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The National Academy of Sciences Committee recommended that NASA abandon a robotic mission to repair the Hubble Space Telescope and fly a manned mission to repair it instead. Is their assessment to recommend a manned mission sound? Does it meet the criteria of the *Columbia* Accident Investigation Board?

I. OVERVIEW

In January of 2004, Sean O'Keefe, the Administrator of the National Aeronautics and Space Administration ("NASA"), announced a decision to cancel the manned servicing mission to the Hubble Space Telescope (SM-4).[1] He believed that compliance with the safety recommendations of the *Columbia* Accident Investigation Board issued months earlier could not be achieved in time to fly a manned shuttle mission to replace the Hubble's batteries and gyroscopes before their anticipated failure.

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1 SM-4 stands for "Servicing Mission Number 4" and was intended to replace aging spacecraft batteries, fine-guidance sensors, and gyroscopes, and to install two new science instruments on the telescope. See National Research Council of the National Academies, Committee on the Assessment of Options for Extending the Life of the Hubble Space Telescope ("NASC"), *Assessment of Options for Extending the Life of the Hubble Space Telescope: Final Report* 8 (Natl Academies 2005), available online at <http://books.nap.edu/openbook/0309095301/html/index.html> (visited Mar 25, 2005). It was the fifth time that a space shuttle would be sent to visit the Hubble. The first visit fixed Hubble's defective ground mirror, which left it myopic, by installing a contact lens of sorts to correct its "sight." That successful mission resulted in turning what was widely ridiculed as "space junk" into the incredibly successful telescope that it is today. Richard Stenger, *Who Should Explore Space, Man or Machine?*, CNN.com (Feb 18, 2003), available online at <http://www.cnn.com/2003/TECH/space/02/18/sprj.colu.space.future/index.html> (visited Mar 14, 2005).

A public outcry immediately followed. The NASA Administrator was vilified and accused of "killing" the inanimate Hubble Space Telescope. The media, politicians, scientists, and public alike were infuriated as they had become hooked on the remarkable and unique images produced by the telescope during its storied history over the preceding thirteen years. The rationale for NASA's decision to cancel the mission was largely ignored and became engulfed by the hue and cry as the outrage persisted. The outspoken critics were shrill in arguing that the decision on the telescope, a national treasure, was too important to be left to the Administrator at NASA. They even went so far as to conclude that the Administrator's decision to cancel the manned servicing mission demonstrated his unwillingness to take risks.[2]

In an effort to quell the rage, NASA responded by proposing to repair the Hubble by employing a "robotic" servicing mission. It undertook full-bore an effort to assess the prospects, scope, cost, and timing of such an undertaking. However, the measure was seen by some as unrealistic and pressure mounted for an independent opinion. NASA finally acquiesced to requests from Congress and elsewhere for an outside study and invited the National Academy of Sciences to review and recommend one of the two options to "save" the Hubble: a manned Shuttle mission or a robotic one.

In the late spring of 2004, the National Academy of Sciences appointed the Committee on the Assessment of Options for Extending the Life of the Hubble Space Telescope[3] (the "National Academy of Sciences Committee," or "NASC"). It issued a final report on December 8, 2004, in which it unanimously concluded that:

> . . . NASA should commit to a servicing mission to the Hubble Space Telescope that accomplishes the objectives of the originally planned SM-4[4] mission.

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2 See, for example, *Death Sentence for the Hubble?*, NY Times A14 (Feb 13, 2005); Guy Gugliotta, *Hubble Decision a Blow to Goddard Engineers; No Chance to Show Feasibility of Robot Mission*, Wash Post A03 (Feb 9, 2005); Alcestis Oberg, *Fade to Black*, USA Today 11A (Feb 16, 2005); Graham Warwick, *Exploration Accelerates Aeronautics' Decline*, Flight Intl 21 (Feb 15, 2005). For Mr. O'Keefe's response to these criticisms, see Editorial, *Re "Death Sentence for the Hubble?"*, NY Times A14 (Feb 19, 2005).

3 Warren E. Leary, NASA Agrees to New Study on New Mission to Telescope, NY Times A12 (Mar 12, 2004).

4 In 2004, NASA had undertaken to study and plan for a robotic servicing mission which would do what was technologically feasible and cost responsible and which might not include all of the requirements originally planned for SM-4. NASA recognized that the more complex and numerous the mission requirements (particularly the installation of the two new instruments), the more costly and risky it would be to complete the mission. Thus, the NASC recommends that the scientific community receive what it had expected: the benefit of the full array of SM-4 mission objectives. The mission is simply too important. See NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 72 (cited in note 1); see also, Gugliotta, *Hubble Decision a Blow to*

> The committee recommends that NASA pursue a [manned] shuttle servicing mission to . . . [the Hubble Space Telescope] that would accomplish the above stated goal. Strong consideration should be given to flying this mission as early as possible after return to flight.
>
> A robotic mission approach should be pursued solely to de-orbit Hubble after the period of extended science operations enabled by a shuttle astronaut servicing mission, thus allowing time for the appropriate development of the necessary robotic technology.[5]

As the former General Counsel for NASA who counseled the agency during the *Columbia* disaster and the subsequent investigation of the *Columbia* Accident Investigation Board and who participated in the decision to cancel the servicing mission, I am distressed by the recommendations of the National Academy of Sciences Committee. This is not because of disagreement, but because the recommendations appear to be based on an optimistic view of the risks attendant to a Hubble SM-4 mission and because they fail to adequately address the whole risk spectrum of such a mission.

Having lived through the tragedy of *Columbia*, there was the danger that NASA would become risk averse. The *Columbia* experience did not, however, have this effect. Instead, NASA and its Administrator merely became more risk conscious. The *Columbia* Accident Investigation Board Report ("CAIB Report") demands greater risk consciousness. The legacy of seven *Columbia* astronauts, seven *Challenger* astronauts, and three *Apollo* astronauts demands greater risk consciousness. And so the Administrator, in assessing risks of a Shuttle servicing mission to the Hubble Space Telescope, views the "best case" *and* the "worst case." If, after reviewing all of the risk from all vantages in a principled way, the decisionmaker cannot accept the extent of the risk, a decision to cancel a mission is not necessarily risk averse. Indeed, it is more likely risk conscious.

II. THE DECISION TO CANCEL THE SHUTTLE SERVICING MISSION TO THE HUBBLE SPACE TELESCOPE

A. THE BUDGET PROCESS

During every annual budget cycle, NASA must evaluate each existing and proposed program and decide which to pursue in the upcoming fiscal year. In doing so, it must decide based on the best information available at the time. In the winter of 2003, NASA Administrator Sean O'Keefe was in the final stage of making decisions about the upcoming budget for FY'04 (fiscal year October 1, 2004 through September 30, 2005). He faced a very difficult decision regarding

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Goddard Engineers, Wash Post at A03 (cited in note 2) (suggesting both that a robotic mission would be too costly and that it would take too long to assemble the necessary machinery).

5 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 106 (cited in note 1).

the Hubble Space Telescope. He contemplated whether NASA should proceed with the then planned shuttle servicing mission to replace aging batteries, guidance sensors, and gyroscopes to keep the telescope operational.

O'Keefe knew that in the pantheon of great tragedies and triumphs of NASA, Hubble was both a tragedy and a triumph. After being deployed by Space Shuttle *Discovery* on April 25, 1990, the telescope's mirror was determined to be defective and the telescope was ridiculed as "a billion dollars worth of space junk." However, NASA was undaunted and mounted an unprecedented shuttle repair mission that many thought too improbable to succeed (just as the NASC opined about the robotic servicing mission above). The mission proceeded in December of 1993, and astronauts successfully installed a corrective lens on the telescope, which turned a "space junk" tragedy into a triumph. A decision to terminate the planned Shuttle servicing mission would not only be a blow to the nation and to NASA, but also to the robust scientific community's reliance on the Hubble Space Telescope for its discoveries—which have changed our understanding of the universe. Certainly, such a decision could not be made lightly, and O'Keefe would not do so in this case.

But O'Keefe was also leading an agency that only ten months earlier had experienced a tragedy of epic proportions—the loss of the shuttle orbiter *Columbia* and its crew of seven.

B. THE TRAGEDY OVER TEXAS

On a clear, cool morning of February 1, 2003, several hundred people, including NASA employees, families of crew members, and guests waited near NASA's Shuttle Landing Facility at Kennedy Space Center to hear Space Shuttle *Columbia's* characteristic double sonic boom (announcing its imminent appearance in the sky). They expected another flawless touchdown on mother Earth after a very successful science research mission performed in zero gravity by seven exceptional human beings. Expectations of another safe arrival were soon to be dashed.

In special bleachers away from the rest of the onlookers the family of the crew of Space Transportation System ("STS") 107,[6] waited for their loved ones aboard the *Columbia.* As was customary for the last several years, the family and their immediate friends were separated from the main crowd and media to avoid the type of media stare that had gruesomely intruded on the families of the STS

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6 Although the flight was originally scheduled to fly as the 107th mission of the Space Shuttle, it was delayed for various reasons. Thus, this was actually the 113th flight of the Space Shuttle and the 25th flight of the orbiter *Columbia.*

51L crew in their moment of anguish and grief when the Shuttle *Challenger* exploded on liftoff in 1986.

NASA Administrator Sean O'Keefe chatted amiably with NASA personnel. He had just completed his first year as the head of the world's premier space agency. At the same time, *Columbia* was streaking across the western coast of the United States near Sacramento, headed on a flight path that would take it over Dallas–Fort Worth and then past Orlando over the Atlantic Ocean, where it would turn and approach final touchdown at the Cape. But, as it streaked across the western United States, unknown to but a few amateur ground observers who filmed *Columbia* in the darkness of an early morning sky, the leading edge of the shuttle's left wing was coming apart—first tile by tile—and then a catastrophic loss of the left wing immediately followed by breakup of the vehicle. At that moment, flight controllers, not knowing that the breakup had occurred, lost all contact with the crew and began several radio communications ("comm") checks to Commander Rick Husband to respond.

About thirty minutes later, the world and NASA's senior leaders were horrified to witness the tragic footage on CNN of the breakup of the vehicle as filmed by a Texas television station. Everyone's worst fears were realized. Commander Rick D. Husband, pilot Willie C. McCool, Michael P. Anderson, David M. Brown, Laurel Blair Salton Clark, Kalpana Chawla, and Israeli astronaut Ilan Ramon were gone—their spouses, children, parents, friends, and colleagues were left devastated. *Columbia*, the oldest shuttle in the fleet and the first one to fly (in 1981) was also gone.

Within an hour, the NASA Administrator selected Admiral Harold Gehman[7] to chair the board that would investigate the loss. The board was fully constituted and staffed by day's end and it was on site in Texas and Louisiana the following day.

America's space exploration program has been marked by both great triumph and great tragedy, the difference between the two being remarkably small. And so it was again that great tragedy would be imposed on this incredible space agency, whether it was ready or not. NASA began a difficult journey to recover from the tragedy that, in less than a year, would prompt a triumph when the President would announce a new vision for civil space leading the nation on a path for humans to explore the moon, Mars, and beyond.

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7 He enjoyed a very distinguished career and completed more than thirty-five 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 US Joint Forces Command, one of the five US Unified Commands. Immediately after retiring, Gehman served as co-chairman of the Department of Defense review of the terrorist attack on the USS Cole.

C. *COLUMBIA* ACCIDENT INVESTIGATION BOARD REPORT

The *Columbia* Accident Investigation Board ("CAIB") began its independent investigation within hours of the accident, and it worked exhaustively for nearly seven months. Its 13 members and a staff of more than 120 were supported full time by over 400 NASA engineers and scientists. More than two hundred formal interviews were conducted, thirty thousand pages of documentation were evaluated, and formal hearings were conducted in which dozens of expert witnesses were examined. More than three thousand comments were received from the community at large. The investigation's depth and breadth were unprecedented in NASA's history.

On the eve of the issuance of the CAIB's report, in anticipation of these findings, NASA senior leadership convened to contemplate its response to the media. The report had not been pre-released to NASA, so contemplating how to respond was difficult at best. But a response would be required, for a non-response or a delayed response would likely be attributed by the media to NASA's lack of interest, understanding, or concern for the findings.

But, NASA did have an idea about how the report would look and how it would be constructed because the CAIB had issued two interim reports which contained findings and recommendations on particular subject matters and because NASA had been providing a great deal of research and analysis for the CAIB investigators to use in their assessment.

The straw man proposal on how to respond to the CAIB Report was put forth to NASA leadership, namely that NASA would accept the findings of the report and comply with its recommendations. A vigorous discussion ensued. How can we accept what we have not studied thoroughly? How can we comply with the possibility that there may be recommendations that require us to forego contemplated shuttle missions that we believe are important?

For example, some in the NASA leadership were deeply concerned that there might be a recommendation regarding debris shedding that would be so hard to comply with as to be effectively impossible. If the recommendation was impossible to achieve, then the space shuttle might never fly again. Thus, compliance could be disastrous for the future of manned spaceflight. Some even worried that the CAIB could be wrong in reaching its findings or making its recommendations. Agreeing to comply before we saw the report would be reckless. But to take this position rejected the whole notion of the need for an independent investigation, which the Administrator had insisted upon all along. In the end, we agreed to conduct an independent investigation and to abide by its consequences, for to do otherwise would be to ignore clear warning of danger and to unreasonably risk another catastrophic loss. NASA could not equivocate and ignore a clear warning of the independent review panel in the

unforgiving arena of space. The tragedy of losing a crew and a ship in the face of clear warning was unacceptable.

At the time NASA was considering its response to the CAIB Report, it did not focus on the possibility that the effect of the report would be to jeopardize the Hubble SM-4 mission. But if it wanted to be consistent, NASA would have to comply with the report whether it jeopardized the continued flight of the Shuttle at all or the Hubble SM-4 mission itself.

It was agreed then: when the report was released, NASA's response would be to accept the CAIB's findings, comply with its recommendations, and accept the consequences that NASA's old way of doing business and any missions already planned would be affected by its agreement to comply.

On August 26, 2003, the CAIB issued a 227-page report appended with several volumes of studies and analyses. The report contained findings, as well as twenty-nine recommendations. It also included non-binding observations, which it offered for NASA's consideration.

In the end, the CAIB concluded that the cause was both physical *and* organizational.

> The physical cause of the [accident] . . . was a breach in the Thermal Protection System on the leading edge of the left wing [of the Orbiter], 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 ... failure of the wing, and breakup of the Orbiter.[8]

Just as important as the physical cause, the CAIB also determined that organizational failure contributed to the accident:

> . . . 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

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8 *Columbia* Accident Investigation Board ("CAIB"), Report (vol I) at 9 (Aug 2003), available online at <http://www.caib.us/news/report/volume1/default.html> (visited Feb 13, 2005).

> informal chain of command and decision-making processes that operated outside the organization's rules.[9]

The CAIB concluded the report by noting that "[t]hese 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 spaceflight, is a developmental activity with high inherent risks."[10]

Although the Board determined that the present shuttle is "not inherently unsafe",[11] it came to an "inescapable"[12] conclusion:

> Because of the risks inherent in the original design of the Space Shuttle,[13] because that 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.[14]

After the CAIB press conference, as expected, the media clamored for a response from NASA. The Administrator stated firmly that NASA would not shy away from the report even though it was very critical of the organization he led. Indeed, he declared that he and NASA would embrace the report: the good, the bad, and the ugly. It was difficult to accept responsibility for the catastrophe that had occurred only one year after he took the helm and was based on causes that, according to the CAIB, were largely years in the making. But he accepted full responsibility for the loss of the crew and their ship. In addition to taking responsibility, he assured the American people that NASA would accept the CAIB's findings and comply with its recommendations, come what may.

He vowed that NASA would return the shuttle to flight, safely and in compliance with all of the recommendations of the CAIB. There were, however,

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9 Id.

10 Id.

11 Id at 208.

12 Id at 210.

13 The 1990 Augustine Commission, convened to develop a vision for civil space, accurately foretold of the likelihood of a tragedy that was to happen fourteen years later.

> 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 in orbit.

NASA, *Report of the Advisory Committee on the Future of the US Space Program*, Executive Summary (Dec 17, 1990), available online at <http://www.hq.nasa.gov/office/pao/History/augustine/racfup2.htm> (visited Feb 17, 2005).

14 CAIB, Report at 210–11 (cited in note 8).

several engineering challenges to doing so. The shedding of the External Tank insulating foam had to be corrected and the Thermal Protection System had to be strengthened.[15] The External Tank insulating foam had, in the past, regularly shed on takeoff, causing damage to the underside of the Orbiter where delicate heat tiles were located. This damage had previously been treated as a maintenance item. However, because of the possibility for significant debris shedding, as in the case of *Columbia*, and with new knowledge of the relatively small amount of debris that could cause serious damage to the Thermal Protection System, significant debris reduction had to be achieved.

Furthermore, NASA had to develop "in space" inspection and emergency repair procedures to handle "the widest possible range of damage to the Thermal Protection System" for both an International Space Station ("ISS") mission and non-ISS mission (for example, the Hubble Space Telescope servicing mission).[16]

These recommendations in the fall of 2003, treated by NASA as unalterable requirements, proved to be vexing even to the brilliant minds at NASA. While there was an air of optimism and confidence that the requirements could be implemented, the question was how long it would take and how complex a solution would be required. Prior to the CAIB Report, NASA planned to return to flight *before* the first anniversary of the tragedy. But that plan evaporated rapidly once NASA realized how stringent the CAIB recommendations were. Having committed to comply with the recommendations, a return to flight schedule was reworked to project a summer 2004 timeframe. Significant management attention turned to trying to meet the schedule, but technical considerations overrode the desire to return to flight quickly. In fact, the technological challenges by the fall of 2003 forced a delay to a fall 2004 timeframe and even that was quite uncertain. The timeframe was later pushed back to spring of 2005. Finally, in the fall of 2004, NASA became fairly "confident," but still by no means certain, that it could meet the now scheduled launch date of May-June 2005.[17]

Thus, it was in this context that the Administrator and NASA, over the next several months, would reassess the shuttle's return to flight and what missions it would undertake. There were two types of missions planned before

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15 Id at 55, Recommendation 3.2-1.

16 Id at 174, Recommendation 6.4-1.

17 Indeed, on February 18, 2005, more than two years after the Columbia accident, NASA announced a nineteen day launch date window beginning on May 15, 2005. NASA, *Space Shuttle Processing Status Report: S05-007* (Feb 18, 2005), available online at <http://www.nasa.gov/home/hqnews/2005/feb/HQ_s05007_shuttle_status.html> (visited Mar 26, 2005).

the accident: continuing construction of the ISS[18] and the Shuttle servicing mission to the Hubble Space Telescope. After *Columbia*'s crash but before the CAIB Report was issued, NASA had planned on having the shuttle resume carriage of varying modules to the ISS (which was orbiting around the Earth about 240 miles away) to expand the living and working space on board and to replenish water, food, and equipment supplies. NASA had also planned the Hubble Servicing Mission, SM-4.[19]

Before the *Columbia* accident, the Hubble Space Telescope was scheduled to be serviced in 2004–2005, as it was anticipated that the telescope may become inoperable by 2006–2007. By the fall of 2003, a Hubble servicing mission would need to be mounted by mid-2007 to keep the telescope operational.

The CAIB recommendation directly applicable to this mission was 6.4-1, which provided, in part: "For non-Station missions, develop a comprehensive autonomous (independent of [International Space] Station) inspection and repair capability to cover the widest possible range of damage scenarios."[20]

As for inspection techniques, NASA did not view the solution as simply sending an astronaut out to do a space walk and "look around" for obvious holes. Spacewalks carry significant risks. For instance, a spacewalk can cause the astronaut or her equipment to damage the exterior of the ship, particularly where the astronaut is in close contact with the ship's surface while performing an inspection. Furthermore, the astronaut might not detect hairline or microscopic cracks that could destroy the vehicle. To alleviate such risks and to satisfy CAIB's recommendations of February 2004, NASA was developing a boom structure to which a special camera would be attached. This structure would extend from the shuttle while in space and the boom would meticulously and methodically pass the "eye" of the camera over the entire edge of the shuttle's wings and other important parts. The device would perform a minutely detailed examination by looking for obvious holes on one end of the spectrum and tiny cracks, which may portend catastrophic failure, on the other. However, as of the winter of 2003, the ability to complete the development of the boom structure in time for the Hubble Servicing Mission is questionable. Moreover, the boom was designed primarily to review the wing edges. The crew aboard the ISS would use

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18 The construction of the International Space Station was about half complete when the *Columbia* tragedy occurred. The large modules, which comprise the science, living, and working quarters, can only be transported to space aboard the space shuttle.

19 While Hubble Space Telescope also orbits the Earth, it is in a different orbit than the International Space Station and at such a distance from it that the space shuttle cannot get from one to the other.

20 CAIB, Report at 174, Recommendation 6.4-1 (cited in note 8).

telescopic lens of digital cameras to view the tiles on the underside of the shuttle. No such technique had been determined for the Hubble servicing mission.

NASA had also been working on repair materials and techniques to use if impact damage was detected in orbit. This was a particularly difficult challenge. As of the winter of 2003, numerous compounds and materials were being studied for use with the Shuttle, but very little progress was being made on openings of any significant size. Additionally, numerous techniques for applying the compounds or attached materials were being examined. Then, as now, the techniques are only barely capable of dealing with a narrow range of circumstances. Many of the techniques also require the use of the ISS. Many efforts are being undertaken to address this, but the question for the agency was whether these efforts would make a mission to the Hubble Space Telescope adequately safe in absence of the corresponding space station.

And so the challenge to NASA was the following: would NASA be able to fulfill the recommendation of the CAIB and prepare two vehicles (one to fly the servicing mission and one to fly the rescue mission, if it were required) in time to repair the Hubble before it became inoperable? As fall became winter, it became clearer to the Administrator, for reasons discussed later, that it was unlikely the recommendation could be met.

There was yet another matter of concern—that of a safe haven. If a shuttle was damaged during launch or in orbit and became stranded in space, would there be time to launch a rescue mission? In its investigation, the CAIB had called upon NASA to study whether or not a theoretical rescue mission could have been timely mounted had NASA been more diligent and had assessed early the damaged condition of the shuttle. It concluded in Finding 6.4-2 that "[i]f Program managers were able to unequivocally determine before Flight Day Seven that there was potentially catastrophic damage to the left wing, accelerated processing of *Atlantis* might have provided a window in which *Atlantis* could rendezvous with *Columbia* before *Columbia*'s limited consumables ran out."[21]

Even though it found that the window of opportunity for a rescue mission was possible but very limited, the CAIB did not go so far as to require a safe haven—a place where crew members of a crippled shuttle could reside while awaiting a rescue mission by another shuttle. However, NASA recognized that the ISS afforded that opportunity for a safe haven (or could be made to do so) so that a more reasonable opportunity at mounting a rescue mission could be managed. A Hubble servicing mission offered no opportunity for a safe haven, except that to a more limited degree, the shuttle itself offered a narrow margin of safety that would allow a rescue mission, if mounted quickly (as was

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21 Id, Finding 6.4-2.

demonstrated by the study requested by the CAIB in connection with the *Columbia* accident). But the amount of time a crippled shuttle could provide a safe environment for its crew waiting for a rescue mission by another shuttle was likely to be less than the time required to mount a rescue mission.

Thus, in the winter of 2003, these capabilities to satisfy the recommendations, though assiduously studied, simply did not exist. The Administrator, amidst all of the circumstances outlined above, determined that it was not likely that NASA could adequately comply with CAIB's recommendations to have in place inspection and repair capabilities that would be able to address a wide spectrum of possible damage to the shuttle in the available window of repair time for the Hubble Space Telescope.

At that time, the return to flight was proceeding very slowly. There were no proven engineering solutions that would prevent significant foam and debris shedding like the kind that caused *Columbia*'s demise, nor was there any assurance that the recommended comprehensive autonomous inspection and repair capability to repair debris shedding could work.

NASA Administrator O'Keefe also knew that Hubble was nearing the end of its original fifteen year mission[22] and that another new observatory was already in design: the James Webb Space Telescope. It was scheduled to be launched in 2011. While it was not intended to serve as a substitute for the Hubble, it did provide some overlapping coverage as well as observational opportunities the Hubble was incapable of performing. O'Keefe was also advised that the Hubble could probably be made to last longer than its projected usefulness (until 2007–2008) by conserving battery usage through more effective and efficient management of the observatory. This could bridge at least some of the gap while waiting for the James Webb Space Telescope to come on line.

While O'Keefe viewed it as a close call, in December 2003, he decided to cancel the SM-4 manned servicing mission to the Hubble Space Telescope. He believed that NASA could not then prove[23] that it was safe for the astronaut servicing crew to undertake the mission given that the required capabilities would not likely be developed in time to adhere to the CAIB

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22 Although subsequent to the setting of the original fifteen-year term, NASA did extend the term by an additional five years predicated upon SM-4.

23 The kind of proof that the CAIB Board called for was well-reasoned engineering analysis. See CAIB, Report at 172, Finding 6.3-23 (cited in note 8) (observing that NASA's managers focused on the bottom line regarding the debris strike on *Columbia* with "little discussion of analysis, assumptions, issues, or ramifications"). See also id at 172, Finding 6.3-22 ("Program managers required engineers to prove that the debris strike created a safety-of-flight issue: that is, engineers had to produce evidence that the system was unsafe rather than prove that it was safe.").

recommendations.[24] NASA had previously ignored safety recommendations, partially complied with them, or simply forgotten them in order to pursue mission objectives. It would be tempting to pursue the continued operation of the immensely successful Hubble Space Telescope. But, in the Administrator's opinion, principled compliance with the spirit and letter of the CAIB recommendations required cancellation.

He planned to announce his decision upon the issuance of the budget in early February 2004. Having made repeated and firm assurances of acceptance of CAIB's findings and compliance with their recommendations, the Administrator was not about to shrink from those assurances in the face of what was expected to be strong criticism.

At the same time, during the fall and early winter of 2003, the White House had convened a working group to develop the vision for civil space that the CAIB said was lacking and which it deemed to be one of the contributing causes in the demise of the *Columbia.* It was in this working group that the wisdom of continuing to fly the shuttle for any purpose was vigorously debated. In the end, on January 14, 2004, less than a year after the tragedy, the President announced his decision to return the shuttle to flight—but only to finish construction of the ISS (projected completion in about 2010).[25] The ISS would be used solely as a research platform to study the long-term effects of space on humans in order to support the overarching goal of having humans return to the moon, and extend a human presence eventually to Mars and beyond. Contemporaneously, NASA should develop a new spaceship, which would be capable of traveling to the moon, Mars, and beyond to explore the universe and search for life. No reference was made to the Hubble Space Telescope.

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24 On June 1, 2004, Sean O'Keefe spoke to the American Astronomical Society and explained the rationale for his decision to terminate SM-4: "The *Columbia* Accident Investigation Board recommended that we change our culture to a commitment to 'prove that it is safe' rather than place the burden of proof on folks to 'prove that it's not safe.' Well, with that guidance in mind, we're nowhere near close to proving that it's safe. It's not the unknowns we are wrestling with, it's the knowns that we haven't yet devised a way yet to conquer." Sean O'Keefe, Administrator, NASA, Speech to the American Astronomical Society, Annual Meeting (June 1, 2004), available online at <http://www.nasa.gov/audience/formedia/speeches/ok_astronomical_060104.html> (visited Mar 26, 2005).

25 This was a tidy solution to the admonition of the CAIB that NASA address the inescapable conclusion that the Shuttle be replaced and to the recertification requirement imposed by the CAIB to make it likely that NASA would do so. The CAIB declared that because of the shuttle's age, flights taking place after 2010 would be predicated on recertification at the material, component, subsystem, and system levels. CAIB, Report at 209, Recommendation 9.2-1 (cited in note 8). Such a recertification could be quite expensive and may not significantly reduce the risk involved. Retirement would avoid the cost and redirect money to a new vehicle—one theoretically safer than the shuttle.

In the days following the President's announcement, speculation ripened that NASA would not fly to service the Hubble. Although the Administrator had hoped to prepare the NASA science community and the public for the rationale behind his decision in a planned news release, the media pressed him for an answer, and he was forced to prematurely publicly acknowledge his decision.

Once O'Keefe's decision became known, it was highly criticized by the space science community of astronomers and astrophysicists as dead wrong.[26] A public outcry erupted from the science community, with a heavy dose of vitriol included—careers had been made on the strength of the science associated with the Hubble and careers would certainly change, if not end, with its demise. The scientists and politicians whose constituents would be negatively impacted by the Administrator's decision undertook a vigorous campaign to reverse the decision. NASA, in its attempt to protect the lives of astronauts, was accused of "committing a crime against science."[27] In the past, NASA had been justifiably criticized for not taking external advice regarding safety seriously. Now its Administrator was scrupulously complying with safety advice and was being criticized for taking it too seriously.

The National Geographic carried an article titled *Fighting to Save Hubble Telescope From Fiery Death.*[28] The hysteria was so intense that one reporter recently said that at the time of the NASA Administrator's decision to cancel SM-4 in January of 2004, it was as if he "had proposed killing the world's last panda bear."[29] The outcry caught on and politicians[30] and the public alike, all of whom

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26 Ironically, the science community (members of which have often derided the spaceflight community as "Shuttle huggers") were now insisting on the shuttle being used to "save" the robotic Hubble.

27 Erik Baard, *Scientists Clamor to Save Hubble*, WiredNews.com (Jan 31, 2004), available online at <http://www.wired.com/news/technology/0,1282,62103,00.html> (visited Feb 16, 2005) (quoting Robert Zubrin, President, Mars Society).

28 Stefan Lovgren, *Fighting to Save Hubble Telescope From Fiery Death*, National Geographic News (Dec 30, 2003), available online at <http://news.nationalgeographic.com/news/2003/12/1230_031230_hubbletelescope.html> (visited Feb 13, 2005).

29 David Kestenbaum, National Public Radio, *Morning Edition* (Dec 9, 2004), voice recording available online at <http://www.npr.org/templates/story/story.php?storyId=4210313> (visited Mar 26, 2005).

30 Senator Barbara A. Mikulski (D-MD), in whose home state the Hubble Institute is located, sent a letter to NASA Administrator Sean O'Keefe on January 21, 2004, expressing shock and surprise at the decision to cancel SM-4. Letter from Barbara A. Mikulski to Sean O'Keefe, Administrator, NASA (Jan 21, 2004), available online at <http://mikulski.senate.gov/Newsroom/Hubbleonesmall.pdf> (visited Mar 26, 2005). In her letter, Senator Mikulski stated that, while she recognized that astronaut safety was important, the Hubble mission was also very important. She requested a study commission to evaluate O'Keefe's decision. Id. In addition, on March 3, 2004, Congressman Mark Udall (D-CO) introduced H Res 550, 108th Cong, 2d Sess (Mar 3, 2004), in

had become addicted to the remarkable and unique images produced over the telescope's storied history over the preceding thirteen years, clamored to reverse the NASA Administrator's decision.

This was not the first time that NASA encountered profound resentment and derision from the scientific community to a decision to terminate a space telescope for safety reasons. On March 25, 2000, Dr. Ed Weiler, Associate Administrator for the Office of Space Science at NASA's headquarters, made the decision to deorbit the Compton Gamma Ray Observatory, a sister observatory[31] to the Hubble Space Telescope for safety reasons. Then, as now, scientists pronounced that "[t]he scientific case for continuation of the mission is beyond question," as they contemplated that their research work would be interrupted for a few years while waiting for a replacement telescope to come on line.[32] But then, as now, Compton Gamma Ray Observatory served its full planned life expectancy and safety concerns (to provide a controlled deorbit to Earth to avoid having debris fall on inhabited lands) were deemed more important than the continued scientific knowledge to be gained by its continued flight.

In an effort to find an alternative means to repair Hubble, thereby allowing it to continue collection scientific data, NASA evaluated the possibility of servicing the Hubble by employing a "robotic" spacecraft that could be remotely operated from Earth and could perform basic tasks to keep the Hubble operational. NASA announced an effort to assess the prospects, scope, cost, and

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150 Cong Rec E 292 (Mar 3, 2004), urging that an independent panel review O'Keefe's decision not to extend the life of the Hubble Space Telescope. Representatives Todd Akin (R-MO), Roscoe Bartlett (R-MD), Bart Gordon (D-TN), Steny Hoyer (D-MD), Nick Lampson (D-TX), Jim McDermott (D-WA), and C.A. Dutch Ruppersberger (D-MD) joined Representative Udall as the original co-sponsors.

31 Compton Gamma Ray Observatory and Hubble Space Telescope are two of four telescopes (Chandra X-Ray and Spitzer Infrared Telescopes being the other two) which comprise NASA's Great Observatories for Space Astrophysics. These observatories had been planned as a family of four orbiting satellites carrying telescopes designed to study the universe in both visible light and non-visible forms of radiation. See NASA, *The Last of the Great Observatories*, available online at <http://www.nasa.gov/missions/deepspace/MI_CM_Feature_01.html> (visited Mar 27, 2005). The first in the series was the Hubble Space Telescope, launched in 1990. See HubbleSite.org, Frequently Asked Questions, *What is the Hubble Space Telescope?*, available online at <http://hubblesite.org/reference_desk/faq/answer.php.id=76&cat=hst> (visited Mar 27, 2005). Compton was launched aboard the Space Shuttle Atlantis in April 1991, and, at seventeen tons, was the largest astrophysical payload ever flown at that time. See SpaceToday.org, *Compton Gamma Ray Observatory: Gamma Rays in a Violent Universe*, available online at <http://www.spacetoday.org/DeepSpace/Telescopes/GreatObservatories/Compton/Compton.html> (visited Mar 27, 2005).

32 Leonard David, *Scientists Try to Save Gamma Ray Observatory* (May 15, 2000), available online at <http://www.space.com/scienceastronomy/astronomy/save_compton_000515.html> (visited Feb 13, 2005).

timing for such a mission. But the pressure for a manned shuttle servicing mission persisted.

III. THE DEMAND FOR AN INDEPENDENT STUDY

Shortly after the Administrator's decision, Barbara Mikulski, Senator from Maryland, issued a press release on January 29, 2004. Analogizing Hubble to a patient receiving a medical diagnosis, she advised that she had procured an agreement from the NASA Administrator to seek "a second opinion."[33] Apparently, the Administrator had given an initial diagnosis that the "patient" did not want to hear. "We cannot prematurely terminate the last servicing mission without a rigorous review," she said. In response, NASA agreed to requests for an outside study and requested a National Academy of Sciences review of the options to "save" the Hubble and for their considered recommendation to NASA.

IV. THE CHAIRMAN OF THE CAIB WEIGHS IN AND DISTILLS THE CRITICAL ISSUES

The NASA Administrator requested that Admiral Harold W. "Hal" Gehman Jr., the Chairman of the CAIB, provide Senator Mikulski with his views ". . . regarding safety and risk factors identified in the report of the Columbia Accident Investigation Board" from his perspective as Chairman of the Board.[34] Admiral Gehman highlighted the importance of the issue by expressing support for national debate. He stated: "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."[35]

He quoted from the CAIB Report and offered the touchstone for any discussion relative to the shuttle: that flying the shuttle was risky and far from routine.

> 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

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33 Barbara A. Mikulski, Press Release, *O'Keefe Agrees to Mikulski's Request for Independent Review Before Canceling Final Hubble Servicing Mission* (Jan 29, 2004), available online at <http://mikulski.senate.gov/record.cfm?id=217968> (visited Feb 16, 2005).

34 Letter from Harold W. Gehman, Jr. to Barbara A. Mikulski, US Senator, at 1 (Mar 5, 2004), available online at <http://mikulski.senate.gov/Newsroom/GehmanReviewsmall.pdf> (visited Feb 13, 2005).

35 Id.

> 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 U.S. space policy, and the American people to adopt a realistic understanding of the risks and rewards of venturing into space.[36]

The risk of catastrophic loss of the ship due to continued operation of the shuttle in the future was quite significant, according to Admiral Gehman. In this regard, the Board Chairman concluded that the thrust of the CAIB Report "[was] *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 . . . .*"[37]

When it came to the more difficult issue, the Chairman punted on making any conclusions about the propriety of a manned servicing mission to the Hubble Space Telescope, but he opined that the bottom line was that "[s]huttle flights are dangerous and we should fly the minimum number necessary."[38] He then concluded that:

> 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* [i.e. a servicing mission to Hubble]. Consequently we decided to differentiate RTF [return-to-flight] 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 [the CAIB's] view, *missions to the ISS allowed a more complete and robust inspection and repair capability to be developed*".[39]

Admiral Gehman went on to say that Recommendation 4.6-1 governing non-ISS missions and providing for repairs of the widest range possible could

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36 Id at 2 (quoting CAIB, Report at 207 (cited in note 8)).

37 Letter from Harold W. Gehman, Jr. to Barbara A. Mikulski at 2 (emphasis added) (cited in note 34).

38 Id at 3. We have flown 111 out of 113 Space Shuttle missions without catastrophic failure, for a 98.23 percent reliability rate. Thus, 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. In this author's opinion, implementing all the Return to Flight recommendations made by the CAIB raises the reliability number somewhat—to what, exactly, no one is sure. A reliability number more like 99 percent seems reasonable, 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.

39 Id at 4 (emphasis added).

translate into other words, to wit: "Do the best you can."[40] This is a fairly remarkable statement, and one might wonder why the CAIB did not simply use those words in the actual report.

He then made another rather remarkable statement. He confessed to the following: "We knew we were essentially REDUCING the requirements [to maintain the same margin of risk as the ISS]. Reducing the rigor of our requirements INCREASES the risk. It cannot be seen any other way."[41] Admiral Gehman thereby waved the proverbial red flag to Senator Mikulski, and later to the National Academy of Sciences Commission, that the CAIB saw a greater risk of not being able to bring a Shuttle home safely when conducting a non-ISS mission. Gehman did go on to say that the increased risk was "probably not knowable in advance, and knowing the technical capabilities involved, the risk difference is probably small, but it is not zero."[42]

One can only wonder why the CAIB permitted NASA to reduce the requirements to maintain the same margin of risk as the ISS, leading to increased risk and danger to astronauts and to one of three remaining shuttles. This permission implies that the CAIB must have actually considered the possibility of a shuttle flight to the Hubble and realized that it was less safe than a shuttle flight to the ISS, but did not want to foreclose that possibility entirely by placing too rigorous of a requirement on NASA at the outset. Thus, the CAIB would leave room for "deep and rich"[43] discussion for another day. Admiral Gehman stopped short of condemning a shuttle flight to the Hubble Space Telescope and clearly focused the nature of the debate for NASA and for the NASC, stating, "[b]ottom 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. "[44]

In the end, Admiral Gehman suggested that ". . . only a deep and rich study of the entire[45] 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."[46]

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40 Id.

41 Id (emphasis in original).

42 Id.

43 Id at 5.

44 Id.

45 The risk to the ship and the astronauts goes beyond the risk of debris shedding. Shedding was the only factor considered for the non-ISS recommendation by the CAIB.

46 Letter from Harold W. Gehman, Jr. to Barbara A. Mikulski at 5 (cited in note 34).

V. THE NATIONAL ACADEMY OF SCIENCES COMMITTEE REPORT

The National Academy of Sciences created its commission, the NASC, and populated it with many distinguished members from relevant and varied walks of life, each of whom brought significant experience, expertise, and intellectual capacity to bear on the problem (including a former NASA Administrator, two Nobel Laureates, an expert in robotics, a former astronaut, and a former member of the CAIB, to name a few). The Committee retained an outside consultant, Aerospace Corporation, to provide technical advice relative to the risk associated with the attempt to robotically repair the Hubble. The report that NASC issued essentially attempts to demonstrate that there are "enormous benefits to science . . . , including enhanced understanding of the physical universe," and that ". . . the safety risk for a single mission to the ISS is comparable to the safety risk for a mission to the Hubble Space Telescope."[47]

This Paper will not endeavor to refute the first point.[48] Indeed, the NASC makes a very compelling argument of scientific value of the research performed based on 1) pictures taken by the Hubble Space Telescope, 2) the long line of scientists who wait to use it, and 3) the very substantial competition there is to use it. Perhaps the most compelling evidence of its value is that the American people are enamored by it. You don not need an NASC report to demonstrate that. However, it is important to point out that there are two other telescopes in space that are part of the Great Observatory program, each intending to capture different segments of the light spectrum. The most recent of them is the Spitzer Infrared Telescope launched in August of 2003, which is producing incredible images and leading to remarkable discoveries of it own. The other observatory is Chandra, an x-ray telescope. Another significant telescope, the James Webb telescope, is currently under development.

The ultimate finding of the NASC that the risk of danger to astronauts going to the ISS is relatively on par with the risk of astronauts going for a servicing mission to the Hubble Space Telescope seemed, from this author's point of view, to be strained to find ways to undercut the favorable attributes of the ISS, on the one hand, and strained to minimize the unfavorable attributes of the servicing mission to the Hubble Space Telescope, on the other. The heart of the analysis is contained in Chapter 6 of its report, which covers seventeen pages.

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47 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 86, 105 (cited in note 1).

48 However, are the benefits to science worth risking the lives of seven people?

At the outset of its analysis of the Shuttle Servicing Alternative, the NASC identified the "requirements":

> A. CAIB requirement 6.4-1 calling for inspection and repair of the Thermal Protection System;
>
> B. CAIB Requirement 4.2-4 "requir[ing] 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."
>
> C. NASA's Return to Flight Space Shuttle Program Action SSP-3 calling for a safe haven on board the ISS providing contingency life support on board the International Space Station to stranded Shuttle crewmembers until repair or rescue can be affected.[49]

A. INSPECTION AND REPAIRS OF THE THERMAL PROTECTION SYSTEM

NASA advised the NASC that it intended to comply with all of the relevant recommendations of the CAIB. Particularly, with regard to flights to the International Space Station, it advised the NASC that

> [o]n ISS missions, inspections will also be accomplished by the ISS crew during orbiter approach. Following docking, inspections will be by ISS equipment and/or extravehicular activity (EVA). TPS repair techniques are being developed to permit repair to both tile and reinforced carbon-carbon (RCC) components. Initially, TPS repairs are planned while the orbiter is attached to the ISS using the SRMS to position the orbiter relative to the ISS to provide an astronaut repair work station. After the ISS Node 2 is deployed (currently scheduled on the eighth flight following return to flight), the SRMS[50] will no longer be able to reach the ISS grapple fixture and so different procedures will have to be developed.[51]

Thus, in order to achieve the requirements of the CAIB recommendations, NASA intended to use the ISS to perform inspections and repairs. That intention will be achievable for the first eight missions. After the eighth mission, different, but as yet undetermined, procedures were to be developed. NASA believed that the above noted methodology was advantageous because it could be performed adequately and in a reasonable time to allow the mission work to be performed.

NASA indicated that a different procedure could be used on a Hubble servicing mission, but it would take more time, thus impacting the ability to perform the mission. The NASC was dismissive of that concern and suggested

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49 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 75–76 (cited in note 1).

50 SRMS stands for "Shuttle Remote Manipulator System" (in plain English, a robotic arm).

51 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 76–77 (cited in note 1).

that "[t]he committee believe[d] that it [was] possible to develop additional sensors that would reduce the time required to perform an inspection on a shuttle HST mission. The options range[d] from new techniques to scaled versions of the current sensors to fill the SRMS coverage gap."[52] The NASC therefore concluded as a finding that "[a] complete inspection of the orbiter thermal protection system can be accomplished on a shuttle servicing mission to HST using the SRMS and the SRMS/OBSS."[53]

Without contesting that something "can be accomplished," the finding begs the question: in what time and with what resources? It is implicit in the NASC findings that this is a de minimis issue. But is it? Will the development of this CAIB-required capability possibly be done on time to make a servicing mission to the Hubble? Will it be able get this done without adding to the risk of preparing for the mission? It seems that the NASC presumes so, but NASA does not have the luxury of such a presumption. As stated earlier, NASA was heavily criticized by the CAIB for failing to prove that the system was safe. Likewise, per the CAIB recommendations, NASA must *prove* the alternatives offered by the NASC are also safe before it can comfortably argue that the CAIB recommendations can be met. Saying it to be so does not necessarily make it safe.

The NASC describes NASA's plan relative to the repairs of the Thermal Protection System:

> [Thermal Protection System] repairs are planned while the orbiter is attached to the ISS using the SRMS . . . to position the orbiter relative to the ISS to provide an astronaut repair work station. After the ISS Node 2[54] is deployed (currently scheduled on the eighth flight following return to flight), the SRMS will no longer be able to reach the ISS grapple fixture and so different procedures will have to be developed.[55]

Again, the NASC demonstrated a very positive attitude towards the Hubble servicing mission option and offered that NASA position the crew at the work site where NASA is currently developing a technique using the SRMS/OBSS. While NASA can be expected to succeed in developing this new technique (because it usually is), the NASC offers no information to demonstrate the likelihood that NASA would be able to do so, the timing of the completion of its development, its limitations, or what the risk associated with

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52 Id at 78.

53 Id. OBSS stands for "Orbiter Boom Sensor System" (an extension of the robotic arm which contains special sensors to detect cracks or holes).

54 A node for purposes of the International Space Station is a module that serves as an attachment point for other living, equipment, or sciences modules in the x, y, and z axes.

55 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 77 (cited in note 1).

such a technique might be.[56] There is an assumption of success without proof that it will be so and that it will occur in time for servicing the Hubble Space Telescope.

B. NASA'S SAFE HAVEN REQUIREMENT

NASA recognized that if the shuttle travels to the ISS, appropriate preparations must be made to provide for the Station's use as a safe haven in the event of an irreparable problem with the shuttle that would prevent its return to Earth. NASA analysis indicates that the astronauts could be housed in the ISS for thirty to ninety days beyond the shuttle mission timeframe. This is an important contingency plan which shows that NASA is thinking more thoroughly about worst case scenarios. Although NASA has endeavored to reduce the possibility of debris shedding on lift off, there is still the possibility of damage from that or other sources.[57] The safe haven contingency plan also accounts for other circumstances that might occur with the shuttle, such as some form of malfunction of the ship itself.

The NASC concluded that ISS's safe haven would offer operational flexibility and time to adapt to real time problems in case of a critical ascent impact event that is both detected and repairable, or that affords the option of a shuttle rescue mission. Specifically, the NASC cautiously observed that:

> [t]he additional time provided by the ISS safe haven capability, assuming it is available, provides the following attributes:
>
> - Additional time to repair the damaged Shuttle and prepare the Shuttle for re-entry.
> - Additional time to make modifications to the rescue vehicle and its cargo if required and to launch the rescue shuttle.
> - Schedule relief for the shuttle launch team.[58]

However, the NASC pessimistically concluded that NASA's plan for a safe haven has significant risks, which undercut its value because of the possibility of

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56 The presumptiveness is sloppy on the part of the NASC. In an effort to rebut the likelihood that NASA would be able to develop a robotic servicing module, the NASC engaged Aerospace Corp ("Aerospace") to critique the NASA effort. Aerospace concluded that NASA's effort was too risky to be successful. Id at 103–04. One wonders whether Aerospace should have assessed the repair techniques being developed by NASA, as these techniques, much like the robotic servicing of a Hubble Space Telescope, have never been tried before in space. If the repairs were to fail, loss of a spaceship and its crew would be likely.

57 Damage could occur in several ways, including upon liftoff (in spite of efforts to reduce debris shedding), due to micro-meteoroid impact, due to space walk inspections (which may be necessary), or even due to space walks to repair the Thermal Protection Shield.

58 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 79 (cited in note 1).

the failure of life support and the difficulty of putting additional supplies aboard the ISS. First, the NASC argued that the ISS life support system is zero fault tolerant, which means that any failure would render the entire system inoperative. Second, it presumed that necessary supplies could not be adequately pre-positioned aboard the ISS to accommodate ten people: the seven crew members of the shuttle and the three members of the ISS.[59] There is, however, no assessment of whether these are significant issues (there has been a historical pattern of difficulty), or whether they are ones which cannot be mitigated.

The NASC then discussed the possibility of a safe haven aboard the shuttle itself while on a mission to the Hubble Space Telescope. It concluded that a safe haven could be afforded for a period of seventeen to thirty days. In contrast, NASA believes that the safe haven afforded by the ISS is between thirty and ninety days. There is no real assessment of the comparative differential created by these suggested safe haven environments.

The NASC then attempted to demonstrate that a safe haven of seventeen to thirty days was sufficient time for a rescue shuttle to launch. After a brief discussion of the matter, the NASC concluded that "[l]imited time would be available to execute a rescue."[60] To achieve this "limited" time, another shuttle would have to be ready for launch on the second launch pad.[61]

But again, there is a dearth of analysis to determine just how realistic the rapid response rescue for a stranded shuttle servicing the Hubble would be. In fact, there are numerous possibilities for risk of a delay of a rescue launch, which were not discussed in the report or apparently considered by the NASC. And if a launch is delayed for even a short period of time, with the "limited" time available for a rescue, the result may be that the lack of an ISS-type safe haven alternative to the shuttle would result in the demise of the crew.

Indeed, delays of a shuttle launch are, in fact, the rule, not the exception. Delays can be caused by technical issues that may be preventable or correctible. On the other hand, delays can be caused by uncontrollable factors, such as weather. With such a short time to conduct a rescue mission for a Hubble Shuttle mission, it is also surprising that the NASC did not cite a factual premise for its conclusion that a rescue mission could be launched without any significant delay either due to technical issues or weather limitations. Indeed, one launch in 2002 was delayed for nearly two weeks due to various reasons, including bad weather at an abort landing site in Spain, even though the weather at the launch site at the same time was perfect.

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59 Presumably, the NASC anticipates that NASA will return the International Space Station crew to its original complement of three, but at this time the crew consists of two astronauts.

60 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 81 (cited in note 1).

61 Id.

Furthermore, it is disappointing that the NASC did not discuss or consider the possibility that a rescue would be intentionally "rushed"[62] and that certain launch requirements would be abandoned because it might be the only way to save the stranded crew due to the limited time within which the crew could survive on a stranded shuttle servicing the Hubble. The NASC failed to explore the consequences of such an action.

Consider, for example, if we would have known that *Columbia*, while in orbit, was damaged and was in danger of destruction on return to the Earth's atmosphere. Assume we chose to send another shuttle to rescue the crew and risk the same damage to the rescue vehicle as befell the *Columbia* (which is an extraordinarily difficult decision itself).[63] What is the likelihood that the window for launch (which is often only minutes in a given day) would be affected by the weather at the launch site or the abort landing site, thus grounding the mission for several days? If safe haven is limited to days, even a technically able shuttle may not get up in time. What if the weather concerns are exacerbated by technical problems? Is the limited survival time aboard a shuttle on a Hubble SM-4 mission simply too brief when facing circumstances that constantly plague shuttle launches?

Moreover, because of the short time for rescue in the scenario where there is no ISS safe haven, there is the nagging possibility that such a rescue mission might be launched before the cause of the stranded shuttle's damage can be understood. Further, there is also the possibility that in order to mount a quick rescue mission, the decisionmaker would choose not to mitigate against a repeat failure in the rescue mission. On the other hand, the decisionmaker may wish to mitigate against a repeat failure and take longer than necessary to rescue the stranded shuttle crew. This was simply not addressed by the NASC.

In fact, the threat of a repeat failure is not the handwringing of a risk-averse mentality. It is a very real possibility. Consider that on October 2, 2002, two flights prior to *Columbia*, on *Atlantis* flying as STS 112, a piece of foam detached on launch from the left bipod ramp on the external tank and struck the solid rocket aft skirt—fortunately resulting in no life or mission threatening events. Later, on January 16, 2003, the foam detached on launch from the very same place on the external tank, but this time struck the leading edge of the left wing of *Columbia*, causing the catastrophe on re-entry. If a failure stranded a

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62 If you were the Administrator of NASA and were faced with the prospect of either abandoning certain launch requirements in order to have a chance to launch immediately to rescue the stranded crew or alternatively to delay the launch until the requirements were met, thereby running a substantial risk that the astronauts were likely to perish, what would you do?

63 Does the decisionmaker know the reason for the damage? Does the decisionmaker know that it won't occur again? Can the decisionmaker mitigate the risk of damage to the rescue vehicle?

shuttle in space, an Administrator (or other decisionmaker) would be in an excruciatingly difficult situation if forced to quickly decide whether to order a rescue flight without knowing the cause for the failure in the first place because, as in the case of STS 112 and STS 107, a repeat event can occur in short order with catastrophic consequences.

There is a dramatic difference between a safe haven for a minimum of seventeen days (shuttle safe haven near Hubble) versus a minimum of thirty days (shuttle safe haven aboard ISS), and the contrasting benefits thereof should have been analyzed and the consequences studied. Further, even though there is a risk of loss of life support aboard the ISS, if a safe haven beyond the shuttle's capability is required, one would be more likely to want to be at the ISS where a life support system exists but may break down (as the NASC was concerned about) than at the Hubble where there is no life support system at all. In the end, even the NASC recognized the fact that having a safe haven external to the shuttle (were it to go to the Hubble) is a good thing.[64]

C. A FLAWED CONCLUSION?

The NASC then undertook an assessment of the relative risks of a flight to the ISS versus a flight to the Hubble Space Telescope. The NASC observed that much of the risk of the shuttle flight is due to debris shedding on launch. Because NASA has done so much good work to reduce the amount of debris, the NASC acknowledged "that post-RTF missions to the ISS will have some[65] safety advantage over an HST mission such as total time required to perform ascent damage detection and the availability of crew safe haven and rescue . . . ."[66]

But the NASC went on to negate the additional risks encountered by a Hubblemission by asserting that ascent damage will be unlikely. It concluded that "this post-RTF advantage will be small—because the need for such repairs

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64 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 80 (cited in note 1). However, there was some recognition that having a safe haven alternative to the shuttle might have been a good idea. In a footnote, the NASC offered that

> "[i]n addition to the safe haven consideration discussed in this section, it came to the committee's attention that commercial companies have suggested options to launch a 'safe haven' vehicle into the HST orbit in order to provide a longer-term capability. The committee understands that NASA has been provided these proposals, which will naturally require a balancing of crew safety, risk reduction, cost and schedule, and so on, if any are pursued."

Id at 80, n 7. Interestingly, the NASC did not undertake to assess the validity of these so-called "options." Id.

65 Apparently, no attempt was made to quantify this risk.

66 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 85–86 (cited in note 1).

and crew rescue will have been sharply reduced by elimination of critical ascent debris."[67] While there have been significant efforts and testing undertaken to reduce the potential for ascent debris, and while these efforts have inspired a corresponding confidence that ascent debris will acually be reduced, it is positively remarkable that the NASC would accept that assertion as fact when there have not yet been any flights to demonstrate whether the ascent debris problem has been fixed.

D. SCHEDULE PRESSURE

The NASC does not even address another important set of CAIB findings[68] and recommendations[69] particularly relevant to the NASC inquiry. These had to do with perceived schedule pressure by NASA's management to achieve a certain stage of completion (Node 2) of the ISS within a given period of time.[70] The CAIB determined that because of the perceived pressure to fly, NASA personnel were less likely to be vigilant in the rigor of their analysis of whether or not to fly and their efforts to be safety-conscious.[71] In Finding 6.2-6, CAIB found that "[t]he environment to the countdown of Node 2 and the importance of maintaining schedule may have begun to influence managers' decisions, including those made about the STS 112[72] foam strike."[73]

A very similar type of schedule pressure would be present in any effort to repair the Hubble. Consider that there is an abiding concern by the NASC that Hubble's batteries or gyroscopes may give out at any time leading to loss of the telescope. While this may or may not happen in the near future, it is predicted to occur in 2007. This is a genuine concern on the part of the NASC. In fact, this is such a real concern for the NASC that it recommended that NASA service

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67 Id at 86. But such a limitation for assessing the risk of the Hubble mission is exactly what Admiral Gehman warned against when he wrote to Senator Mikulski at the outset of the controversy over whether to cancel the Hubble Telescope servicing mission. In that letter, he pointed out that "[i]t 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." Letter from Harold W. Gehman, Jr. to Barbara A. Mikulski at 4 (cited in note 34).

68 CAIB, Report at 139, Findings 6.2-1 through 6.2-7 (cited in note 8).

69 Id, Recommendation 6.2-1.

70 Id.

71 Id, Findings 6.2-1 through 6.2-6.

72 This foam strike occurred on *Atlantis* on October 2, 2002.

73 CAIB, Report at 139, Finding 6.2-6 (cited in note 8).

Hubble "as soon as possible" and as early as the seventh flight after returning to flight.[74]

The NASC is projecting that the shuttle servicing mission needs to fly between July 2006 and July 2007.[75] Thus, it will have to take place in the next two years. Considering the delays in the attempts to return to flight already experienced and the ordinary delays that have been experienced in the years before *Columbia*, one wonders whether it is realistic to expect that the return to flight effort will be able to provide the necessary servicing before the Hubble becomes inoperable. This fear of scheduling pressure-increasing risk is precisely one of the most significant factors that moved the Administrator to terminate SM-4. Yet, there does not appear to be any assessment by the NASC of the risk that the schedule may be compressed because of the fairly strict deadline on servicing the Hubble.

The CAIB determined that there was a palpable perception that the *Columbia* Shuttle mission was under pressure to meet the ISS construction (Node 2) deadline—with known but unappreciated flaws in shuttle operations and safety. It reprimanded NASA for creating this perception. Now the NASC would knowingly recreate just such a schedule pressure—this time to meet an uncertain Hubble operational status—with a shuttle system which should not be considered routine and which will knowingly impose greater risk on the shuttle and its crew. It is difficult to imagine that the NASC ignored the CAIB's report, but it is also hard to conclude that the NASC forgot the guidance and recommendations of the CAIB because the passage of time between its report and that of the CAIB was only sixteen months. One is only left to wonder why this schedule pressure issue was not addressed in the report. Perhaps the NASC itself felt schedule pressure to deliver a report and glossed over truly understanding and assessing the risks involved. Perhaps addressing the schedule pressure issue would have led to a less dismissive conclusion about the risk of flying a manned servicing mission or of a rescue mission.

VI. CONCLUSION

The Hubble Space Telescope is an important scientific instrument that, if timely and adequately serviced, will continue to contribute to the knowledge and benefit of mankind for some time to come. However, we must be cautious not to become caught up with the wonder and success of the instrument and lose

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74 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 83 (cited in note 1) ("To avoid putting the Hubble at risk and to maintain continuous science operation, the HST servicing mission could be flown as early as the seventh flight after return to flight without a critical operational impact on the ISS.").

75 Id at 55.

sight of our capabilities. The lessons of *Columbia* have reminded us that the pursuit of exploration and scientific discovery in the vastness of space can be unforgiving, with catastrophic consequences to the crew and vehicle involved, as well as to a civil space program. We must maintain vigilance and avoid doggedly pursuing a scientific or engineering objective while losing sight of safety concerns for humans aboard a space ship still deemed to be in a developmental stage.

Having served as the Chief Legal Officer for NASA and having evaluated whether to fly the Hubble servicing mission, I believe that the leadership of NASA took the findings, recommendations, and report of the CAIB seriously and endeavored to thoughtfully and completely consider all of the risks involved. I believe that they arrived at a principled decision, and one that was mindful of, but not overwhelmed by, the importance of the Hubble Space Telescope and its science mission.

Certainly, reasonable people could disagree with NASA's conclusion. However, reasonable people would want to evaluate *all* of the risks and benefits from such a mission. In fully evaluating risks and benefits, there may still be some who would choose to pursue this mission. However, what is clear from the NASC report is that many risks considered by the CAIB and by NASA in its decision to cancel the SM-4 Mission were either not addressed fully or not addressed at all. Perhaps if the CAIB were called to address those matters, many of which are referenced in this paper, it would have made a better assessment of the relative risks of flying the mission and a reasonable person would be better informed in making a decision.

Because the risks of a manned servicing mission to the Hubble Space Telescope are not adequately addressed in the NASC report, it would be difficult to responsibly rely on the report's conclusion that "... the safety risk for a single mission to the International Space Station is comparable to the safety risk for a mission to the Hubble Space Telescope."[76]

VII. EPILOGUE

On February 8, 2005, the outgoing Administrator of NASA announced the Bush Administration's plans regarding the Hubble Space Telescope in the aftermath of the National Academies of Science report. In addition to staying the course and declining to conduct a manned servicing mission, Administrator O'Keefe announced, only days before his departure from NASA, that the NASA effort to conduct a robotic servicing mission would be cancelled, citing the National Academies of Science report as the principal reason:

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76 NASC, *Assessment of Options for Extending the Life of the Hubble Space Telescope* at 105 (cited in note 1).

> The academies "view it as highly unlikely given the expense of the task and the effort necessary as well as their view [that] even if we could do it, we probably could not [do it] in . . . time," O'Keefe told reporters. He said the position has left "an incredibly difficult hill to climb to demonstrate the contrary."[77]

As the calls for a manned servicing mission have recommenced[78] (and even calls for continuation of the robotic servicing mission[79]), members of the scientific community have begun to question whether the Hubble should even be repaired. At a recent hearing before the House Science Committee chaired by Congressman Sherwood Boehlert of New York, "an international team led by Johns Hopkins University astronomers . . . [offered that] the best answer may lie not in a robot-led or manned repair mission, but through the launch of a brand new, free-flying telescope called the 'Hubble Origins Probe.'"[80]

Should NASA decide that the analysis of costs and benefits of servicing an aging telescope is more favorable than the same analysis for placing a new telescope in the night sky and proceed to revisit the matter, a different Administrator will make the call, one who perhaps will not have personally experienced the tragedy accompanying the risks of flying the shuttle. For the sake of America's civil space program one would hope that the next Administrator and his or her leadership team come to deeply understand the lessons of *Columbia* and its implications for all other future shuttle missions, including a Hubble SM-4 mission, should it be reconsidered.

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77 Gugliotta, *Hubble Decision a Blow to Goddard Engineers*, Wash Post at A03 (cited in note 2).

78 Senator Barbara A. Mikulski, Press Release, *Senator Mikulski Vows to Fight for Hubble* (Feb 7, 2005), available online at <http://mikulski.senate.gov/record.cfm?id=231696> (visited Feb 16, 2005).

79 In an interview with the Washington Post, Joseph Rothenberg, a former NASA associate administrator for spaceflight, said, "although the academies' study did not think this could be done quickly enough, the [NASA] engineers 'need an opportunity' to prove the contrary." This is merely interesting until you realize that Mr. Rothenberg was a member of the NASC and endorsed the report's conclusion that such a mission was too risky to mount. Gugliotta, *Hubble Decision a Blow to Goddard Engineers*, Wash Post at A03 (cited in note 2).

80 The Johns Hopkins University, Press Release, *Astronomers Urge Congress to Continue Hubble Science: Johns Hopkins-Led Team Presents New Option* (Feb 2, 2005), available online at <http://www.jhu.edu/news/home05/feb05/hop.html> (visited Feb 16, 2005).

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