

## **Directors' Perspective: Human Space Flight**

With exquisite grace and remarkable stamina, seven astronauts restored Hubble to full working condition last December. Actually, they left it in better condition than it was even before the fourth gyro failed in November. By jostling the spacecraft – or maybe by simply cycling the power – they fixed a nagging problem with a power control unit that was not delivering full power to the satellite because of a resistance that developed in the circuit path. That was not in the carefully choreographed flight plan but, hey, who are we to complain? The human factor worked in our favor.

It was a big kick to see the whole thing live on television. The broadcast piqued public interest in the mission, too. It was one of NASA's few visible successes last year. After a couple of failed Mars missions, the success of the astronauts in repairing astronomy's most famous research tool was a big boost for the agency and the manned space program. It was a big boost for astronomy, too. Hubble's success helps all astronomers by maintaining public interest in what we do.

Each servicing mission has become more complex. Servicing mission number 3 (SM3a) bumped up against several records for the duration of the space walks. Fixing the gyros, upgrading the computer, installing voltage improvement kits, and inspecting the satellite all took a bit longer than planned. Photographs of the solar arrays revealed that some critical hinge pins had worked their way loose, threatening the long-term viability of the satellite. In a series of dramatic meetings reminiscent of scenes from the movie, *Apollo 13*, engineers from ESA and NASA concluded that no fix was necessary, thus relieving the astronauts from a potentially difficult, unplanned duty.

Not everyone cheers NASA when they mount repair missions to space satellites. The cost to the Hubble project of SM3a was about \$30 M. The cost of training and getting the astronauts to orbit and returning them safely is several hundred million dollars, depending on how one amortizes the cost of the manned space program over the number of shuttle missions each year. Not cheap. Is it worth several hundred million dollars to fix a two billion dollar spacecraft?

Many of us would say yes, especially when the object of the fix is already firmly part of the taxpayers' positive image of Hubble. Look what the first servicing mission did for us. Hubble is an example of how manned space flight can be a good value for science.

On the other hand, it costs more to build satellites that can be serviced. There is more engineering involved in making all units modular and accessible and in making the structures strong enough to be grappled, jostled, opened and closed. Servicing certainly increases the total cost of a science project by more than the incremental cost of servicing. When is the cost of servicing a good investment for a field?

The answer may lie in the speed of improvement of the telescope technology compared to the rate of advance in instruments. For many years, the power of telescopes has improved slowly, whereas the advance of instruments, driven mainly by improvements in detectors, has occurred rapidly. Even the giant 10m Keck telescope only increased light gathering power by a factor of four over its predecessor, the Palomar 5m, despite nearly 50 years between the two. The size of detector arrays increases by factors of four every few years, and each generation of detectors has demonstrably better quality and sensitivity. In this environment, it makes sense to upgrade existing telescopes with better instruments, since a modest investment pays a rich reward.

But the future of space telescopes may be different. The Next Generation Space Telescope project confidently predicts that they can increase the light gathering power of NGST over Hubble by a factor of 10 for less than half of Hubble's cost. In their current budget, the instruments cost only a bit less than the telescope itself – though some of us think the instrument costs are seriously underestimated. If the estimates are correct, it would be cost effective to simply build new telescopes rather than service the old ones, especially since it would be expensive to make the telescope serviceable in the first place. We would be better off building a backup NGST to buy down the risks rather than making it serviceable.

Of course, if it turns out that making an 8m space telescope is harder than we think, these arguments may be wrong. Under current projections, NGST will be launched two decades after Hubble. NGST's instrumentation budget is clearly inadequate to equip it with the most capable instruments possible even with today's technology, let alone that of 2010, say. If it takes another two decades to improve upon NGST by even a modest factor, we may look back fondly on the days of manned visits to our great telescopes and wish we could find some way to send our best and brightest into space to keep our observatories at the state of the art, the way we have with Hubble.

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