chairman, than to ask if I could ask it under these circumstances. Thank you very much, Mr. Chairman.

Mr. EHLERS. [Presiding.] The gentleman's time is expired. And we will see if there can be a second round for burning follow-up questions.

I apologize if my question is not relevant or has been answered, because I have been popping in and out of three meetings this morning, all of which, unfortunately, happen to be urgent. And I apologize for that.

CHARACTERISTICS OF A FOLLOW-ON VEHICLE

But looking toward the future, it seems to me the very first thing that we, in the Congress, and frankly, the American people have to decide is whether we want to continue human exploration of space. And I suspect the answer is yes just because, as Dr. Widnall mentioned, there is some magic to aerospace that this is something that we want to do. It is part of our background or ethic that we should be out exploring in every dimension. So assuming the answer is yes, it seems to me that our highest priority has to be to design, develop, and build a new type of space vehicle.

My first question is do you see that, and what do you regard as the characteristics we need. It seems to me that, given modern

technology that has developed since the design of the Space Shuttle, that we can build it safer and better, more efficient, with less turnaround time and higher efficiency and lower cost. And that, perhaps, in the long run, we will, in fact, save money to have a new vehicle if we can design one that satisfies those criteria. So that is the first question.

And secondly, I would appreciate just a comment from you on the balance between what one might call scientific research and what one might call human exploration. We all know that, dollar for dollar, we get much more science done with unmanned experiments, satellites, rovers, than we do with human exploration of space. I—just—even though this was not your task, I am asking for your opinion. What is the balance now and what do you think it should be between those two? So two questions.

And we will start at——

Admiral GEHMAN. Well, I am going to ask Dr. Hallock to take a shot at the first one, sir, and then we will rearm——

Mr. EHLERS. Okay.

Admiral GEHMAN [continuing]. To take a shot at the second one.

Mr. EHLERS. Dr. Hallock.

Dr. HALLOCK. When you look back at what we—this thing that we were studying, the Shuttle, remember it came from the 1960's technology. And it also, as we point out particularly in chapter one, it—when it was being put together, a lot of the requirements were actually given to people. To follow up on a question that we discussed earlier this morning, you know, why do you put the Shuttle where you do where it can get hit by all of this material that is out there? Well, the reason is that one of the key requirements that was levied upon these people back then was that you wanted to put together a system that would be reusable. Things like those big engines and everything that you put on the Shuttle. In order for them to be reusable, you had to put it on something that came back. Well, the—what I am really saying is when you—if—I fully agree that one needs to look at trying to come—look to the future and redesign, come up with a design of a vehicle to get us safely into space, but not burden it with so many things that actually were compromises.

And these are the things that I think that have led to all of these problems. For example, you know, if you look at the Shuttle and look at some of the earlier designs, you know, you put the Shuttle on the top. So what is going to fall on it? Nothing. If anything, it is shedding material as opposed to having things that could come off and hit it. So that is my point is that you really can do it, but you need to have a clean slate. And as part of that clean slate, you can also add in those other issues, which were what can we do to allow ways for the crew to get out in case there is a real problem? There are a number of things you can add.

Mr. EHLERS. So in your opinion, do you think that we can design something that meets the criteria I mentioned: safer, less expensive, more efficient, less turnaround time?

Dr. HALLOCK. But once again, we have got 30 years of technology now behind us at this point, and I firmly believe that you can do that. Yes.

Mr. EHLERS. And can that be a good replacement for the tile system which is one of the biggest factors in the slow turnaround?

Dr. HALLOCK. Well, they even have an interim thing where they have come up with a tile that is much stronger and can withstand a lot of strikes more so than the existing. So there is some intermediate technology types of things that can be done, too. Yes.

MANNED VS. UNMANNED SCIENCE

Mr. EHLERS. Right. And the second question——

Admiral GEHMAN. First of all, I would—I agree with Dr. Hallock, and I would ask you to factor into your equation of the—not only the next vehicle, but also the robotics versus the human—the value of the human space flight program, that as long as the only way that we have to get outside of the Earth's gravitational field, or to get into orbit or to escape the Earth's gravitational field is to sit on top of an enormously explosive chemical reaction, which is—right now, that is the only way we know how to do it. You are flirting with a very dangerous process. And there is no getting around it, and we should not ever diminish how dangerous that is. And then when you come home, you have to take all—every single kilojoule of that same amount of energy and you have got to somehow dissipate it in order to slow yourself down from orbital speed. And that is also extraordinarily dangerous. You have got to figure out a way that you can reenter the Earth's atmosphere and dissipate all of that energy in the form of heat. You have got to change the speed into heat, and then you have got to dissipate all of that heat, which puts the humans in a very dangerous situation. And we should not minimize that danger.

And now the reason I gave that little lecture, if you will forgive me, is because when you start—that is job one is to get the humans safely up there and back in.

Mr. EHLERS. Well, I will just interject. That assumes a return vehicle. You are going to have a capsule come back and dispose of the engines.

Admiral GEHMAN. But even if you bring the—even if you were using a capsule, you still have a kinetic energy problem. You have got to get up there, and you have got to get back down.

Mr. EHLERS. No, but you don't have as much to dissipate.

Admiral GEHMAN. That is correct.

Mr. EHLERS. Considerably less.

Admiral GEHMAN. Considerably less. That is right. But if you consider job one to be safely—get into orbit and safely get back, then everything else that you add on to—every other requirement, you are going to—and if you say you want it to be efficient and cost-effective and reusable, et cetera, et cetera, et cetera, you are whittling into that safety requirement. And so this Board, with this experience that we have gained from this investigation, would say let us not, in any way, diminish the danger and the physical challenges here and start adding additional requirements into this. Let us just get them safely into orbit and safely home.

Now the robotics or the human thing, I would offer that we didn't really do much of a study in this, but we did educate ourselves into this matter as well as the vision thing so that we could put our report into context. And my personal view is that every

briefing I have listened to, every book I read on the subject indicates that no matter what your vision, long-range vision is for what we are going to do with interplanetary travel or stations on the moon or whatever it is, all visions, they all start in low-Earth orbit. None of them start on the surface of the Earth. And therefore, we have to perfect getting into and out of low-Earth orbit, no matter what the plan for the future is. That is our view. And perfecting getting into and out of low-Earth orbit is a worthy enough goal by itself.

Mr. EHLERS. Okay. I have to excuse myself to go vote, and the Chairman has returned. Thank you very much.

Chairman BOEHLERT. The Chair recognizes, Mr. Bell.

Mr. BELL. Thank you, Mr. Chairman.

DEFINING CULTURAL AND ORGANIZATIONAL PROBLEMS

Admiral Gehman, good to see you again. I want to commend you for the report and also the way you and the committee conducted yourselves throughout the investigation. It was impressive, and I certainly respect the openness that you demonstrated both with Members of this committee but also with the public throughout the process.

I want to follow-up on something that my colleague, Mr. Wu, was talking about in terms of the cultural and organizational problems that you point out in the report. The day the report came out, I had the opportunity to speak to a group of NASA employees that evening. And while there seemed to be a general acceptance, certainly an expectation that the report would be critical, the one area that they seemed to feel that there will be some difficulty with has to do with changing the culture of NASA. And in looking at the report, in chapter seven, I wanted to go over some of the statements therein and see if maybe you can expand on them so there is—there will be a clear understanding of what we are talking about when you say "changing the culture."

Starting with avoiding oversimplification, and I will just read this particular part, "The *Columbia* accident is an unfortunate illustration of how NASA's strong cultural bias and its optimistic organizational thinking undermined effective decision-making. Over the course of 22 years, foam strikes were normalized to the point where they were simply a maintenance issue, a concern that did not threaten a mission's success." And when you read something like that, I can—you point to a cultural bias, but was it so much a cultural problem or was it a—caused by not having a system in place that would help identify that kind of problem and address it?

Major General HESS. I think the answer to your question is basically yes in both counts. But what we are getting at is in the definition of organizational and cultural that we adapted is how does—even absent rules react to—in the instance of oversimplification, what we saw was an almost immediate assumption that there is not a problem. And this is a learned behavior. It took 22 years for them to learn that, perhaps there is not a problem with foam—but when you put down one of the things that you need to avoid, if you are a highly reliable organization that deals in high-risk technology is that you don't just assume that there are no problems. You start by assuming that there is a worse case and by——

Mr. BELL. Admiral, did you want to comment as well?

Admiral GEHMAN. No, I agree. And we thought long and hard about that particular section. And the relationship to culture is that, as we carefully defined in our little blue sidebar in the front of that chapter seven, that culture is, as we used it in here, in this report, culture is how the organization acts kind of intrinsically. It is how they act outside of the rules. It is how they act when their boss is not in the room. And it is how they think.

And in this particular case, they have an oversimplified view of a complex issue, and they stick to that oversimplified view. They get rigid in it, and they do not realize that these are complex things in which one flaw can affect another system.

Mr. BELL. And please, let me be clear. I am not, in any way, critical of what is stated. I just think there needs to be a clear direction going forward so that people understand exactly what you mean when we talk about changing the culture, because I would agree. There are obvious problems that need to be addressed, but they can't be addressed unless there is a clear understanding.

In the paragraph above, importance of communication. Every manager knew the party line. We will wait for the analysis. No safety of flight issue expected. In the course of the investigation and the people that you talked to, what did—what was your understanding of how such a "party line" is developed?

Admiral GEHMAN. The—there are a number of factors, but the one that I would point to is what I would call—I like to characterize it as an informal chain of command. That is, once the Space Shuttle program opined on something, then other people, other divisions, other agencies, even though they are technically independent, were hesitant to move against that opinion. The Shuttle program——

Mr. BELL. For fear of reprisal or——

Admiral GEHMAN. For fear of reprisal, for fear of being ridiculed, but mostly, the problem was that even though on paper they had a set of checks and balances, independent engineers and independent safety, the fact of the matter is the Shuttle program over the years had become so powerful that all funding flowed from the Shuttle program. All promotions go from the Shuttle program. They had become so powerful that independent voices and minority opinions were not welcome. And it takes—in a complex matrix organization, like the Shuttle program is, it takes a very elegant communication scheme carefully managed and carefully nurtured to make a matrix organization work. And they had allowed some of those characteristics to atrophy over time.

And I don't know if General Hess, who is the expert on this, wants to comment on it.

Mr. BELL. Well, so the goal would be to develop a system where communication is encouraged rather than discouraged. And from what you are saying, it sounds like perhaps it wasn't discouraged, but people feared.

Admiral GEHMAN. They did. They did. And we think that our fix about having this independent technical review authority, which owns all of the specifications and requirements, which would be full of engineers and safety people who have no relationship to cost and schedule of the program, would be free to discuss all of these

things, because they wouldn't be intimidated by the guy who is worried about cost and schedule.

Mr. BELL. Lastly——

Admiral GEHMAN. As a matter of fact, their reward system would be based upon bringing problems up. That is how they get rewarded.

Mr. BELL. Lastly, I want to go to the section commitment to a safety culture and the last line in that. "Organizations that successfully deal with high-risk technologies create and sustain a discipline safety system capable of identifying, analyzing, and controlling hazards throughout a technology's life cycle." Obviously that system was not in place. How do you accomplish that, because that has to be the number one goal that whatever is developed will last throughout a technology's life cycle?

Major General HESS. I think that the answer to that question also rests in—that is their job. That is going to be their role in life is to bring that life cycle and systems analysis look into the technology that is involved. The second part of it, obviously, in this chapter we talk a great deal about the information systems that are there that are supposed to be tracking anomalies and giving trend information and the fact that they really don't. So you know, there is a fix that could happen just in information systems and how you manage the information but having somebody whose job it is to run risks and do trends and to control the level one requirements and the waivers is going to give you that life cycle that we think is so very important.

Mr. BELL. Thank you, Mr. Chairman.

Chairman BOEHLERT. Proceeding along those lines, because of the many important recommendations that you have made, two of the most important are one, establish an Independent Technical Engineering Authority and have that funded directly from NASA headquarters so it has no connection to or responsibility for schedule or program costs. And the second one is the Office of Safety and Mission Assurance should be independently resourced. I think those are highlighted recommendations. And we are going to follow through, and so is NASA.

Mr. Feeney?

Mr. FEENEY. All right. Thank you, Mr. Chairman. And thank you to Admiral Gehman and your entire Commission. I haven't thoroughly read from cover to cover the report yet, but my office staff has several times, and we are going to continue to pay attention to it.

I am impressed by the entire approach you have taken. I want to thank you, particularly for being accessible. I got a briefing just before our break personally from Admiral Gehman. I thank you for that, for the time we spent together at the hangar where we were putting together the Shuttle. And several other members of the Board were there. It was certainly a quite moving experience. And I will tell you that, you know, part of the appreciation for the way you have memorialized the astronauts that have passed away in human flight is in the emblem that you put on the back here. We are not just talking about the most recent disaster. You include discussions about *Apollo 1,* the *Challenger,* and the *Columbia* as well. And of course, the Latin phrase there—my Latin is a little rusty.

I got a D in Latin and had to quit the basketball team because of it. And actually, the Latin teacher's wife was the coach of the basketball team. He understood why I had to quit, but to the stars, despite adversity, always explore. I think that that is the mission that I believe in and that basically was the fundamental mission of your report.

THE CULTURE OF SAFETY

I want to pick up where Congressman Bell left off talking about the culture of safety, because it is sort of in amorphous concept to some of us. It is not a technical issue. It is not a precise issue, and—but it is a cultural issue that is very important. And as a lawyer by background, I am under—I understand burdens of proof. And I would like you, at one point, to describe for me the difference between a culture in safety where you presume that everything is okay unless you know otherwise as opposed to a culture that basically tells you that nothing is right unless you can prove that it is functioning. And I want to ask you as you go through that sort of switch and, say, a burden of proof approach, which is something that I can understand, to talk a little bit about NASA's history. NASA originally approached the Board in its initial briefings and espoused their confidence that they had developed a culture of safety and were surrounded by the culture, and yet, upon investigation, this Board found out that that simply wasn't accurate.

In the aftermath of *Challenger,* there were some interesting differences between the approach that NASA took and the lessons it learned and the way it trained its inspectors and the way it dealt with response to the disaster and say the Navy took. The Navy, for example, developed the SUBSAFE program and the naval reactor program. They trained some 5,000 Navy nuclear propulsion program personnel on the lesson specifically learned from *Challenger.* And yet it seems like all too quickly, NASA, for a variety of reasons, fell right back into some of the same habits. And so I guess I would like you to tell me number one, whether NASA has—understands in how their going to implement this shift in burden of proof, number two, how they reacted to the lessons of the *Challenger* disaster, and number three, in a more generic sense, this isn't the only near disaster we have had.

We had the *Apollo 12* issue. We had the fuel cell explosion on *Apollo 13.* We have had launch pad aborts on Shuttles involving non-personnel craft. We have got the commercial problems we have from time to time, the military launches. How are we, on a routine basis, going to learn from all of the, not only disasters with people involved, but also the new disasters or situations where people were not involved? And with that sort of open-ended question, Admiral Gehman, if you will refer the answer to the appropriate people or pick it up.

Admiral GEHMAN. Mr. Feeney, first of all, I will say something about the culture of safety and something about learning and then turn it over to my colleagues here who studied this more closely than I did. I was quite confident and quite firm in my deliberations with my colleagues about hammering this subject fairly strongly, because of the way we defined culture. We were very careful in our report to make sure that, for our readers, that we didn't confuse

management and we didn't confuse leadership with culture. Culture is what you do rather than what you say.

For example, if you say that safety is the most important thing we do and nothing we do is going to compromise safety, but I want you to come up here to Washington, DC every 30 days and give me a brief on how you are doing on making the node two complete schedule, that is doing one thing and saying another. And that, of course, trickles down to the workforce. I mean, that word gets out as to what is important.

We studied at great——

Mr. FEENEY. By the way, if I can, Admiral, just to interrupt briefly, but you have a wonderful definition of culture. It is not like the—I mean, people that read the report on page 101 it is very specific and then later throughout the report but especially 177 you talk about the organizational and cultural problems that exist in NASA today, so you do a great job in the report.

Admiral GEHMAN. Yeah, we knew that there would be some misconstruing and blurring of what the terms meant, so we were careful to define them. We also found, if we go back to that list that General Hess was referring to earlier, we tried to put a recipe or—in there for what we considered to be the characteristics of a high reliability organization, which we would certainly hope that NASA would be a high reliability organization. And one of the characteristics is that the organization is a learning organization. And by that, they not only learn from big disasters, but they learn from the little things.

And just as you point out, in the organizations which we consider to be high reliability organizations, they teach their people from big disasters and little disasters. And they like to keep bringing up *Three Mile Island* and they keep bringing up the *Challenger* and they keep bringing up the loss of the submarine *Thresher,* and they keep bringing these things up to see what we can learn from them. NASA tends not to do that. And they tend not to do that, at least our interviews, and our experience was they tend not to do that, because for some reason they have gotten the idea that by bringing up all of these failures or near-misses that somehow they are tarnishing the image of the employees or they are diminishing the impression that they are all perfect. And that, of course, is wrongheaded. And therefore, we determined, and we wrote in our report, that NASA is essentially not a learning organization and they do not learn from these mistakes. And of course, that is a very serious problem.

General Hess, do you want to make any further comment on that?

Major General HESS. That is right. And the part that I would add in the overall construct of how they approach this cultural dynamic that we are trying to get it is just exactly the issue of, absent rules, they are going to react and respond in a way that is dedicated to performing the mission reliably. Okay. And in almost any check and balance that we talk about inside the program, these attributes can be enhanced just by some of the organizational changes that are there. But organization alone is not going to fix the problem. You are going to have to lead your way through it. You are going to have to get managers to understand and buy into

this at all levels so that it becomes the way that the organization responds in times of crisis and in times of planning as well.

Chairman BOEHLERT. The gentleman's time is expired.

Ms. Jackson Lee?

Ms. JACKSON LEE. Thank you very much, Mr. Chairman, and allow me to thank the Chairman and the Ranking Member of the Full Committee and as well the Chairman and Ranking Member of the Subcommittee for what will be, in think, a very effective line of hearings that we will have and, as well, an ability to be able to follow this line of reasoning that has been so ably played out for us by this very strong report.

Might I say to the Board, thank you, also, for your good work. And as I begin my remarks, allow me to put this in the focus that I can recollect was the experience on that fateful day, February 1, and that is that this whole debate is on the question of lives as well as the mission and vision of this Nation on behalf of the American people. So I would like to note that what we do today is in tribute to and reflection of the sacrifice that Rick D. Husband made, William C. McCool, Michael P. Anderson, David N. Brown, Kalpana Chawla, Laurel Blair Salton Clark, and Ilan Ramon. Clearly, I think, this is a major tribute, if you will, or need for a major tribute to their lives that we not allow what has occurred to be repetitious.

I do want to also say to the Board that this is in no way a cover-up. And we thank you for your forthrightness and your instructiveness. I will say again, referring back to February 1, that since it was post-9/11, you can imagine the various thoughts that occurred. So it was even larger than maybe incidents of the past that we do not diminish any of the incidents of the past.

You have spoken about the question of a culture of safety, and I want to refer to some of the language that you used in the report. The Board found that there is a broken safety culture. You also mentioned that schedule pressure related to the construction of the International Space Station, budget constraints, and workforce reductions also were factors in the question of what caused the *Columbia* accident. One of the initiatives that I am going to propose would be enhanced whistle blower legislation, specifically for NASA personnel, because I think that the comment that the Ranking Member made at the very beginning is so potent, and that is what happened after *Challenger* and the emotions and the interests and the commitment seemed to peter out.

I am holding in my hands a series of hearings over 1997, '96, '99 where we discussed the question of safety over and over again. And I would refer you to some words that I offered in 1996: "So that there is no mistake, I do have questions and concerns regarding some of the issues involving NASA, the personnel reductions which continue to take place, and the safety of the Space Shuttle." That was in 1996, March 28. On September 23, 1999: "We want NASA to provide safe vehicles for our brave astronauts, yet it would be an aim of us to demand a strong Space Shuttle safety policy when we are cutting the very resources that would fund this policy."

Now you have already shied away somewhat from numbers, but allow me to ask these questions on the safety element, and I applaud this freestanding organizational structure that deals with

safety and oversight from NASA headquarters. I want you to comment on the responsibility of NASA headquarters aside from directly the Administrator as it relates to your report. I would like you also to explore the idea of holding managers accountable for errors, because when we talk about the safety culture, how do we break that line of reasoning? And you might add your thoughts about whistle blower protection overall. You haven't seen the legislation, so I would imagine you couldn't comment on that.

And finally, Admiral, would you put yourself—and others that might want to comment, would you put yourself, Admiral, in the position of being an Admiral and finding or having an incident such as this occurring under the military structure? What would be your reaction or your actions as it relates to personnel who were directly associated with the responsibility of ignoring information that came directly to them that questioned whether or not there was a sense of safety? My last point is for Dr. Widnall, because I was fascinated by your comments with respect to education. How do we retain the bright and the best as we have moved toward outsourcing over the last decade? I remember growing up looking to those bright folks at NASA. And you admired them and wanted to be like them. How do you restrain—have that—solve that problem?

And I thank you very much for your presence here today.

Mr. SMITH OF MICHIGAN. [Presiding.] The gentlelady from Texas' time has expired in asking the question, but we will now turn it over to Admiral Gehman.

ACCOUNTABILITY

Admiral GEHMAN. Thank you very much, Ms. Jackson Lee, and thank you for your support during this—during the time of this investigation. We enjoyed talking to you several times about it.

The Board, while, indeed, it decided not to make judgments about the responsibility of individuals, the Board, in no way suggests that our position—suggests that individuals should not be held accountable for their actions. They should be held accountable, and they should be held accountable by their appropriate supervisory chain of command. On page 203 of our report, we have a little editorial in there about the role of leaders and the role of managers and their responsibility for setting the conditions for either success or failure. And they are, indeed—we do believe that the top level managers are responsible for setting the conditions up, and if they set conditions in which free and open communications were stifled or engineers were intimidated or safety was shortchanged, and they are responsible for that, and they have to hold responsibility for that. I believe that we document in our report, and we are pretty careful to do this. I mean, we wanted to be very careful about this. These bad traits and these ill characteristics that we are all numbering here came about gradually and slowly over a long period of time due to budget constraints, manpower constraints, and lots of other reasons.

But these things didn't happen all in one year or one month or—they happened over a long period of time, and they happened in response to forces, both internal and external. I think that we have kind of—it is all there in the report, I think. And I think I kind

of agree with your comment that there probably is some account taking that probably needs to be done by the proper authorities. We just didn't feel we were——

Mr. SMITH OF MICHIGAN. Admiral Gehman, I—excuse me for interrupting. I would ask everybody to be brief in reacting to Congresswoman Jackson Lee, and we will try to get one more five-minute series in before we——

Admiral GEHMAN. Maybe I will let Dr. Widnall respond to the last point.

NASA RECRUITING AND RETENTION

Dr. WIDNALL. I would like to respond to that question a little more broadly with respect to this question of how do we retain the best and the brightest, because this is the very Committee that is charged with that responsibility. I believe the Nation has been richly rewarded by the investments that we have made in science and technology education and research across a broad range of scientific and engineering disciplines. So it isn't just the question of how we retain these individuals in NASA. I think the question goes much deeper. How do we strengthen our science and education system? How do we encourage young people to pursue professional careers in science and engineering? And how do we utilize their talents once they graduate? I think in order to do that, it really requires a vigorous program of research and technical development across a broad front. And I would certainly include NASA within that.

I do think, as an aerospace educator, that NASA has a built-in advantage with, what I view, as the innate passion that goes along with the exploration of space. But we really need to pursue these issues across a much wider front.

Mr. SMITH OF MICHIGAN. The gentlelady's time has expired.

PRIORITIZING SPACE RESEARCH WITHIN THE FEDERAL BUDGET

I will proceed with my five minutes. And let me start out by suggesting that since the successful Soviet launch of *Sputnik* in 1957, certainly our country's space program has been an intricate part of our excitement as Americans and certainly a stimulus to more students getting into science and math. I think we have lost some of that.

Congress is charged with setting priorities. As some of you may know, I Chair the Research Subcommittee, and we have had testimony in terms suggesting that much of the scientific research could be better accommodated as effectively on unmanned space flight, and some of the research could be accomplished in ground labs. And so not only manned versus unmanned flight, but also should some of these research dollars go into NIH to cure cancer rather than man's exploration of outer space?

It would seem to me that we need to analyze the costs and the benefits of this program. And really, as I understand the Board, and congratulations for the time that you have sacrificed and the efforts you made to do this, such a good and thorough job, but your charge really was what went wrong and how do we keep it from

going wrong again. But in terms of the costs and benefits, how do these compare with that of unmanned space flight or other science research that we might conduct, and did the Board look at these issues?

Admiral GEHMAN. We did not, Mr. Smith. What we attempted to do to help you with that question was to properly characterize the risks and properly characterize the costs of the Shuttle program. And we did not look into those other issues. And I am going to have to defer on that. I don't have any knowledge of the value—the cost value of——

THE VALUE OF RESEARCH IN SPACE

Mr. SMITH OF MICHIGAN. Well, as I talk to other scientific groups, including JPL, we don't have a good quantitative evaluation of the science research. Some have suggested, well, once we get the Space Station up and running and get it fully manned, maybe we can do some really constructive research. But it would be my opinion, and for any Board member that—for any of the witnesses that would like to comment, that manned space flight can contribute a great deal to the additional information of how humans acclimate themselves in outer space. And maybe part of that is do we intend to put people of this country into outer space for longer periods of time. We have been in this endeavor for quite a while. And with the new technology of, not only robotics, but of nanotechnology and miniaturization, a tremendous potential for unmanned space flight, it seems to me. Does—would there be any comment from the witnesses?

Admiral GEHMAN. We did not evaluate that, but if anybody wants to comment, help themselves. We did not look into that.

Mr. SMITH OF MICHIGAN. What—how might we best—you know, and I think it is exciting to have high school students put in research projects, but in terms of real valuable scientific research, it is probably not substantial in contributing to our research efforts. We are now reducing funding for NIH for—to develop better research on health. We are now reducing research dollars for the National Science Foundation, which I oversee in our Research Subcommittee, in terms of basic or fundamental research. So a tremendous challenge, I think, for this committee and this Congress as we evaluate how quickly do we want to push the program and maybe a comment that you might react to is NASA projected the March launch before you came out with your final report. It seems like this is pushing more rapidly than NASA's ability to totally react to some of the recommendations in your report. Admiral Gehman?

Admiral GEHMAN. I—yes, sir. I would—I believe Mr. O'Keefe and I are going to have an opportunity to appear beside each other next week before your Committee. But yesterday, before the Senate, he reiterated to that question—reiterated an answer to that question several times in which he said that NASA's return-to-flight plans are events-driven, not calendar-driven. And that date out there is just a hypothetical mark on the wall. It is not the—it is not a firm date. I will let him answer that question.

Mr. SMITH OF MICHIGAN. And I just say to Dr. Hallock and General Hess and Dr. Widnall that part of my bias, which I have expressed in my statement, which, without objection, will be entered

into the record, is my son and daughter were—both worked at JPL, and so they led me down the road of the kind of information of how valuable unmanned space flight was and—in the reductions of budget that limits a tremendous potential in that arena.

Any other comments from the witnesses? If not, the Committee stands in recess. Oh, here he is. The Committee does not stand in recess. I thought you were one of the upper ranking staff people that said I have only got three minutes left.

Chairman BOEHLERT. And he promptly ignored it. I never ignore it.

We are going to have a series of votes all day, unfortunately. But let me, while we are waiting for—Mr. Nethercutt, you are here. Thank you.

THE PROCESS OF DEFINING A VISION

Mr. NETHERCUTT. Thank you, Mr. Chairman. Ladies and gentlemen, thank you for being here.

Admiral, I appreciate all the work you and the Board have done. I think you have done a great job of being frank, both personally and privately, in giving a clear indication of your independence. I noted that the Board noted: "It is in the Nation's interest to replace Shuttle as soon as possible as the primary means to transporting humans to and from Earth orbit." And it strikes me, as I listen to the questioners and the Chairman and others have an exchange with you witnesses, that it seems to me the question of vision has come up a number of times. What do we really want the space program to do? Where do we want to go? How do we invigorate our young scientists to be excited about working at NASA, and so forth?

And I have thoughts about a vision, and that is not necessarily—certainly not the point of this hearing. But I know that you all have become very familiar with the culture at NASA, the process that NASA goes through, the experts that are employed there. And I am wondering whether you feel that NASA can organizationally be capable of defining its vision, a vision, an adequate, thoughtful vision, or the future of the agency. Is the organization, perhaps, too risk-averse at this point, given the seriousness of your report, to define some sort of a grand national vision for human space flight? It is a little theoretical, but I think it is a valuable theoretical question to have answered, because it sort of defines where we are headed with respect to the agency and human space flight. I mean, my sense is maybe we ought to be looking at the moon and have, sort of, a lunar expedition policy that guides us. There is great science, I think, that can come from there. But there is Mars and there are other places. So I am wondering if you could answer those questions for the record and for me.

Admiral GEHMAN. I think we ought to ask all four Board members, but I will answer very briefly and say I have confidence in NASA. I think it is a great organization. I think they are capable of proposing and staffing a national vision. But of course, NASA's vision doesn't count. It is the—we were very careful to say it has to be an agreed vision. So it has to be your vision and the White House's vision. I don't believe NASA is too risk-adverse or that they are in any kind of a defensive crouch as a result of this acci-

dent. I think they are fully capable of leading us and proposing us, but they can only propose. The—my view is that NASA is fully capable of that challenge.

I will ask my colleagues to help.

Dr. HALLOCK. I agree, too. The issue, though, is that one can have quite a few visions. There are so many, many things, as some of you have already talked about today, whether—from the robotics issues to the manned space flight issues as well as is it—should we be going to the moon at this point or should we be thinking about putting Space Stations further out? Someone mentioned libation points, too, as being places. So the hard part is—I think we can all come up with visions of them.

The problem is how do we constrain them, because there are only so many things we can do. I think it is important for the country to have one, because it really does have a lot of secondary issues, secondary things. And one of the main ones that pops to mind is one that we have been talking about here, and that is the education thing. We need to stimulate people to start thinking about these very technical issues and want to go into those fields and work on them. But picking what the vision should be? Oh, boy. I would like to be a part of picking it, but I—it would be very hard to say this is the one and only thing we should be doing.

Mr. NETHERCUTT. General Hess, do you care to—Dr. Widnall?

Dr. WIDNALL. Sure. Yeah. You know, when you raised the issue of vision and NASA constructing a vision, I wrote down the word "partner." And then I wrote down the word "tough." I think NASA needs a tough partner. If I had to make a comment about NASA, it is not that they are risk-averse. It is that they have often overreached technologically. They have been overoptimistic in looking for the leapfrog in accomplishing certain goals. Another—and my Board members basically said it before I said it. An unconstrained vision is not a vision. NASA needs a tough partner to rub right up against and get a common agreement about what the vision is that is—matches the resources that the Nation is willing to provide to accomplish this vision. So tough partner. And that—it would be you guys.

THE DIFFERENCE BETWEEN "OBSERVATIONS" AND "RECOMMENDATIONS" IN THE REPORT

Mr. NETHERCUTT. Yeah, I understand. And I think we are willing to be partners. I just—culturally, I am willing to be sure—I think we look to the experts there to make these judgments. Let me ask a question for—on behalf of the Committee that—for the record, that I hope will be helpful to all of us, if I may. The report provides 29 recommendations and 27 observations. "Please explain the substantive differences between an observation and a recommendation." And I am wondering whether NASA can ignore the observations and still be in compliance with your report.

Admiral GEHMAN. Well, we started off with this—the first draft of this report back in June was 1,000 pages. And after some hard negotiating, I got it down to 400 pages. What you see now are 248 pages after some more arm-twisting. And we had to do some prioritizing. The observations are—they are all true. They are all serious. They all are potential danger points for maybe some future

accident, but they didn't affect—they aren't talking about this accident, and that is kind of how we made the differentiation. We think that they are offered as serious matters. They are offered as things that we observed and as we saw as we traveled around and talked to people. They are potential problems for NASA. One of them could be the cause of a future accident. So they do need to be addressed by NASA, but they aren't related to this accident. So——

Mr. NETHERCUTT. So you want the recommendations followed up on and responded to, but you want the observations to be noticed and acted upon, I assume, as well?

Admiral GEHMAN. That is correct. That is correct. As a matter of fact, we say in there that NASA must take action on these things.

Mr. NETHERCUTT. Thank you, Mr. Chairman, for the extra time.

Chairman BOEHLERT. Thank you very much.

And vision has been thrown around very loosely today. We all want vision, you know. Proverbs. But the vision, you have got—tough partnership is very important, Dr. Widnall. And part of that vision has to include what you hope to accomplish, at what cost, and at what risk. So we can talk about vision all day, you know. I still remember Martin Luther King's speech of his vision, a nation where the people are judged not by the color of their skin but the content of their character. And we are still not there yet. So the vision we need is a vision where the Executive Branch and the Legislative Branch are the senior partners. NASA is part of the Executive Branch, so—well, enough sermonizing.

NASA ENGINEERING AND SAFETY CENTER

Let me get to a couple of very pertinent questions on my mind. You have made some specific recommendations, the Board has. And NASA has established a new safety center at Langley. Incidentally, it was established before the report was out. I know you have had interaction with NASA, but can you tell us, Admiral and members of the Board, whether you believe that the new center reflects any of the changes you have recommended in the report?

Admiral.

Admiral GEHMAN. The way I would answer that is that I would suggest that if you—if one were to write down the specifics of our recommendation for this independent technical review authority and make out a checklist or a template that the emerging and still changing engineering and safety center at Langley does not match up, not exactly. That doesn't mean that it is not good and they shouldn't do it, but it does not match up exactly.

Am I—Board members, am I—have we got it right? Yeah. I don't want to speak for them, but I think we are in agreement on that.

Chairman BOEHLERT. Have you had any conversations with Administrator O'Keefe? Is this—should this be considered, as I feel it should be, a work in progress?

Admiral GEHMAN. Yes. That is my understanding that they haven't even agreed on their charter. They haven't agreed on——

Chairman BOEHLERT. Okay. Fine. So this is not the be-all-and-end-all. This is——

Admiral GEHMAN. That is correct.

Chairman BOEHLERT. Okay. All right. Next question I want to ask is——

Admiral GEHMAN. Mr. Chairman. Mr. Chairman, can Dr. Widnall stick her——

Chairman BOEHLERT. Oh, by all means. I would never silence Dr. Widnall.

Dr. WIDNALL. No. Just let me add that I consider safety to be a professional or technical discipline. And it would not be a bad idea to have an organization—the one that is described at Langley, as—I would view as almost like a research organization to look at the fundamentals of safety as a technical discipline. That is independent from the line organization that we have suggested that would have a function in the actual conduct of operations. So both organizations could exist and be mutually supportive.

Chairman BOEHLERT. Thank you. And I just want to make sure we have the record clear so we don't have presentation from NASA that says, "Well, look at what we are doing at Langley. Boy, we have addressed the problem." That is only a very small part of the problem.

SFOC BOARD OF INVESTIGATION

This is a quickie, Admiral Gehman. I want to get it on the record. In the section of Space Flight Operations Contract between NASA and USA, there is a section of the contract dealing with the fee reduction for catastrophic loss. That provision requires the NASA Contracting Officer, in conjunction with the Board of Investigation, to make a determination as to the cause of the loss. There has been some confusion about whether the *Columbia* Accident Investigation Board is the Board of Investigation referenced in the SFOC. Is the *Columbia* Accident Investigation Board the Board of Investigation referenced?

Admiral GEHMAN. No, sir.

Chairman BOEHLERT. All right. Thank you.

COST ESTIMATES AND MISSION PARAMETERS OF A FOLLOW-ON VEHICLE

Next—that was an easy one. In chapter nine, the Board talks about designing the Shuttle replacement without regard to cost. But isn't that just a recipe for getting into the same problem we did with the Shuttle? Does it make sense to design something without cost parameters and then reassess it once we know real budget projections? Doesn't that just encourage the disconnect between ambition and resources that you cite in the report?

Admiral GEHMAN. I am sorry we didn't make ourselves more clear. What we are suggesting, we are actually—we were—what we were doing there is criticizing the current process of our Democratic—wonderful Democratic institutions of trying to design the next vehicle with a start and stop kind of a process before there was complete agreement on what the vehicle is supposed to do. And what we suggested is that the right process would be we have a good healthy debate on what we want to do in space, we agree on what it is we want this vehicle to do, then you go into the design process and the cost process. And what we suggest is that it

is a—it would be a wonderful leap forward if you agreed that the only—that we—that what it is we want to do is to get into and out of orbit safely. And that would—even that would be a giant leap forward.

And then once you decide what it is you want to do, then the design and the cost of the vehicle follows that. We—I am sorry we weren't clear on that, but we recommend that you and the Senate and the White House, first of all, agree on what it is that you want this vehicle to do then go into the design process. We are hearing things about people have even got pictures of this vehicle and we haven't even decided what it is going to do yet. And then the process is reversed.

Chairman BOEHLERT. Thank you very much for that clarification.

Now here is the deal. We have promised our very distinguished panelists that we would have them out by 2. Mr. Rohrabacher, you are next, followed by Ms. Jackson Lee. Mr. Nethercutt, do you have any more?

Mr. NETHERCUTT. No.

Chairman BOEHLERT. All right. Mr. Rohrabacher is recognized.

ISS SUPPLY

Mr. ROHRABACHER. As we move forward with certain decisions that need to be made and our discussions with NASA, it will be helpful to us to have certain issues totally clarified. And I think this is pretty clear, but I want to ask you very specifically. Is it the recommendation of the Commission that if the Space Station can be supplied by an alternate system rather than the Space Shuttle, that it should be supplied by the alternate system?

Admiral GEHMAN. It is our recommendation that we separate the people from the cargo as soon as possible.

SHUTTLE SUPPORT OF ISS CONSTRUCTION

Mr. ROHRABACHER. As soon as possible? Mr. Chairman, I would like you to note that answer. That is——

Chairman BOEHLERT. Duly noted.

Mr. ROHRABACHER [continuing]. Something that we have been receiving some—a lot of resistance from NASA, for safety reasons and every other reason, it sounds like. It is unclear to us. In terms of using the Shuttle, when necessary, would the Commission agree that the Shuttle would be necessary to finish the construction of Space Station?

Admiral GEHMAN. Oh, we believe that the Shuttle can be safe—could be operated in a more safe manner than it is now, easily, for another decade.

Mr. ROHRABACHER. Thus, Mr. Chairman, in making a decision as to whether to move forward and finish the Space Station and the Shuttle, the Commission is deciding that it would be safe—well, at least we can change and develop the situation so that the Shuttle is safe in completing the mission of building the Space Station.

Chairman BOEHLERT. That opinion is duly noted.

FUNDING AS A FACTOR IN THE ACCIDENT

Mr. ROHRABACHER. Right. Finally, is it the finding of the Commission that funding is not—was not a major cause of the *Columbia* tragedy? That—is it your finding that even if we would have funded the Shuttle at a higher level, that the complacency that you have spoken about in your testimony may well have continued and that that was an issue at least as big, if not bigger, than the—any funding issue at hand?

Admiral GEHMAN. The Board did not evaluate the relative contribution of the factors that we listed, but constrained and squeezed budgets was a factor as a—it was a contributing factor to this Shuttle——

Mr. ROHRABACHER. Okay. So funding was a contributing factor as was, of course, what you have been saying——

Admiral GEHMAN. A lot of other things.

Mr. ROHRABACHER [continuing]. Along with complacency within——

Admiral GEHMAN. That is correct.

Chairman BOEHLERT. If the gentleman will yield?

Mr. ROHRABACHER. Certainly.

Chairman BOEHLERT. There is always—we are all partners to this venture. We all have to share our part of the responsibility, but let me tell you, if we had written a blank check to NASA, that wouldn't have changed the decision or the manner in which the request for imagery was treated. If we had written a blank check to NASA, that wouldn't have changed the manner in which they responded to the repeated instances of foam debris falling. So while we are not going to just wipe our slate clean in the Legislative Branch, as I enumerated earlier, and your report put out very specifically. It was within NASA that decisions were made to transfer funding——

Admiral GEHMAN. Right.

Chairman BOEHLERT [continuing]. Out of the program. It is within NASA that the decision was made to sort of not give the proper responsibility authority and independence to the safety function. So I don't want this to be misinterpreted by anybody as this is an apology for the Congress. We will share part of the responsibility. We have got to stand up to that, but the fact of the matter is changes are needed, they are needed, and they are clearly articulated in your report. I will have some closing comments in a moment.

Mr. ROHRABACHER. Just finish?

Chairman BOEHLERT. Just one more, and then we will go to Ms. Jackson Lee.

Mr. ROHRABACHER. And finishing up on that area, the funding—the institutional process of funding may well be what you were looking at in terms of the way we fund NASA, not necessarily the specific funding decisions made by the Congress. I just—for the record, as well, there are numerous occasions which we—which I heard Members of this committee, on both sides of the aisle, talk to people who are sitting right in the spot that you are in right now and say anything that in any way affects safety should be taken care of without regard to budget and that we will back you up if

that is what—if you tell us that this is the reason you need that money. However, Mr. Chairman—our internal—sometimes there are internal deadlines that are made based on funding that is already agreed to and those internal deadlines of NASA sometimes are reflected in the decisions we have made at—funding certain projects.

Chairman BOEHLERT. Thank you very much, Mr. Rohrabacher.

Ms. Jackson Lee.

ACCOUNTABILITY

Ms. JACKSON LEE. Thank you very much, Mr. Chairman. The importance of this warranted me in staying with you, Admiral. And I do not—and the Board, I do not want to keep you away from tasty cuisine. And I thank you very much for your patience.

I want to just reinforce my earlier remarks with respect to reciting the names of those who lost their lives on *Columbia* 7, because this is about them and their families. And particularly, it is about them because there are how many in line following them, meaning astronauts in training, who would do it at a drop of a hat, meaning go into space ready, courageous. And I hope that my colleagues will join me in sponsoring the Congressional Gold Medal that we have now filed to be able to honor them. But I believe it is important to restate their names and to note their families, because I don't think one family member publicly did anything to suggest that we should not continue whatever our vision and our mission is. And I think this question of probing responsibility is not simply finger pointing, and I think the Chairman has just said we all can stand in line right now. And I want to put on the record that when I made the comment about safety, it was in 1999 where there was a billion dollar cut through the appropriations process out of this Congress for the NASA budget. I might suggest that the belt tightening was their way of saying, "We can handle it."

And I want to get back to you were in the middle of saying the word "accounting." And I would like to be able to have you answer that along the lines of your role militarily on how you would deal with that. And I would like Major Hess to comment that if a tragedy of this moment occurred, I am recalling the submarine issue with the Japanese fishing boat and the sort of scenario that occurred. I would appreciate your comment on that. I also would appreciate a comment as to whether or not we should be concerned about the International Space Station. Is that susceptible to the same management problems that tragically helped, if you will, result in the *Columbia* 7 tragedy? And I would also like to find out—as I look at this report globally, you are not condemning human space flight. There is vitality to humans going in space. I didn't see it in the report. I don't want to miss it. And I would appreciate you commenting on the value of that through your work and interviews with individuals.

Admiral, you were in the middle of the accountability question and who we should hold, how we should hold those responsible.

Admiral GEHMAN. Right. I will let General Hess, who has conducted many, many safety—accident investigations in the aircraft accidents and comment on that. But generally speaking, in our military experience, we conduct two separate investigations. And

one investigation is—does have an accountability, responsibility kind of a goal. And the other one is an investigation to really find out, no kidding, what happened and every single contributing cause that may have contributed to that accident in which we assure people that no accountability will be—there will be no punishment, no intimidation of any witnesses or anything like that. And what we tried to do in this investigation is to roll those two kinds of investigations into one in which we brought out the performance of people. We documented it in our report. And if the proper authorities want to hold those people accountable, I think they should. We are not escaping the issue of accountability. We just decided that we aren't the judges. But we did—we were the investigators, so we put it all in the report.

Ms. Jackson Lee, we did not examine the International Space Station program, but I suspect that many of the things that we unearthed in this investigation probably might be good to look at in that program, also, not that it is not well run and not well managed. I have no evidence whatsoever to indicate that it isn't well run and well managed, but if we have cultural problems with communications and openness and the role of engineers and things like that, it probably is in more than one program.

General Hess, do you want to comment on the military—how military would handle a loss of life like this?

Major General HESS. I think that there is—a good way to approach the answer to your question is that when we investigate accidents, it is very likely that outcomes can kind of fall in three general areas. One, if you find culpability on the part of leadership, a removal from position is not an unheard of event. Two, if you find that in the case of, let us say, a pilot flying an airplane and he flew it outside of the rules, that pilot going to a flight evaluation board to determine whether or not he retains his wings as a result of that event is not unheard of. In the cases where, for example, there is a mechanical failure, for example, F–16s, being a single-engine airplane, we were dropping them out of the sky left and right in the late '90's because of mechanical failures, those are problems that you go back and you fix logistically. Well, there is not any personal culpability in the operation. So accountability is part of what we do. And we think it is very, very important, because it helps us continue to follow the rules.

Chairman BOEHLERT. General, you have had the last word. We are going to—your—the gentlelady's time has expired.

Ms. JACKSON LEE. Thank you, Mr. Chairman.

Chairman BOEHLERT. And we are going to be faithful to our promise to our distinguished panelists to have them permitted to exit. And incidentally, the fine cuisine, they each grabbed half a sandwich——

Ms. JACKSON LEE. Oh, did—that you provided, Mr. Chairman?

Chairman BOEHLERT [continuing]. Provided to them here. Yeah.

Ms. JACKSON LEE. Mr. Chairman, would you yield for a moment so that you can—so that he could have the last word? I just want to—I will pose it to you.

Chairman BOEHLERT. Who is "he" going to have the last word?

Ms. JACKSON LEE. You indicated this witness, but I will pose it to you. I assume I heard Admiral Gehman say that we would be

able to speak with him directly one on one and have the opportunity to visit with at least Admiral Gehman and maybe some of the Board members.

Chairman BOEHLERT. Not right now. I mean, let me tell you, it has been my experience, and we are finished now, because we are going to be faithful to our promise to the panelists. It has been my experience that this Board, Admiral Gehman, every single member of the Board, has been accessible——

Ms. JACKSON LEE. Right. That is all I needed.

Chairman BOEHLERT [continuing]. And very receptive to any requests we have made of them. Let me tell you, I just want to stand and applaud you for what you have done for us and for America.

[Applause.]

Chairman BOEHLERT. We are now adjourned.

[Whereupon, at 2 p.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Admiral Harold W. Gehman, Jr., U.S. Navy retired, Chairman of the Columbia *Accident Investigation Board*

Questions submitted by Representative Ralph M. Hall

Q1. You made 15 return-to-flight recommendations and 14 recommendations that do not have to be completed before return-to-flight. How did you go about deciding what is a return-to-flight requirement and what isn't? Four example, your report just says "initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source. . ."

Q1a. If you are concerned enough to call for an aggressive program to eliminate all ET Thermal Protection System debris-shedding, why shouldn't NASA keep the fleet grounded until they have completed the task?

A1a. The exposure of the Orbiter to some amount of debris is a feature of the Shuttle's original design and cannot be eliminated at this time. The Board concluded that it would be impossible to eliminate all debris-shedding but NASA needed to take a three-pronged approach which will improve the safety of the Shuttle: reduce the level of debris to the minimal level possible, work to strengthen the orbiter to take any debris hits and establish the capability for inspection and repair on orbit. If NASA follows all the RTF recommendations, redesigns the Bipod area, improves the photographic capability on launch, develops a capability to do an on-orbit inspection, develops a repair capability for the tile and RCC in orbit and has the Space Station as a possible sanctuary, the safety level increases for RTF.

Q1b. How much time should NASA have to complete the program?

A1b. We did not specify a specific time for the non-RTF recommendations, but it is considered a mid-term recommendation, which means one-three years.

Q1c. The bipod problem is being fixed by getting rid of the ramp entirely. There is another area of ET foam where shedding has been noted—the so-called flange areas at the edges of the inter-tank zone. Shouldn't this area be fixed before return-to-flight?

A1c. The Board believed that NASA could make some significant improvements in the flange areas with proper testing and understanding why foam debris has originated from this area.

Q1d. In another critical area, do you think the Shuttle flight should remain grounded until NASA has fully developed a means to repair reinforced-carbon-carbon leading edge panels while in orbit?

A1d. The Board was very clear on this issue—". . .develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the TPS, including tile and RCC. . ."

Q1e. In another critical area, in view of the early warning signals that NASA is getting of a potential problem, as well as the potential catastrophic consequences of a failure, why shouldn't redesign of the "hold down" bolt system be a return-to-flight requirement?

A1e. The "hold down" bolt system is already a redundant system, but the Board felt it had the potential to be a catastrophic failure. Specific observations were made and this significant issue should be addressed by NASA because it fell into the category of "weak signals" that could be indications of fixture problems.

Q2. The CAIB calls on NASA to "initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles.. . ."

Q2a. Again, the Board does not require installing an improved thermal protection system on the Orbiter before the next flight. Why not?

A2a. The Board feels it is NASA's responsibility to develop and implement the technical solution.

Q2b. The specification for the TPS tiles and panels requires that the maximum impact they are designed to sustain is 0.006 foot-pounds. This is quite small. We now know that foam can inflict massive damage on the leading-edge panels. Why should anyone have confidence that the Orbiter can return to flight until the plans for replacing the Orbiter thermal protection system are completed?

A2b. Risk will always be inherent in space flight but the Board felt that if NASA followed through on the RTF recommendations, the Space Shuttle would be safe to fly in the short-term. If NASA redesigns the Bipod area, improves the photographic capability on launch, develops a capability to do an on-orbit,inspection, develops a repair capability for the tile and RCC in orbit and has the Space Station as a possible sanctuary, the safety level increases for RTF. Furthermore, the RCC is actually much more impact resistant than this specification, but no one knows for sure how much tougher. This recommendation is aimed at requiring NASA to test its flight hardware rather than rely on analysis.

Q3. The Board dissects at some length the weaknesses of the "Crater" model as used to analyze the foam damage during the Columbia*'s flight. As a result of the investigation, do you have any indication of the extent to which NASA is relying on equally weak analytical models in the Shuttle or Station programs?*

A3. There is clear guidance that NASA must update its model regarding the evaluation of TPS damage: "Develop, validate, and maintain physics-based computer models to evaluate TPS damage from debris impacts." One area NASA needs to look into is the use of hydrodynamic structural codes. The Board found other areas where systems were certified for flight by analysis rather than actual testing, such as the Bolt Catchers, and the Board found that this was not proper for a flight development vehicle.

Q4. Your report was critical of the 1995 Kraft report's assumption that the Shuttle could be viewed as a mature fleet of "operational" vehicles. You argue quite forcefully that the Shuttle is still an R&D vehicle—not an operational vehicle. Then in your discussion of a proposed approach to improving NASA's Shuttle safety system, you highlight the safety programs of the nuclear Navy as being a good model to emulate. However, the nuclear Navy consists only of operational *vehicles—no one would argue that our nuclear missile submarines are R&D vehicles. As a result, the differences between the Shuttle fleet and the Nation's submarine fleet would seem to be far greater than any perceived similarities—and the safety model would not seem to be relevant. Would you care to comment?*

A4. There will never be a perfect match on benchmarking. The Board was impressed with the fact that the nuclear Navy manages a complex system and it can be argued they continually learn about nuclear power as it ages and matures and it has comparable responsibilities in research, design, construction, testing, training, operation, and maintenance—there are some valid lessons learned that can be applied to NASA regarding: communication and action; recurring training and learning from mistakes; encouraging minority opinions; retaining knowledge; worst-case event failures. The Board's Report takes the best safety practices from several case studies, not just Naval Reactors.

Q5. While rejecting the premiers underlying the Kraft Report, the Board was silent on the future structure of a Shuttle contract.

Q5a. Why didn't you provide some guidance to the agency, the Administration and Congress on the wisdom of continuing with the Space Flight Operations Contract as it stands?

A5a. In the Board's investigation, we did not find any direct relationship between the SFOC and the cause of the mishap. However, there was clear mention that outsourcing has an unintended consequence of reducing the in-house engineering and technical capabilities in the civil servant side of NASA and complicating the issues of safety independence. The Board clearly said, ". . .In the aggregate, these mid-1990s transformations rendered NASA's already problematic safety system simultaneously weaker and more complex."

Q5b. Are the incentives in the SFOC contract, which includes an incentive for cost savings for both NASA and the contractor, a part of the problem here?

A5b.

The Board found no evidence that the extensive use of incentives contributed to this accident. However, the Board did find what are apparently unintended consequences on the NASA work force that it felt were worth noting. Among those unintended consequences were: migration of technical expertise, increased communications challenges, systems of informal hierarchies, loss of truly effective checks and balances.

Q6. After the Challenger *tragedy, part of NASA's return-to-flight action required the cancellation of all existing waivers and the review of all existing documentation relating to critical items, failure modes, and the hazards of flying the vehicle.*

Much of the time needed to return to flight was consumed by this effort. The Board does not recommend a similar effort as a requirement for returning to flight this time, although you do recommend a re-certification program if the Shuttle is to be flown past 2010. Why shouldn't we re-certify the vehicle now? Do you think the Shuttle would pass a re-certification in 2010?

A6. The Board shares this concern, and based its fundamental recommendation to create an independent technical authority with the ownership of all technical specifications and all waivers to those specifications on the premise that certification to "continue to fly" should be very carefully monitored. Included in the duties of this independent authority will be the requirement to understand and safeguard the systems specifications over time. The Mid-Life Certification program will bump up against this authority, just as we intended.

The Mid-Life Certification (MLC) is a necessary process that will require NASA and Shuttle program managers to review all the basic vehicle design and certification criteria and revalidate them. This re-certification will uncover design and manufacturing assumptions that were made using the limited 10-year/100-launch life span of the system. Shuttle program management has delegated the development of MLC to the individual elements and subsystem managers. Approximately 80 percent of the effort will reside in the orbiter itself. The orbiter element is beginning its MLC program development using a three-step process, an expanded Certification of Flight Readiness (called CoFR plus), certification verification, and certification extension.

CoFR plus is the first step for orbiter return to fly as well as MLC. This more rigorous certification will begin this summer in preparation for the anticipated first flight after *Columbia.* In addition to the normal subsystem-by-subsystem review of flight certification, reported upchannel to the program management, the orbiter MLC office wants to add a horizontal check to verify certification between subsystems. Essentially, they want to look at known problem areas in one system and determine if there's a risk to other systems. An example of this horizontal review is the integrated approach used to alert other systems of the problem with the flex hoses. This will facilitate an integrated approach to certification of all the subsystems as part of the overall system as well as their interaction. The intent is to integrate this process improvement into all future certifications.

The SSP's extended life raises several questions about the vehicle and component's original certification. The verification of certification step is envisioned to be a review of the CoFR process with intent to verify that the program is reviewing the right areas, prior to flight approval, with regard to the current operating environment (as compared to the anticipated operating environment in the late '70s). The long-term exposure to salt air and the high wear induced by maintenance are two examples of environments that the original certification did not anticipate. The flex hoses, mentioned previously, failed under low frequency vibration induced stress that was not anticipated in the original certification. This MLC process is expected to be a one-time review. The orbiter office is planning to complete this verification for all CRIT 1.1 systems in time for the next CoFR. The remaining CRIT systems will be accomplished thereafter.

The extension of the SSP certification beyond 2020 is the final step. This data intensive process will include a review of the NASA and contractors' databases with intent to mine all the original certification criteria and assumptions that may not be valid today. Their intent is to do this archival review as well as current trend analysis using UA, PRACA, CARS data et al. This information will then be used to build new certification criteria and maintenance or modification programs to sustain the SSP. Additionally, this review will build a database to be used in future certifications and provide training for younger engineers in the program invaluable experience relating to system certification processes. The extension program will be designed as a one-time review as well.

The MLC is currently ranked in the third tier of SLEP projects, at the top of a list of undefined projects. This list of undefinitized projects, including Mid-Life Certification, Fleet Leader and Corrosion Control, are the core of a service life extension for this system. Funds to start MLC are programmed to begin in '04 and include adding 50 to 100 additional personnel to get this program started. MLC is expected to increase certification confidence and build a sustainment program complete with maintenance, inspection and modifications that will extend the life of the Shuttle program. The key to success will be in its funding and rigor as the program office integrates the various systems toward one goal.

The Shuttles next certification and the SLEP program should be founded on the basis of a thorough Mid-Life Certification. The SLEP management recognized this problem at the 7 May 2003 program review; "We need a focused effort to move these

activities from the undefinitized to the definitized portion of the budget. Progress should be targeted to support the 2004 Summit." The orbiter program is starting out with some outstanding ideas on how to organize this tremendous MLC task. The program office should standardize the approach between the systems to ensure rigor and accuracy of the final product. NASA has most of the necessary ingredients for a successful sustainment program for the Shuttle Program. The only impediment to building it is a centrally organized sustainment office with authority to integrate the various SSP systems and sites.

Q7. Your report did not address the issue of the role played by the astronaut corps in agency management. Do you have any opinions on the subject? Is it on balance healthy or unhealthy?

A7. The Board was disappointed in the Astronaut office participation in the MMT. The representation at these meetings was random and there was little consistency in tracking valuable information. In fact, the Astronaut office did not know there was even a foam debris issue until after the *Columbia* mishap. The Board also believes simply assigning mal-prepared Astronauts to management positions is not a course of action with high probability of success. If Astronauts are to be encouraged to enter the management field, they require proper education and training.

Q8. Admiral Gehman, your report devoted a great deal of space to a discussion of the pressure exerted by NASA Administrator O'Keefe to meet the artificial milestone of Space Station "Core Complete" by February 19, 2004. Do you think that the explanation that "all of the Shuttle launches were delayed anyway, so it wasn't real pressure" is plausible, or was the reality that each Shuttle launch delay simply added to the pressure perceived by the NASA workforce?

A8. If a Shuttle launch is delayed, it may not mean that all subsequent launches slip. Many times the next mission moves ahead of the delayed mission. During this investigation the Board found that people who work at NASA have the legendary can-do attitude, which contributes to the agency's successes. But it can also cause problems. When workers are asked to find days of margin, they work furiously to do so and are praised for each extra day they find. But those same people (and this same culture) have difficulty admitting that something "can't" or "shouldn't" be done, that the margin has been cut too much, or that resources are being stretched too thin. No one at NASA wants to be the one to stand up and say, "We can't make that date." It should also be noted that the number of days delayed is not a one-to-one match on the amount of margin lost. The Board found sufficient evidence that schedule pressure was felt at the working level.

Q9. Your report is critical of the "NASA culture" and you say that it needs to be changed, that it is a question of "leadership." What specifically needs to be done and how we will in the Congress be able to confirm that the culture has successfully changed?

A9. Changing culture is a very difficult thing to do in any organization. The Board feels that it will require management changes that include the CAIB recommendations for an: independent technical engineering, a truly independent safety authority and a fully integrated Shuttle program. Secondly, the Board feels it will require leadership from the top that must come from the senior levels of NASA. The Report clearly defines what we mean by "culture." Good cultural habits can only be established by consistent and steady demands by management over a prolonged period of time.

Q10. At several points in your report, you seem to be critical of the fact that the number of mandatory inspection points for Shuttle launch processing has been cut back dramatically over the years, but you don't produce a clear recommendation on this point.

Q10a. Did the Board think that there were too few mandatory inspection points? If so, what was the specific basis of your concern?

A10a. The Board observed that the GMIPs changed from over 40,000 in the early 1990s to approximately 8500 in 2003. There was a general movement in the Government to outsource to contractors. While the Board could not tie this reduction in GMIPs to a causal relationship to the accident, there is a concern that NASA went too far in reducing the GMIPs that resulted in a decreased engineering expertise in NASA civil servants for proper oversight.

Q10b. If you think significantly more mandatory inspection points are needed, why wasn't that one of the report's recommendations?

A10b. The Board did not have the expertise to recommend specific additions to the GMIPs but clearly was concerned that this needed to be reviewed by NASA in the observation: . . .Perform an independently led, bottom-up review of the KSC Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections."

Q11. The report's discussion of the budgetary history at NASA, especially in the Shuttle upgrade and safety programs, is incomplete.

Q11a. What documents did you receive from NASA and OMB that detailed upgrade requests from the Shuttle or Safety programs to the NASA Headquarters budget office, from NASA to OMB, and pass-backs from OMB to NASA?

A11a. We received no documents from OMB, and no documents containing predecisional budget data from NASA.

Q11b. Technically, your Board was a NASA panel, so why couldn't the Board at a minimum have gotten all the material in the possession of the agency?

A11b. Executive privilege protects pre-decisional, NASA-executive office communications. We could have requested such information from NASA, but we were advised by NASA general counsel's office that the request would have been denied on the basis of executive privilege.

Q11c. Did anyone advise you not to pursue the budget document requests? If so, who?

A11c. Executive privilege protects pre-decisional NASA-Executive office communications. We could have requested such information from NASA, but we were advised by NASA general counsel's office that the request would have been denied on the basis of executive privilege.

Q11d. Do you have any strong opinion about the current mix of Shuttle upgrades and the appropriateness/robustness of the Shuttle upgrades program? On what is that opinion based?

A11d. The Board does not have a strong opinion regarding this question.

Q12. The report notes on page 78 that the tests conducted to validate the hypothesis that the foam had damaged the thermal protection system did not meet with wholehearted approval from NASA. Please describe the circumstances surrounding the conduct of the test program? Is this episode related to the Board's comment that, "The changes we recommend will be difficult to accomplish—and will be internally resisted?"

A12. The foam impact testing became so important to the investigation that the Board felt we must have control over the entire process. There initially was resistance from some NASA personnel as to the type of testing that was required and the importance of testing to the final outcome of the investigation. The Board concluded that the most effective method for conducting the test was for the Board to have final authority over the entire foam-testing program. This issue was not specifically related to the Board's concern that changes would be internally resisted, but did contribute to the overall sense that NASA is resistant to outside criticisms.

Q13. One thread running through the Board's review of NASA's budget history is the continuing quest to find efficiencies in the Shuttle program, to reduce the annual request for appropriations. Congress has heard testimony on many occasions that budget cuts have safety impacts, but there is no metric by which a particular *reduction in budget can be tied directly to a specific reduction in safety. Group IV John Logsdon has been contacted and is responding.*

Q13a. Is it fair to say that your report concludes that because of budget pressures the Shuttle program was operating at thin margins, but that you couldn't tie this accident directly to budget cuts? If so, why couldn't you make a stronger statement about the effect on safety of the declining Shuttle budget?

A13a. Precisely because there was no way of establishing a direct causal link, we felt that what is said in the report was as strong as we could substantiate.

Q13b. Does the Board have any advice for us on how to recognize in the future when a lack of resources has pushed the program into an unsafe condition? How will we know? Who will be competent to make this assessment?

A13b. Both the independent technical authority and the independent safety authority we recommend in the report will be able to make these judges, as would a reconstituted and effective ASAP.

Questions submitted by Representative Bart Gordon

Q1. Please provide some specific "benchmarks" that will allow Congress to assess the extent to which NASA is complying with the recommendations of the Columbia *Accident Investigation Board (CAIB) over the next several years.*

A1. The HSC has asked that the CAIB be reconvened in one year to track the progress of the recommendations. The CAIB is prepared to do this.

Q2. Many of the findings and recommendations in your report were in fact clearly stated in the 2000 report of the Space Shuttle Independent Assessment Team (SIA), chaired by Dr. Henry McDonald. One could conclude that if SIAT report had been embraced by the agency, the Columbia *accident might never have happened.*

Q2a. Can you explain why *NASA failed to heed Dr. McDonald's report in the three years after its release?*

A2a. It is unfair to say that NASA failed to heed the SIAT report since there was follow-up on some of the report's recommendations by NASA; however, NASA did not agree with all the recommendations of the SIAT report. The reasons NASA resists implementing recommendations from outside reviews are complex. Among the chief reasons are: NASA thinks it knows better; budget constraints have caused shrinkage of R&D activities and independent, in-house engineering work; schedule pressure; and, leadership shifts toward managers and away from engineers.

Q2b. What will have to occur for your report to receive a more favorable reception, and how likely do you think that is?

A2b. The Stafford-Covey RTF group will be one means to track the short-term recommendations. A newly chartered ASAP, periodic reconvening of the CAIB and Congressional oversight may be a means to ensure mid-term and long-term recommendations are followed. The Board Report predicts resistance to change, which are the primary reasons we recommended an independent technical/engineering authority with the authority to safeguard and/or grant all waivers to basic system requirements and specifications.

Questions submitted by Representative Sheila Jackson Lee

Q1. What actions would you recommend be taken by NASA and the Congress to ensure that the International Space Station program is not facing safety concerns similar to those uncovered by the CAlB investigation?

A1. The investigation of the ISS was not part of the Charter of the CAIB so we do not feel qualified to answer this question. However, the lessons learned from the *Columbia* Accident should be studied by the ISS program management for benchmarking purposes. The NASA IG is capable of using the *Columbia* Accident Investigation Board's report as a roadmap to use in the case of the ISS.

Q2. Your report seems to be quite critical of the amount of downsizing of the government employees and the amount of contracting out that has occurred at the agency.

Q2a. Is that true? If so, what is the basis of your concern?

Q2b. How many government employees do you think will need to be added to address the concerns raised in your report?

A2a,b. Since NASA was established in 1958, its civil service workforce has fluctuated widely. In 1967, at the height of the Apollo program, the workforce reached approximately 35,900 personnel. In the mid-70s an involuntary separation program decreased the workforce by several thousand employees. By 1980, the workforce had stabilized near 21,000. It remained close to that level until 1986, when the Space Shuttle *Challenger* accident forced a re-examination of NASA, adding significant man-hours to Safety and Quality Assurance processes.

NASA began some ambitious new programs in the late '80s and its workforce began to grow again peaking in 1992 at more than 25,000. When the Clinton Administration took office in 1993, it initiated steps to reduce the size of the overall federal workforce. Total NASA headcount went from approximately 25,000 civil

servants in FY 1993 to slightly more than 18,000 (full-time permanents) by the end of 2002. As the NASA workforce declined, the continuing strategy was to lose junior personnel first, resulting in an experienced but aging workforce. In November 1995, NASA selected United Space Alliance—a Rockwell International and Lockheed Martin partnership—as the prime contractor for space flight operations. Thus, fewer civil servants were required to manage the program, NASA estimated that it would be able to make personnel reductions in the range of 700 to 1,100 full-time equivalent personnel (FTEs) at the Kennedy Space Center alone. The challenge to Space Shuttle contractors, including United Space Alliance, was to address the aging workforce concerns through a continual influx of inexperienced personnel who could stay with the industry for many years. Contractors have much more flexibility in their personnel decisions than does the Federal Government. Compensation packages, including both wages and benefits, are tailor made to address the shortages that face the industry while correcting oversupply in some skills.

All SSP contractors, including United Space Alliance, have been given financial incentives to reduce the cost of performing the contract. Personnel costs can be reduced by eliminating personnel in overhead support or management functions, or by encouraging efficiencies in the direct labor elements. United Space Alliance, through the Space Flight Operations Contract, is accountable for professional, managerial and technical workforce support to the Space Shuttle Program. Jobs range from maintenance personnel at Kennedy Space Center to subsystem managers within the Mission Control structure. USA recognized its obligation to maintain a balanced workforce in the professional skills, and that there must be a flow of personnel through the "pipeline" to guard against future shortfalls in critical skills.

United Space Alliance stated that while they accepted the challenge to reduce the headcount on the Space Shuttle program, they intended to do so without reducing the direct headcount. They would do this primarily through efficiencies achieved by consolidations. USA did not place the same emphasis on the retention of the nonprofessional, technician workforce. USA has stated that they do not suffer from the same concerns as with engineers and has never faced a shortage of applicants for these jobs.

United Space Alliance closely tracks personnel trends, especially with respect to engineering manpower. USA has a nearly bi-modal distribution with respect to age or experience. There are a significant number of personnel over 40 years of age as well as a significant number in the under 30 age group. This illustrates a pipeline from which the workforce of the future will be drawn. Other Space Shuttle contractors may not have had the flexibility to make these kinds of "overhead only" process gains, as elimination of direct as well as indirect personnel was necessary. While reducing the cost of labor through lay-offs, the contractor must continually guard against creating an impression of the company as an unattractive workplace. Contrast the United Space Alliance distribution with ATK Thiokol Propulsion in Utah, the supplier of the Reusable Solid Rocket Motor (RSRM) since the 1970's.

During the peak production of the RSRM in the 1980's, Thiokol employed over 4,000 personnel. Today, with production of the RSRM at less than 30 units annually, their personnel count is stable at 1350. Demographics at the Utah plant show a spike in the 45–49 age group, with the majority of the workforce being over 45 years old. This trend is true for engineering as well as plant personnel. ATK Thiokol has identified their aging workforce as a significant issue in relation to the Shuttle program Service Life Extension Program (SLEP). ATK Thiokol recognizes that they must "pump significant new energy into recruiting new talent and retaining/training the younger ones currently in our workforce now." The contracting community at Marshall Space Flight Center recognized the risk associated with downsizing and has eliminated incentives associated with cost cutting in the latest RSRM contract.

The Michoud Assembly Facility workforce has been declining over the past five years. In 1998, there was some increase in hiring as a result of the RLV and X–33 programs. However, after that, hiring was limited to budget driven replacements only. Budget challenges have led to the involuntary separations which approached ten percent in 2002. One of the risks of multiple periods of downsizing is that it may lead to a perception among the workforce of limited potential for both growth and reliable employment. This has been highlighted as one of the most significant reasons for the voluntary attrition over the past three years. The average age of the employee at Michoud is now 47.8 years, but the skilled labor (represented) employees average 48.2 years. In conclusion, the issues associated with aging workforce present formidable challenges to the future of the Shuttle Program, especially if the vehicle is expected to serve until 2020 and beyond. Of the major contractors only USA has a recruiting effort with significant numbers.

Additionally, while USA's benefit packages have been considered by some to be below the industry standard, we have reviewed DCAA documentation that reflects

that the packages are among the better in the industry and may actually be considered excessive. It is essential that NASA take actions to ensure a stable experienced base of support for the Shuttle programs. This may require modifications to way contract incentives are used or other contractual changes. It may benefit NASA to continue the bundling of Space Shuttle element contracts, ETR, SSME, and RSRM under the SFOC and USA in order to maximize the return on leverage of personnel recruitment efforts.