The Quest for the Cosmos:
The Perilous Life of the Hubble Space Telescope

By: W. Henry Lambright
Professor of Public Administration and Political Science
The Maxwell School of Citizenship and Public Affairs
Syracuse University

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1. Background

Minnowbrook has featured ancient quests – those of Odysseus, Perceval, and many others. Other quests come to mind – such as those of Columbus and others in the 15th and 16th centuries to explore a new world. The heroes in these quests needed equipment ranging from ships to horses. Today, our quests of exploration are mainly in space, and the equipment consists of complex, expensive, often huge machines. The machines are rockets, spaceships, and also telescopes.[1] As before, human beings are deeply involved. As in the ancient stories and myths, there are large stakes, riveting adventures, and life and death issues. Similarly, the people involved face obstacles, take risks, sometimes audacious, because they believe them justified by some larger values. What is the nature of the modern quest? What is the contemporary search for a Holy Grail? One answer to these questions lies with the journey we take with revolutionary versions of an old technology – telescopes.

2. Awareness of Need

At least since Galileo in the 1600s, humanity has been aware how telescopes could extend the vision of the human eye. Over the years, telescopes have gotten bigger and more sophisticated. However, as good as they have become, they have been limited to some degree by the distorting effects of Earth's atmosphere. Scientists speculated for many years about what it

would be like to view the cosmos from above the atmosphere. In 1957, *Sputnik* ushered in the space age and it was only a matter of time before an attempt was made to do just that.

3. Search/Planning

In the 1960s, when America went to the Moon, NASA launched also a major scientific program using unmanned satellites and probes to near planets. A number of these carried astronomical equipment. However, they were short-lived.

In the early 1970s, with Apollo winding down, the last Moon-visit being in 1972, NASA desperately needed new, long-lasting missions. Circumstances were such as to draw NASA's only significant approved program in manned space, the Space Shuttle, into alliance with one of the most important scientific programs on its drawing board, what was then called the Large Space Telescope (LST).

The Shuttle was authorized by President Richard Nixon in 1972. It was originally seen as a vehicle to go back and forth to build a Space Station, a giant laboratory in space. But Nixon did not approve a Space Station. So what was the Shuttle to do? It could put big satellites into orbit and occasionally service them. And one of those satellites could be a giant telescope, the dream of astronomers. Thus, a fateful marriage took place between the Space Shuttle and the Large Space Telescope.

4. Adoption

It took a while for advocates of the telescope to obtain a decision to start the program, given the competition for funding at NASA. In 1977, the telescope was authorized by the president and Congress, and development got underway. At the beginning, NASA saw the

project as costing hundreds of millions. It eventually cost $2 billion. It was projected at the outset that a telescope could be put into space in the early 1980s. It wound up taking until 1990. Also, because of budgetary constraints, Congress, in agreeing to the program, demanded that NASA seek help in financing the project from other nations. Europe, through a consortium called the European Space Agency (ESA), was enlisted and agreed to fund about 15% of the projected expense.

5. Development

5.1. Implementation and Evaluation

As the project got underway in the late 1970s and continued into the 1980s, it became clear that both projected costs and schedules were optimistic. In 1983, NASA Administrator James Beggs overhauled the program's management and NASA evolved a more realistic budget and timetable. It was still scheduled to go up in the latter 1980s.

5.2. Disaster and Delay

However, in January 1986, Space Shuttle Challenger exploded as it launched into space, killing all seven astronauts aboard including the first teacher in space. All NASA and the workforce applied to the Hubble Space Telescope, as it was now called, could do, was wait. Hubble depended on the Shuttle for launch.

6. Deployment

Finally, on April 24, 1990, Space Shuttle Discovery roared from the launch pad in Florida with the Hubble Space Telescope aboard, a planned 15-year mission ahead. This was an

important moment for NASA, still recovering from Challenger. NASA needed a success, and it had extravagantly advertised – indeed hyped –Hubble. The expectations were extremely high for pictures that would revolutionize astronomy and restore NASA's reputation for technical excellence.

6.1. Spherical Aberration

The pictures came back, but something was wrong. The images of the stars were blurred, and it was these images – the truly distant ones – that constituted Hubble's main advantage over conventional ground telescopes. It took until June for NASA to diagnose the problem – "spherical aberration." The primary mirror had been ground and polished by computer-controlled equipment *perfectly* – but to the wrong specifications. Somehow human error had crept into the design-development-manufacturing process a decade before and no one had spotted the mistake. Perhaps this failure in detection was because potentially critical tests had been omitted or curtailed for reasons of time and budget. Whatever the reason, the result was a flawed telescope and a shaken NASA.

The mistake was 1/40 the thickness of a human hair – microscopic, in human terms, but huge for a telescope with Hubble's assignment. NASA became the butt of late-night comedians and editorial cartoonists. Senator Barbara Mikulski of Maryland, a space enthusiast and key democrat on the Senate subcommittee funding NASA, was frustrated and angry. She called Hubble a "technoturkey" and accused NASA of giving it a "cataract."

Fortunately, the problem was correctable – not be removing the cataract, but by giving Hubble the equivalent of a "contact lens." Hubble had been built so it could be serviced

periodically by the Shuttle to keep it maintained and operating over its lifetime. No one had anticipated Hubble would need a service call for blurred vision.

But Hubble would have to wait in line. A number of other missions using the Shuttle were ahead of it. It was not until December 1992 that a repair mission could be scheduled. In the meantime, a crew of astronauts was picked for the job – astronauts with maximum experience in what was called EVA, extra-vehicular activity. The leader of the team was the man considered the very best in this art, Story Musgrave. The repair mission was unprecedented in its demands on astronauts. The training therefore was unusually long and rigorous. At one point, Musgrave, in his space suit, when through a routine in a chamber whose temperature was brought down to a level he would encounter in space, far below zero. He spent hours in extreme conditions, learning to manipulate tools, and apply them to repair work in space. The result was that Musgrave suffered frost-bitten hands.

Not only Musgrave, but NASA learned from the experience. The gloves the astronauts used had to be insulated better while still being useable for work in space. The repair time would have to be scheduled so that it would take place in part when astronauts would have the benefit of solar heat.

NASA knew how important this mission was and appointed one man as “mission director.” This was a high-level managerial position rarely used. It ensured that this single mission had top priority for resources. If the director needed help to circumvent bureaucratic roadblocks, he could go right to the NASA administrator. The NASA administrator had his own set of advisers helping him monitor progress. What made Hubble repair so critical for NASA was that its flagship project for the future, the International Space Station (ISS), which had been

authorized in 1984 but not yet built in space, required even more demanding EVAs than Hubble to be assembled. If NASA could not repair Hubble, critics asked, how could it build a Space Station? Since NASA's future depended on Space Station, and station funding to a considerable degree on Hubble repair, Hubble's stakes were immense. NASA's administrator told the mission director: "…don't screw this up, the future of NASA lies in the balance."

7. Repair

On December 2, 1993, Space Shuttle Discovery took off. Five astronauts were aboard. Musgrave, who had recovered from the frost bite, was in command. Two days later, the shuttle positioned next to Hubble, and the astronauts began their work. Day after day, for long hours, they labored, not only to correct the vision of the main camera, but also to fix or upgrade other systems needing attention. They had to exercise extreme caution moving components of considerable size – some the equivalent of a piano in scale. One mistake and they could leave the delicate apparatus of Hubble in worse shape than it was when they arrived. They rested in accord with a rigorous schedule. All seemed to go well. Much of their repair work was watched by cameras on the Shuttle and transmitted back to Earth to scientists, government officials and the public alike.

8. A New Life

On December 13, the crew returned safely to Earth. Now the wait began to see if Hubble worked as hoped. On January 13, 1994, NASA held a press conference in Washington, with many government officials present, to convey the results. "It's fixed beyond our wildest expectations," NASA Program Scientist Ed Weiler beamed. NASA Administrator Dan Goldin

compared the pictures Hubble was sending back with the great explorations of history. Senator Mikulski almost shouted: “The trouble with Hubble is over!”

In the next few months Hubble proved its exceptional worth, revealing evidence of the theory of Black Holes, obtaining images of young stars and possible planets around distant stars, seeing a comet hitting Jupiter, confirming theories of missing mass or dark matter in the universe, and showing early galaxies after the Big Bang billions of years ago. There was one discovery after another, and as the 1990s continued, Hubble not only rewrote astronomy textbooks, but communicated the awesomeness of space to the average citizen. The pictures were not only spectacular, but in many cases beautiful. As the 21st century began, Hubble was called “the people’s telescope” by some and was universally regarded as one of the top success stories of space exploration since Apollo. There were additional repair missions over the years, and Hubble was scheduled for a fourth and probably final repair mission in 2006 that would extend its life to 2010. A successor telescope was already well into planning. The aim of NASA was a minimal gap, if any, between Hubble and its successor. But disaster struck again.

9. A Premature Death Sentance

9.1. The Columbia Disaster

On February 1, 2003, the Columbia Shuttle disintegrated as it entered the atmosphere in preparation for a Florida landing, killing all seven astronauts aboard. The subsequent investigation made it clear that the Shuttle was getting old and, though old, was still experimental in many ways. Each flight was a high risk, life and death venture.

The body investigating the disaster, the Columbia Accident Investigation Board (CAIB), set forth certain safety criteria NASA should meet in flying the Shuttle in the future. What had caused the Columbia to fail was insulating foam that damaged a wing of the shuttle on take-off. In reentering Earth's atmosphere, the hole in the structure allowed intense heat to enter the Shuttle and destroy the vehicle. If foam was ruptured again, it had to be repaired, CAIB said. Thus, NASA needed a foam-repair capability in space, whether based at the Space Station or independent of the Station. The only non-Space Station mission scheduled was Hubble servicing.

9.2. O'Keefe's Hobson's Choice

The NASA Administrator, Sean O'Keefe, saw the Space Station as a safe haven for astronauts if a repair mission got into difficulty. For Hubble, because of its orbit, there was no safe haven, thus an extra risk. O'Keefe believed he had to make a choice. Either terminate the Shuttle-Hubble repair mission and thus sentence Hubble to a premature death; or, go ahead with the repair mission and take the extra risk. Personally seared by the Columbia experience, and believing he had to emphasize safety first, O'Keefe decided to let Hubble die earlier than necessary, rather than risk astronauts on a Shuttle mission. This decision was inadvertently leaked and appeared on the front page of *The Washington Post* on January 15, 2004 – one day after President Bush announced his decision to go back to the Moon by 2020 and eventually on to Mars.

The O'Keefe decision came across to most observers as a budgetary trade-off between Hubble and Moon-Mars. The media and opposition to the decision framed it as such, and O'Keefe could not fashion it in the safety terms he intended. Senator Mikulski, a Hubble

advocate, pointed out to O'Keefe that when you have a death diagnosis, you better get a second opinion. O'Keefe sought it from the Chair of CAIB, who refused to back O'Keefe, praised Hubble, and called for a broader and deeper study. O'Keefe, bruised by an avalanche of protest – scientific, political, media, and public – said he would try to accomplish the repair mission by robotic means. He also asked the National Academy of Sciences to examine the options, Shuttle and robotic.

In February 2005, as O'Keefe departed NASA to become Chancellor of Louisiana State University, the NAS reported its findings. It said that there was slightly more risk with a shuttle flight to Hubble than one to the Space Station, but the benefit justified the risk. The additional risks, in NAS's opinion, were marginal. As for the robotic option, NAS declared: it would not work. The technology could not be developed in time, before certain key systems on Hubble ceased to operate.

10. Reprieve

In April 2005, NASA got a new Administrator, Michael Griffin. Griffin, to no one's surprise, said he would reconsider O'Keefe's decision after two successful flights of the Shuttle and make his own risk assessment. In 2006, with those conditions met, he reversed O'Keefe.

The Hubble repair mission is set for November 2008. If successful, that mission will take Hubble beyond 2010, perhaps even to 2013, the year its successor is scheduled to be launched. The successor, presently in development, is the James Webb Space Telescope. Costing $4.5 billion or more, it is scheduled to take Hubble's place and go beyond it in capability. Its goal: to

see and investigate the “first light” of the universe after the Big Bang, when the primordial material of creation first gave birth to stars.

11. Conclusion

The story of the Hubble Space Telescope is analogous to that of ancient searches of discovery as well as voyages of discovery in the middle ages of Europe. It brings out a glimpse of the modern quest to explore and know. Like the quests of old, space exploration, especially by human beings, is filled with peril. There are stops and starts, success and failure. But if intrepid heroes persist and take risks, humanity advances. There are risks to nations also, because space exploration, whether by machines or humans, costs a very great deal. Is the risk of lives and national treasure worth it? The Holy Grail in this case about a great telescope is more understanding of our origins as a universe and species. The deeper into space we look, the longer back in time we go, almost to the beginning of everything.

In a world filled with pain, war, famine, and unending folly, space exploration may seem to some a frill. But, it is also a source of adventure and pride. It has always been in our human nature to explore the next frontier. Space, the modern frontier, fulfills a human need so basic it cannot be stopped by setbacks in space or adversity on Earth. Human beings are inherently curious. They want to know what is over the next ridge. Hubble is important because it is an embodiment of our humanity as well as a giant tool of exploration. It brings out something positive, even noble in human nature. It gives hope to answer questions that are the most basic human beings can ask, and have asked since the primitive ancestors of us all looked up at the heavens and wondered: Who are we? Where did we come from? What is our destiny? Are we alone?

[1] Material for this paper came from Joseph Tatarewicz, "The Hubble Space Telescope Servicing Mission," in Pamela Mack, ed. *From Engineering Science to Big Science*, (Washington DC: NASA, 1998), 365-296; and W. Henry Lambright and Steve Dick, "Sean O'Keefe's Hobson's Choice: The Hubble Repair Decision," unpublished paper (February 16, 2005).