Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Fixing Hubble*.

The venerable Hubble Space Telescope was launched in April 1990. This was quite a year astronomically - with Voyager 1 sending back the historic Pale Blue Dot photo (being Earth from 5.6 billion kilometres away) and it was also quite a year politically with the first McDonald's opening in Moscow and it was quite a year humanitarianly with the World Health Organisation removing homosexuality from its list of known diseases - and yes, I did say 1990. Wow.

Anyway, the Hubble Space Telescope was launched aboard the Discovery orbiter on Space Shuttle mission STS 31 and after it was set into a stable orbit, it pretty much didn't work.

You probably know about the spherical aberration of the 2.4 metre main mirror - which was a major problem, to be sure. But also three of its six gyroscopes weren't functioning properly and one of its solar arrays kind of wobbled. So even if the mirror had been OK, the wobbling solar array of this Hubble Mark 1 would have sent a shudder through the scope with every temperature swing from direct sunlight to shadow. And this would have happened about 16 times a day. The remaining gyroscopes could have put the telescope back on point each time - but if just one more of them had failed, protocol required that the telescope functions would be shut down and the spacecraft put into safe mode.

But although it was all on tenterhooks, a bit of useful work did get done in those first couple of years. Since the mirror aberration was a mathematically determinable quantity, you could *deconvolute* the distorted vision received and get something in the way of useful data - although this wasn't quite the same as getting the pretty Hubble pictures that we are used to today.

But in any case, the whole point of putting Hubble in a low Earth orbit was so it could be upgraded during occasional visits by astronauts - which happened a total of 5 times up until the last servicing mission in 2009, not long before the Space Shuttle fleet was retired.
So, having at least got the telescope up there in 1990 but then finding the darn thing didn't work properly, the first Hubble Servicing Mission was undertaken in 1993.

The mission, STS 61 involving the Endeavour orbiter, brought up a ten metric ton payload, including a new set of solar arrays, new gyroscopes, a new wide field camera and COSTAR - the Corrective Optics Space Telescope Axial Replacement, essentially a set of prescription glasses that would fix the mirror problem. STS 61 was one the most complex Shuttle mission ever undertaken and included five space walks. First the mission team replaced four of the telescopes six gyroscopes, then they installed the new solar arrays and then the camera replacement and finally the COSTAR corrective optics.

From there the Hubble Space Telescope really did start delivering the goods and the next scheduled servicing mission in 1997 was just to upgrade a few bits bits and pieces. This was STS 82, flown by the Discovery orbiter, which installed NICMOS, the Near Infrared Camera and Multi-Object Spectrometer and STIS, the Space Telescope Imaging Spectrograph and some enhancements to the guidance and orientation systems - because remember Hubble isn't just a telescope - it's a spacecraft.

From there things went swimmingly for a year or two. But then, plans for a routine third servicing mission, which might have happened in 2000, were suddenly out the window as Hubble's gyroscopes began failing again. An advance repair mission was scheduled for 1999 when the telescope was down to just three functioning gyroscopes - and a fourth gyroscope failed in November 1999 rendering Hubble inoperative as a telescope - but fortunately the third servicing mission, known as 3A arrived in December 1999.

Hubble Servicing Mission 3A, which was STS 103, again flown by Discovery, managed the emergency replacement of all six gyroscopes, updated Hubble's on-board computer and also added some new thermal blankets.

Then Hubble Servicing Mission 3B was flown in 2002 to do all the other things the original Hubble servicing mission 3 was meant to do. Also known as STS 109, this was the Columbia's orbiter's last successful mission before it was destroyed on re-entry in 2003. But at least STS 109 was a great success. Hubble got a new camera - ACS, or the advanced camera for surveys - a new set of solar arrays, a new cooling system for NICMOS, the Near Infrared Camera and Multi-Object Spectrometer since the old system had failed in 2001 and some replacement reaction wheels for the guidance system - because remember Hubble is also a spacecraft.

Then there was always going to be a fourth servicing mission, but Columbia's heat shield failure in 2003, resulting in the death of its entire crew, put a whole bunch of things on hold. So it wasn't until 2009 that the fourth servicing mission, also known as STS 125, actually flew.

Hubble Servicing Mission 4 saw the installation of yet another new camera - Wide Field Camera 3 and also COS, the Cosmic Origins Spectrograph - which actually replaced COSTAR - the original corrective glasses for Hubble - because by this stage every astronomical component that had been replaced in Hubble over the previous 4 missions already had adjustments built-in for the mirror aberration - so COSTAR had become redundant.

Assuming 1993 as the point where Hubble did start working properly, the venerable Hubble Space Telescope has been working brilliantly for almost twenty years now - and NASA cautiously predicts that it will remain fully operational until at least 2014. This functional end-point won't be because of any problems with the optical systems. It will be because the camera or other data collection systems will begin to fail, or maybe just their power systems will begin to fail, as we have seen happen fairly regularly over the life of the telescope so far.

And even if these components don't go down first, the gyroscopes are likely to begin failing before long. In the dying days of the telescope, there will be no point in putting the spacecraft into safe mode when half of the six gyroscopes are gone. Instead contingency plans are already in place to maintain some limited pointing capability on two or even one remaining gyroscope.

But even though we hope to keep squeezing just a bit more science out of the old girl in her last geriatric years, Hubble will begin re-entering the Earth's atmosphere sometime after

2019 and certainly by 2032. At one stage, there was a plan to bring it back down with a space shuttle orbiter and put it in the Smithsonian Museum - which would have been a nice gesture, but needless to say that ain't going to happen now. When the time comes, Hubble will be given a guided re-entry since it won't completely burn up in the atmosphere – but that's only to protect us here on the surface and presumably whatever debris does make it through the atmosphere will end up deep in the ocean. Ah well, I am glad to have been around during Hubble's twenty year plus mission. We did ourselves proud on this one.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website which we keep running smoothly with upgrades, snippets, and remakes. No ads, no profit, just good science. Bye.