Cancellation of the Fifth (SM-4) Hubble Servicing Mission

Executive Summary

The Hubble Space Telescope (HST) was originally launched aboard the Space Shuttle in 1990, with an as designed mission lifetime of 15 years. Since then the telescope has been serviced or upgraded four times, each requiring a very complex, dedicated Space Shuttle mission and unique HST servicing support equipment. Even before its repair mission in 1993, the HST had generated significant scientific discoveries. The science return from HST has already vastly exceeded the original expectations.

NASA plans continued operation of the HST until it can no longer support scientific investigations anticipated to occur in the 2007-2008 time frame. The telescope's life may, in fact, be extended if NASA is successful in employing operational techniques to preserve battery and gyroscope functions. Meanwhile, NASA is aggressively investigating innovative ways to extend the science lifetime of the HST for as long as possible, including robotic servicing to provide extension of power storage. Current plans are to safely deorbit the HST by a robotic spacecraft by approximately 2013.

Although the HST deployment mission and four subsequent servicing missions were successfully conducted, the Columbia tragedy underscored the inherent risk in each and every Space Shuttle mission and reinforced the need for increased ability to deal with all potential contingencies, particularly catastrophic damage to the Orbiter's thermal protection system (TPS).

Without the benefit of docking at the ISS many new tools, processes, and techniques would be required for inspection and possible repair of the TPS. More significant would be the requirement to dedicate two Space Shuttles to the mission to ensure astronaut safety. In the event of a significant problem with no safe haven for the astronauts to wait as in ISS missions, a second Shuttle would have to be launched and employ untried and uncertified techniques to perform a rescue. Hence, a Shuttle based HST servicing mission presents known additional risks, and offers few options to respond to serious problems in orbit.

Recognizing the increased risks involved in all Shuttle flights following the tragic loss of the Columbia and crew NASA elected to reduce its planned Shuttle manifest to only missions to the International Space Station (ISS). The decision was also made, on the basis of risk, to not pursue a final servicing mission to the HST, but instead to investigate other options to extend the life of the Hubble.

Columbia Accident Investigation Board Findings and Impact on Future Missions

The Columbia Accident Investigation Board presented NASA with 29 recommendations, 15 of which were required to be completed before the Space Shuttle could return to flight. Highlights of these flight-critical recommendations included elimination of damaging insulation shedding from the external tank -- the cause of the Columbia tragedy -- ascent imaging, on-orbit inspection, and thermal protection system tile and Orbiter leading edge repair. NASA will satisfy all of these recommendations before it launches STS-114, the next Shuttle mission. The Board stressed that the Space

Shuttle is still a developmental vehicle and that risk and risk mitigation must be treated accordingly. NASA's original vision was to fly the Shuttle to mid-decade or 2020 for a total of 75-80 more flights. NASA fully accepts the Board's recommendation and balancing mission criticality against possible loss of crew and vehicle, consciously decided to retire the Space Shuttle after the completion of the International Space Station (ISS), recognizing that the best risk mitigation strategy is to fly less.

In addition, NASA realizes that a "safe haven" in space capability is required. This "safe haven" capability goes beyond compliance with the Columbia Accident Investigation Board recommendations and is designed to increase crew safety during the remaining Space Shuttle missions. Should damage occur to the Shuttle thermal protection system that can not be repaired and that would preclude safe reentry, the crew will be able to shelter at the ISS until another vehicle can be readied for rescue. Agency policy will require each Space Shuttle mission to have backup rescue capability. "Safe haven" is the ultimate recognition that, while NASA will make the Space Shuttle as safe as possible, the Columbia tragedy has taught us that there are still significant risks inherent in Space Shuttle launch, orbit operation, and reentry.

Unique Requirements and Increased Risk in the Hubble Servicing Mission

Whereas tools, techniques, and procedures would be similar on each ISS mission; e.g., inspection, thermal protection system repair, safe haven readiness, and rescue scenario, an HST servicing mission would have unique requirements, both on-orbit and in ground processing. Options for dealing with an on-orbit emergency are reduced and decisions for reacting to any emergency would have to be made quickly. These two considerations, and the attendant schedule pressure on the flight crews and support teams, add considerable additional risk.

<u>Lack of Significant Safe Haven</u>

The areas of additional risk relate to the ability to provide "safe haven" while inspection, repair and potential rescue are undertaken, and to the procedures for inspection and repair themselves. It has been projected that a typical Space Shuttle flight crew of seven astronauts could stay aboard the ISS for up to ninety days, if warranted, due to an emergency situation on the Space Shuttle. This safe haven capability allows the flight crew and ground teams to consider all options, determine the best course of action, take the time required to understand the cause of the failure and affect repairs, or send the appropriate rescue vehicle with the right equipment to bring the crew home. Clearly, rushing this process would introduce considerable new risk and in the worse case result in the loss of another vehicle.

In the case of a Hubble servicing mission, the amount of stay time on orbit is significantly shorter due the limited stores of cryogenic oxygen on the Orbiter. Therefore, other measures would be required. Specifically, a second Space Shuttle on an adjacent launch pad would have to be specially prepared, uniquely configured to launch expeditiously if required to perform a rescue mission. This scenario raises several concerns, addressed in the paragraphs below.

Unprecedented Double Workload for Ground Launch and Processing Teams

Two vehicles would be processed for essentially the same launch date. Any processing delays to one vehicle would require a delay in the second vehicle. The launch countdown for the second launch would begin before the actual launch of the first vehicle. This short time period for assessment is a serious concern -- it would require a highly complex process to be carried out in parallel, and it would not permit thorough assessment by the launch team, the flight control team, and the flight crew.

No Changes to Cargo or Vehicle Feasible

Because of the very short timeframe between the launch of the first vehicle and the requirement for a rescue flight, no significant changes could reasonably be made to the second vehicle or the cargo. This means that it would not be feasible to change the cargo on the second Space Shuttle, to affect a repair to the first Shuttle, add additional rescue hardware, or make vehicle modifications to avoid whatever situation caused the need for a rescue attempt in the first place. Not having sufficient time to make the appropriate changes to the rescue vehicle or the cargo could add significant risk to the rescue flight crew, or to crew transfer. The whole process would be under acute schedule pressure and undoubtedly many safety and operations waivers would be required.

Rescue Mission

Space Shuttles routinely dock with the ISS; Soyuz evacuation procedures are well trained. These represent the normal operations mode today supported by extensive training, analysis and documentation. A rescue from the ISS, with multiple hatches, airlocks, and at least one other vehicle available (Soyuz), is much less complex and risky than that required by a stranded Space Shuttle being rescued by a second Space Shuttle.

In response to a question by the Columbia Accident Investigation Board, NASA analyzed a hypothetical rescue mission between two Space Shuttles and found that the effort would have required many unproven techniques, such as emergency free-space crew transfer in space suits while performing Space Shuttle to Space Shuttle station-keeping while traveling 17,500 mile per hour above the earth. These major safety risks are not incurred during rescue from the ISS.

Tile Survey (expanded inspection requirements) and Thermal Protection System Repair

The current inspection method for acreage tile, gear door seals, and the elevon cove is to photograph these areas from the ISS during rendezvous. To support an HST servicing mission, NASA would have to develop a new method for inspecting these critical areas using an Orbiter boom. Unvalidated autonomous boom operations represent an unknown risk. NASA's current planned TPS repair method for an ISS-based repair uses the ISS robotic arm to stabilize an EVA crew person over the worksite. These assets are not available for an HST servicing mission, so NASA would have to develop a single-use alternate method for stabilizing the crewmember. This method would have to provide greater stability than the current ISS option under development to protect both the crewmember and the other TPS areas from additional damage. Such a concept represents a challenging undertaking, which could take months or years to develop in order to meet safety and mission assurance standards/requirements.

Return to Flight and ISS U.S. Core Complete Timeline

In the process of addressing the Columbia Accident Investigation Board recommendations and implementing additional improvements to achieve the safest flight possible, NASA has uncovered a number of problems that had previously gone undetected. The removal and replacement of unsafe hardware has deferred Space Shuttle launch milestones. NASA projects the first opportunity for a Space Shuttle launch to the ISS to be in March 2005. Eight flights are scheduled to meet our international commitments, the assembly of the U.S. core segments of the ISS. Given the ISS assembly schedule, the earliest NASA could launch a servicing mission to the HST, based on requirements for daylight launch to fully assess ascent conditions by imagery and thermal constraints when docked to ISS, would be Spring 2007.

Based on the evaluation of the engineering data on the HST, the lifetime of the Observatory on orbit is ultimately limited by battery life, which may extend in to the 2007-2008 timeframe. Scientific operations are limited by gyroscope lifetime that is more difficult to predict. If all of the NASA effort is concentrated on a Shuttle servicing mission, every step in the process must be successful with no allowance for schedule slips. Before launch all of the recommendations of the Columbia Accident Investigation Board must be met. The launch conditions must be perfect, and all tailored HST mission unique components must be in place with very tight schedule constraints. If any of the many elements do not develop as planned, the telescope may cease operations before a successful mission could be mounted.

Hubble Space Telescope's Scientific Legacy

Not since Galileo turned his telescope towards the heavens in 1610 has any event so changed our understanding of the universe as the deployment of the Hubble Space Telescope. From its orbit above Earth's atmosphere, the HST is free from the atmospheric turbulence that all ground-based telescopes must contend. Thus, HST has been able to return images of astounding clarity and sensitivity. HST imaging and spectroscopy have resulted in remarkable scientific achievement, including the determination of the changing rate of expansion of the universe and detailed studies of forming galaxies, black holes, galaxy hosts of gamma-ray bursts and quasars, active galactic nuclei, protostars, planetary atmospheres, and the interstellar and intergalactic medium. Scientific results have significantly surpassed original expectations. By 2005, the HST will have fulfilled every one of its scientific objectives and top-level technical requirements. Moreover, the Hubble will continue to collect observations for several more years. Even after the HST is no longer in service, the rich archive of HST data (already more than 100,000 observations of 20,000 unique targets) will continue to provide new discoveries for the years to come, with full support by NASA for both archive operations and research grants.

Future Plans for Hubble Space Telescope and Astronomy

Astronomy is a critical part of the NASA's exploration initiative. NASA is aggressively investigating innovative ways to extend the science lifetime of the HST for as long as possible, including a possible robotic servicing option. We are receiving several responses to our recently released Request For Information (RFI) on HST End of Mission Alternatives soliciting concepts for robotically-provided battery power extension. Indeed, this option appears to have greater likelihood of success than the possibility of accomplishing all the recommendations of the Board in time for a successful Hubble servicing mission.

HST is not NASA's only portal to the stars. It is one of many telescopes used by astronomers to study the universe using various apertures and wavelength bands. Hubble, primarily used for observations of visible light, is one of the four orbital "Great Observatories" designed for use across the spectrum. The other three include the Compton Gamma-Ray Observatory (1991-2000), the Chandra X-Ray Observatory, and the infrared Spitzer Space Telescope. In the years since Hubble was launched with its 2.4-meter aperture, many new ground-based telescopes have been built with larger apertures that enable observations with increasingly higher angular resolution, though subject to the blurring effects of Earth's atmosphere.

The James Webb Space Telescope (JWST) program has been strengthened to assure a 2011 launch date. Once on orbit, this advanced technology infrared telescope will provide insight into the a region of the spectrum where we will be able, like never before, to view the formation of the earliest galaxies. The JWST will build on the successful science of the Hubble via the most advanced instrumentation and a larger 6.5 meter aperture.

The following table lists larger optical telescopes now or soon to be available along with Hubble and also several examples of large telescopes available or in development for observations at other wavelengths.

Examples of Large Telescope Facilities Available or In Development

Radio/MM	Infrared	Optical +IR (aperture, meters)	Ultraviolet	X-Ray	Gamma Ray
VLA	Spitzer	SALT (11.0)	HST	Chandra	GLAST
GBT	SOFIA	Keck I, II (10.0)	GALEX	XTE	SWIFT
ALMA	JWST	Hobby-Eberly (9.2)		XMM-Newton	
Arecibo	HST	LBT (8.4 x 2)		Astro-E2	
FCRAO		Subaru (8.3)		SWIFT	
VLBA		VLT (8.2 x 3)			
CSO		Gemini (N & S) (8.1)			
		HST (2.4)			

The HST program has provided a significant amount of funding support for U.S. astronomers; in fact, it is currently providing approximately 20% of all direct grant support. After HST observations have ceased, NASA plans to continue to support ongoing grants and to offer new grant support for HST archival research until a similar grant program is in place for the upcoming James Webb Space Telescope program.

This will ensure stability to the research community and full use of the rich HST data archive throughout this period of transition.

Conclusion

The cancellation of HST-SM4 was a difficult decision. HST is producing world-class science. However, NASA cannot justify the additional risk that such a unique mission would entail, based on what must be done to assure greatest protection to the crew. It is increasingly apparent that our choice is to either fully comply with the Columbia Accident Investigation Board report <u>or</u> conduct the servicing mission, but not both. We must be responsible on all future flights and be fully compliant. NASA will continue to aggressively pursue options to extend the science lifetime of the Hubble by means other than Shuttle servicing. NASA will continue to be a major supporter of astronomy in the future as the Agency continues to explore the universe.