Statement of
Harold W. Gehman, Jr.
Chairman
Columbia Accident Investigation Board
Before the
Committee on Science
United States House of Representatives
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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 spaceflight.

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 previous 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 PhD 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.