March 5, 2004

Dear Senator Mikulski,

In his January 28th letter to you regarding the cancelled servicing mission to the Hubble telescope, NASA Administrator Sean O'Keefe indicated he had asked me to provide to you my views "...regarding safety and risk factors identified in the report of the Columbia Accident Investigation Board." from my perspective as Chairman of the Board. The purpose of this letter is to provide you my views on this matter.

I am pleased to undertake this task because it is fully consistent with the goals of the Columbia Accident Investigation Board (CAIB). At the very front of our report, in the "Board Statement", we expressed our belief that:
"The loss of COLUMBIA and her crew represents a turning point, calling for a renewed public policy debate and commitment regarding human space exploration. One of our goals has been to set forth the terms for this debate."

Whether to fly another mission to the Hubble is one of the public policy debates this nation should have, thus I am pleased to add whatever clarity I can to the terms of the debate.

As you are aware, the CAIB no longer exists; therefore, these views are my own. They are, however, based on the extensive investigation into the Columbia accident. Members of the Board are aware of my efforts, and while the Board is split on the merits of flying this mission, the Board's characterization of the risks as noted in our report are fully agreed. This letter is based on our work and insights gained during the most of careful study of the manned space flight program ever conducted, as well as recent consultations with the Stafford-Covey Return to Flight Task Group and others.

HOW RISKY ARE CURRENT SHUTTLE FLIGHTS?

The introduction to Chapter Nine, Implications for the Future of Human Space Flight, is an excellent place to start:

"In this report we have documented numerous indications that NASA's safety performance has been lacking. But even correcting all those shortcomings, it should be understood, will not eliminate risk. All flight entails some measure of risk, and this has been the case since before the days of the Wright Brothers. Furthermore, the risk is not

distributed evenly over the course of the flight. It is greater by far at the beginning and end than during the middle.

This concentration of risk at the endpoints of flight is particularly true for crew-carrying space missions. The Shuttle Program has now suffered two accidents, one just over a minute after takeoff and the other about 16 minutes before landing. The laws of physics make it extraordinarily difficult to reach Earth orbit and return safely. Using existing technology, orbital flight is accomplished only by harnessing a chemical reaction that converts vast amounts of stored energy into speed. There is great risk in placing human beings atop a machine that stores and then burns millions of pounds of dangerous propellants. Equally risky is having humans then ride the machine back to Earth while it dissipates the orbital speed by converting the energy into heat, much like a meteor entering the Earth's atmosphere. No alternative to this pathway to space are available or even on the horizon, so we must set our sights on managing this risky process using the most advanced and versatile techniques at our disposal.

Because of the dangers of ascent and re-entry, because of the hostility of the space environment, and because we are still relative newcomers to this realm, operation of the Shuttle and indeed all human spaceflight must be viewed as a developmental undertaking. Throughout the COLUMBIA accident investigation, the Board has commented on the widespread but erroneous perception of the Space Shuttle as somehow comparable to civil or military air transport. They are not comparable; the inherent risks of spaceflight are vastly higher, and our experience level with spaceflight is vastly lower. If Shuttle operations came to be viewed as routine, it was, at least in part, thanks to the skill and dedication of those involved in the program. They have made it look easy, though in fact it never was. The Board urges NASA leadership, the architects of the U.S. space policy, and the American people to adopt a realistic understanding of the risks and rewards of venturing into space."

In other words, for now and for the foreseeable future, by far most of the risk in space flight is in the launch, ascent, entry and landing phases, with a small portion of the total risk associated with the actual on-orbit mission. One could say that, within reasonable bounds, whatever one does once on orbit; it doesn't change the total risk factor very much. The conclusion from this observation, therefore, is to launch the fewest possible number of Shuttle missions. Indeed, the bottom line of the "Future" part of our Report is to replace the Shuttle as soon as possible, and to keep this risk equation in mind when developing the replacement system.

It was one of the CAIB's goals to help national policy makers understand the risks of Shuttle flights by putting space flight as we presently conduct it into context. We as a nation need to understand, as best we can, the amount of risk we accept while accomplishing our goals of space exploration. In Chapter Five, we quote the 1989 Office of Technology Assessment:

"Shuttle reliability is uncertain, but has been estimated to range between 97 and 99 per cent. If the Shuttle reliability is 98 percent, there would be a 50-50 chance of losing an Orbiter with 34 flights...The probability of maintaining at least three Orbiters in the Shuttle fleet declines to less than 50 percent after flight 113."

(STS-107, the ill-fated Columbia flight, was the 113th Shuttle mission).

And we quote the 1990 Augustine Commission Report:

"And although it is a subject that meets with reluctance to open discussion, and has therefore too often been relegated to silence, the statistical evidence indicates that we are likely to lose another Space Shuttle in the next several years...probably before the planned Space Station is completely established on orbit."

To put these very accurate predictions into today's context, we should use figures we know are accurate. We have flown 111 out of 113 Space Shuttle missions safely, for a 98.23 percent reliability rate. The chance that we will be able to fly 25 future missions using this reliability figure without a loss is 64 percent. The more missions we fly, the more that 64 percent number goes down. It is my opinion that implementing all the Return to Flight recommendations made by the CAIB raises the reliability number somewhat, although no one knows for sure what it is. A reliability number more like 99 percent seems reasonable to me, giving a 78 percent chance we will fly the 25 missions without loss. Once again, more missions cause that 78 percent number to go down. Flying one more mission, 26 in all, reduces the probability of series success by about one percentage point.

The bottom line: Shuttle flights are dangerous and we should fly the minimum number necessary. Almost all the risk is concentrated in the front and back of the mission, where one goes on orbit makes little difference.

WHAT CAN BE DONE TO MITIGATE THE RISK?

The recommendations contained in the Columbia Accident Investigation Report pertaining to return to flight are specifically designed to break the coupling or linkage between the propensity of the Shuttle external tank to shed ice and debris and the loss of crew and vehicle. To increase the chances of mission success and decrease the chances that future shedding events, which are inevitable in our view, will result in a catastrophic outcome, four measures are required. The Board feels all four are required; picking and choosing from among the four does not meet our intent.

First, measures must be taken to more fully understand why foam shedding in particular occurs and what steps must be taken to reduce it. This recommendation requires research and development activity as well as some sub-element re-design steps. NASA is well along in implementing this recommendation.

Second, measures must be taken to more fully understand the true strength of the parts of the Orbiter that are most likely to be damaged. The CAIB found, for example, no agreement, backed by test data, on the current strength of the Reinforced Carbon-Carbon wing leading edge components. This recommendation will allow NASA to understand the true nature of the risk to the orbiter from debris shedding events.

Third, measures must be taken to image the Orbiter both during launch and on-orbit to characterize any hits and to essentially "re-certify" the Orbiter for entry. This

recommendation includes much better launch complex camera systems, range imaging systems and an ability to thoroughly inspect the exterior TPS of the Orbiter in space prior to entry.

Fourth, measures must be taken to develop and deploy a capability to make emergency, on-orbit repairs to the TPS to any damage that is deemed threatening to successful entry. This step cannot be accomplished unless steps two and three above are done.

In the view of the Board, all four steps are required, and selecting from among them is not sufficient. While we studied and deliberated these Return to Flight recommendations, it became apparent to us that missions to the ISS had a significant advantage in implementing our recommendations over those that were not going to the ISS. Consequently we decided to differentiate RTF recommendations between missions to the ISS and non-ISS missions. Our report refers only to ISS missions or non-ISS missions. We did not specify what non-ISS missions might be flown (Columbia's final mission was, of course, a non-ISS mission). In our view, missions to the ISS allowed a more complete and robust inspection and repair capability to be developed.

However, knowing that there are situations where docking to the ISS may not occur, we required that ultimately NASA must develop an autonomous on orbit inspection and repair capability. Very frankly, we called for a less technically challenging inspection and repair capability, by stating:

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

In other words: "Do the best you can". We knew we were essentially REDUCING the requirements. Reducing the rigor of our requirements INCREASES the risk. It cannot be seen any other way. If fully complying with the CAIB RTF technical requirements decreases the risk, complying with lesser requirements must increase the risk. The risk difference is probably not knowable in advance, and knowing the technical capabilities involved the risk difference is probably small, but it is not zero.

It is important to remember the CAIB is talking about risk to the Orbiter from debris shedding events. There are many other factors involved that influence the total risk equation, sometimes very significantly. One of the more significant factors is the heavy cargo loads that are frequently carried to the ISS at high inclinations, which creates risk factors of their own. We did not look at total mission risk and I am not prepared to analyze the total risk equation for all possible Shuttle missions. Further, the CAIB specifically used the generic term "non-ISS" missions to avoid any judgments regarding the relative value of one mission over another.

Bottom line: Complying fully with the CAIB's RTF recommendations is less a challenge when factoring in the ISS. The CAIB allowed more latitude in complying with our recommendations for non-ISS missions, which may be slightly more risky, taking into account only the debris shedding threat to the Orbiter.

Senator, in Chapter Nine of our Report, titled: "Implications for the Future of Human Space Flight", we made the declarative statement that: *"It is the view of the Board that the present Shuttle is not inherently unsafe"*. We were under no pressure to conclude either way on this issue. But I always like to point out that there are two negatives in that quote. We are not saying the Shuttle is "safe", it certainly is not by any common understanding of the word "safe". Nor are we saying it is unsafe and should be abandoned. Our study and report are designed to help NASA manage the substantial risks involved. I suggest only a deep and rich study of the entire gain/risk equation can answer the question of whether an extension of the life of the wonderful Hubble telescope is worth the risks involved, and that is beyond the scope of this letter. What I have attempted to do is offer a very frank review of the risks to all Shuttle operations, Hubble or non-Hubble, as we understand them.

I hope this letter is useful, and as always, I am prepared to answer any questions you or your committee may have.

Very Respectfully

/signed/
Harold W. Gehman,jr
Admiral, USN(ret)

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January 21, 2004

Honorable Sean O'Keefe
Administrator
National Aeronautics and Space Administration
300 E Street NW
Washington, DC 20024

Dear Administrator O'Keefe:

I was shocked and surprised by your recent decision to terminate the next scheduled servicing mission of the Hubble Space Telescope (HST). I fully appreciate and support your emphasis on astronaut safety. Astronaut safety is my number one priority. However, given Hubble's extraordinary contributions to science, exploration and discovery, I ask you to reconsider your decision and appoint an independent panel of outside experts to fully review and assess all of the issues surrounding another Hubble servicing mission.

This panel should report its findings to you and the relevant committees in both houses of Congress this year so we can understand fully the risks, costs and benefits of another Hubble servicing mission. In addition, I request that all planning, preparation and astronaut training activities continue without interruption until Congress has reviewed and decided this issue. Should this panel confirm the need, value and safety of another servicing mission, it is critical that time not be lost. Given Hubble's extraordinary contributions to science, exploration and discovery and its value to the nation and the world, a decision to terminate the next servicing mission must not be made without a thorough, rigorous and comprehensive analysis.

Hubble has become the most successful NASA program since Apollo. It can not be terminated prematurely with the stroke of a pen without a thorough and rigorous review while planning, preparation and training activities continue. I look forward to hearing from you.

Sincerely,

Barbara A. Mikulski

Barbara A. Mikulski
Ranking Member
Subcommittee on VA/HUD
And Independent Agencies