Astronomy Cast Episode 88:
The Hubble Space Telescope

Fraser Cain: Hey Pamela.

Dr. Pamela Gay: Hey Fraser, how are you doing?

Fraser: Good, a lot happier this week.

Pamela: Good.

Fraser: Yeah. All the sad episodes are gone and now it's time to move on to the happy stuff.

Pamela: Oh, I'm sure we'll find something else to be sad about.

Fraser: Later. Later. We won't make it happen too often. Let's talk about the happiest place in space, which would be the Hubble Space Telescope. Our understanding of the cosmos has been revolutionized by the Hubble Space Telescope.

The breathtaking familiar photos like the pillars of creation pale in comparison to the astounding amount of science data returned to Earth. Hubble's getting old though, serviced several times already and due for another mission later this year. Let's relive the historic observatories amazing life so far and see what the future holds.

Pamela: You know, I just have this wonderful realization that Hubble is now of legal age and could vote.

Fraser: Perfect, and then next year it could drink. Well, I guess in Canada.

Pamela: It has a few years before it's allowed to drink.

Fraser: Let's go back to the history of Hubble. Where did the idea of building an observatory in space, how long has this been in the works for?

Pamela: The idea of going into space with telescopes has been around since the 1920's, pretty much since we first started to think about putting anything into space.

Our atmosphere is the one thing that sits between us and the stars and anytime you can get a telescope above the atmosphere you can improve the amount of science that you are able to do.

Fraser: The atmosphere has dogged astronomers since the dawn of time. It is their worst enemy, except for maybe daylight.

Pamela: [Laughter] But at least in daylight we can see the sun, so we've still got one star left.

Fraser: Right, but atmosphere has been awful.

Pamela: It blocks certain wavelengths entirely. We can't see gamma rays on the surface of the planet, we can't see ultraviolet, and we can't see infrared. There are all sorts of colors of light that our atmosphere just doesn't let through at all so the only way we can see those colors is if we go into outer space.

Fraser: So when did the concept for Hubble first happen?

Pamela: Well, Liam Spitzer in about the 1940's, 1946 or so, put forth the idea of let's have an extra-terrestrial observatory. He basically did the whole, let's get where we can see infrared and ultraviolet, which are two things the Hubble space telescope can do, and he did the, let's get somewhere where the atmosphere isn't going to blur all of our images out.

The idea was to put a fairly large sized telescope on orbit and start looking for things that we're currently blind to.

Fraser: So that is the infrared, the x-rays, the stuff that's blocked by the atmosphere.

Pamela: Today we have a whole suite of space telescopes that look at all these different colors. Hubble was just the first of this suite of massive national observatories on orbit. It's these ultraviolet, optical and infrared light.

Fraser: So when did work really get going on Hubble?

Pamela: Hubble itself started to emerge as a plan in the 1960's. We first did a couple of test cases, a couple of orbiting astronomical observatories. The first one had a battery failure but the second one was able to carry out some ultraviolet observations.

When these two missions, or at least one of these two missions, became successful we started looking for funding. Well, not we, I wasn't born yet, the astronomical community started looking for funding to say hey let's go and put something significant in space.

At the beginning of the 1970's a couple of different committees were put together (because that's how we do everything is in committee) and they started looking for funding, looking for ways to do it, specking out what we wanted to do. Originally it was slated to be about 3 meters and it got shrank down to 2.4 meters so that it could fit inside the space shuttles cargo area.

We also went in and we found partners to help us pay for all of this. We have the European Space Agency, Canada built the wonderful robotic arm and as we built this coalition and raised money from Congress, the whole project took shape.

It was originally hoped that it would launch somewhere around 1983, but as always happens with massive telescope projects and massive satellite projects, delays ended up taking place.

Fraser: So when did it finally launch?

Pamela: 1990.

Fraser: So 7 years late.

Pamela: Seven years late. It could have launched much earlier than that, except in 1986 we had the Challenger disaster.

Fraser: Yeah, that was a bad year for launching things into space.

Pamela: Yeah, so prior to the Challenger disaster we had been on target to have the quickest turn around, the most launches, all these historic space shuttle, space shuttle, space shuttle wonderful things were slated to happen.

But then we lost the Challenger and the Hubble Space Telescope was slated to go up shortly after that, and instead it got put into storage to the tune of 6 million dollars per month to keep it the way you need to keep a telescope, in a nitrogen rich clean room where no dust was going to get into it, where nothing was going to have bad chemical reactions with stuff in the atmosphere.

Very expensive storage, but it did allow us to fix a few things with the Hubble that were faulty that we hadn't known about.

Fraser: Yeah and missed one major flaw.

Pamela: That would be an understatement.

Fraser: So finally the Hubble launched in 1990 up into space, here we go, the most sensitive telescope ever built by humanity in space away from the atmosphere. How did it go?

Pamela: It took the ugliest pictures anyone had ever seen and many astronomers cried.

Fraser: So, what was the problem?

Pamela: It has this mirror that was supposed to be ground down to amazingly precise layers. We're talking a hair would be a huge mountain on the surface of the mirror. They needed the surface to be perfect, to within about 2.3 microns. And it was in the center of the mirror. The problem was that the outskirts of the mirror weren't polished correctly. The curvature of the mirror was wrong.

This was done by a company called Perkin-Elmer that NASA had been having issues with. Some of the major reasons the telescope was originally being delayed was the amount of time it was taking to grind, grind, grind at this mirror. This was back in the days before we were spin-casting mirrors.

When they checked the surface of the mirror they checked it with three different devices. Two of those three said uh-uh doesn't work, try again. The third one, the one that they used to check the surfacing most of the time, said it was perfect.

Instead of saying wait, why are two of them saying it is bad and one of them saying it's good, PerkinElmer decided they were only going to trust the one that we used most of the time to have been correct which was really a stupid decision to make.

Fraser: Sounds like a classic mistake in science, right? Trust the data that says what you want to hear and ignore the data that is saying something you don't want to hear.

Pamela: Yeah, how many drug studies have gone this route? What ended up happening was the outer part of the mirror, the donut on the outskirts of the circular mirror, focused light in a completely different place than the inner part of the mirror. If you were looking at a star, if you were looking at some sort of a point source, this wasn't too big of a problem, because you still got a nice friendly point source in the exact center.

The problem was when you went to look at extended objects you just ended up with this really nasty image that was very hard to with computers take apart and figure out okay, this light belonged here, this light belonged here, and figure out exactly what was going on. They tried, they had software, Phil actually worked with some of it, but it wasn't pretty. The thing is though you can use lenses to bend light wrong or right. Having bent it the wrong way, you can correct it using a second lens.

Once they figured out what was wrong and once they figured out where everything went so terribly wrong, they are able to go and essentially build glasses for the Hubble Space Telescope and go back and fix the problem with new instruments that took out this error that was created by the outer edges of the mirror.

Fraser: This is one of the great advantages of the Hubble Space Telescope and it's orbit. Hubble was launched into an orbit, was launched from the space shuttle, which only flies a few hundred kilometers above the surface of the Earth and Hubble was launched into that orbit with the whole goal that shuttles could come back and service it from time to time.

They could install new detectors; fix failing gyros and just sort of keep the whole telescope running almost as if an entire observatory on Earth. You would go in and make changes, and fixes and upgrades and so on. This is the wonderful outcome of that decision to make the telescope serviceable. They could launch up just a couple of years later with corrective lens, install it and fix the problem.

Pamela: This actually goes to showing one of the reasons that astronauts are really useful. They're great construction workers. They can do things that you just can't do with robotic arms because they can be creative and they come fully gimbaled, which cost a lot more to do in a robotic arm.

The corrections that they put in for some of the instruments weren't things the Hubble Space Telescope was originally designed for. The telescope wasn't designed with the plan of oh, it's going to have faulty optics, we're going to need to put in COSTAR (Corrective Optics for the Space Telescope Axial Replacement). This is a crazy instrument that went in the optical train in a place that they weren't planning on having to put an instrument. They actually had to pull out one of the planned instruments, the faint object spectrograph, in order to be able to fit this thing in.

The astronauts could figure out how to do it. In some cases these guys have their arms up to shoulder crammed into the space telescope and they're reaching for things that they know where they are because they've trained so hard. They're basically feeling around the same way you might replace something under your sink that you can't see.

They're doing all this while wearing astronaut gloves and knowing that if they catch the corner of their space suit on the sharp corner of something inside the space telescope that they could shred it and die.

Fraser: You can just imagine the amount of training. They've done this maneuver many, many, many times in a simulation on Earth in a pool in their spacesuit just for the moment when they're up in space and they have to do it for real. They get really good at it.

Pamela: In 1993 the first shuttle-servicing mission went up and they put in this COSTAR instrument that corrected the optics for some of the side instruments. The light comes in, hits the mirror, goes through COSTAR and goes off to places it needs to go.

They also built some of the instruments with the corrective optics built into them, the wide-field planetary camera for instance. It was built to be able to see things in the ultraviolet and it incorporated corrective optics directly into this original instrument. They have gotten creative with, well, let's figure out new ways to make Hubble work better and to incorporate the corrections we need into the instruments we built.

Fraser: Have the corrections completely resolved the problem? If Hubble had gone up with perfect optics, is it as good with the corrections as if it had been perfect?

Pamela: It's in terms of focus as good as it would have been, but with every optical surface you're going to lose a little bit of light so the total amount of light that it's able to get from the front of the telescope to an instrument is slightly diminished, but it's not a huge amount. I have to admit I don't have the numbers in front of me, but the times I have seen them I always went, "Oh yeah, that's not that bad, it's okay."

Fraser: Right. So you've got it going through a lens and some of the photons get absorbed by the lens and they never make it to the instrument.

Pamela: They get reflected off. We've all looked at someone who is wearing sunglasses. Part of the reason that the light isn't getting to their eyes isn't just because the dark lenses are absorbing some of the light, but it's also because they're reflecting some of the light.

When we look at windows and we see reflections off of a window, that's light that is not getting into the room beyond. These reflections, which you have no matter how many nice great over-coatings you have, have an effect. It's a small, small effect.

Fraser: Let's talk about some of the other upgrades that have happened to the telescope since then.

Pamela: It's gone through a whole series of different instruments. In fact it's even repaired itself a few times. There was originally an instrument called nichmass. It was designed to be able to do spectroscopy and imaging in the near infrared. Great instrument, but it has to be kept cool because infrared light is light that you get from anything that's warm. If the instrument is warm the infrared light the instrument is giving off will blind it from seeing any of the infrared light that is coming from distant objects. Infrared is one of the most important colors to astronomy.

The most distant objects in the universe – as their light travels across the universe to reach us – it's getting red-shifted. It's getting stretched out both by the fact that the object it's coming from is moving away from us due to the expansion of the universe.

It's getting stretched out, which is a different type of red-shift by the expansion of the universe. These two different factors add up to take the light from these distant objects and transform it from where it might have started in the ultraviolet or other bright bluish colors and have moved it out into the red and the infrared where we can't see it on the surface of the planet.

Fraser: That's why the next major space telescope, the James Webb is designed as an infrared. It's going to be able to see the most distant objects, which have all been shifted out to the red end of the spectrum.

Pamela: This is the wavelength that the Spitzer Space Telescope works in.

Fraser: Get used to infrared.

Pamela: Yeah, it's where all the cool kids are going to play science. The Hubble Space Telescope is the first space telescope able to see out into the .8 micron, the 2.5 micron really long red wavelengths. It was the first to give us glimpses of what early deformed, not quite pulled together galaxies looked like.

Unfortunately though the instrument shifted and it ended up touching something else and it blew through its coolant trying to cool off not just itself but also the heat that it was getting from what it was touching. Initially it had a much-shortened life, but during a subsequent servicing mission they re-cooled nichmass, gave it new coolant and were able to resurrect this instrument.

It's actually a very important instrument because it was one of the ones that was used to first determine that there's super massive black holes in the centers of galaxies.

Fraser: Then there is another servicing mission coming up.

Pamela: Oh yeah. We've had four so far and now we are about to move onto the fifth which is actually called the fourth but that's the way NASA numbers things. We went servicing mission 1, 2, 3a, 3b and now 4.

Here we're going to install a new wide-field planetary camera. If you've ever looked at a Hubble image that was really weird shaped, where it looked like a corner had been snapped off of it, that would have been from one of the wide-field planetary cameras. We've gone through several generations of these that have been progressively getting more sensitive.

They're putting a new one of these in. It's a new high-resolution wide-field camera that should allow us to take images that span from the ultraviolet all the way out into the near infrared. They're also putting a new ultra sensitive ultraviolet spectroscope on that will help us gain more understandings of part of the universe that we don't get to see through our atmosphere.

They are also going to work on repairing the STIS spectrograph and updating the advanced camera for surveys. So there are some repairs, some replacements and most importantly they are also going to be replacing the gyroscopes in the Hubble Space Telescope.

The gyroscopes are in some ways the weakest link on this telescope. If you lose the gyroscopes, you lose steering and it's really hard to use a telescope that you can't point.

Fraser: Right, and just explain that the gyroscopes, these are spinning wheels inside the telescopes which depending on which of the wheels spin, causes a counter spin on the telescope itself. This is very commonly used in most spacecraft now is they have these gyros. The gyros spin and if you've done one of those experiments you hold a gyroscope or you hold a bike wheel and you turn it and then you sit on something that can spin as you turn the gyro in one way or the other you'll spin in the opposite direction.

Two gyroscopes that are perpendicular can make the telescope spin in any direction without having to have thrusters. They can have solar panels, which gather power and then use the power to turn the gyroscopes and the gyroscopes will allow the telescope to spin around and aim at different targets and track targets and stuff like that. Without the gyroscope, Hubble and any of these space telescopes can't see anything and that's the biggest disaster is when these gyros go.

Pamela: The gyroscopes don't work alone. There's actually fly wheels as well that when they spin up the fly wheels you get the fly wheels spinning clockwise, the Hubble Space Telescope will actually rotate counterclockwise. This is another way of getting the system pointed and re-oriented a little bit more effectively.

The gyroscopes also help tell them where they're pointed. They're sensitive to the space telescope is rotating, I sense this rotation, I need to do something to fix this rotation.

There are a lot of different things working together. There's the fine guidance system that aligns on stars, there are the flywheels they use for bulk motions and there's they gyroscopes. It went into orbit with six gyroscopes. The original plan being they'd use three at a given time and hold three in reserves.

When they got down to two of them were broken they decided how they would use the system with only two gyroscopes and two in reserve. We're just sort of hoping everything keeps going until the August servicing mission and then they're going to put six brand new ones in.

One of the sad things they are also going to do in the servicing mission is they're going to attach to the Hubble Space Telescope, basically a way for a robotic mission to go up and grapple onto Hubble and steer it through the atmosphere and help it commit suicide some day in the future.

Fraser: This was never planned. It's funny because they had expected that Hubble would eventually crash back down to Earth through the atmosphere.

Pamela: Even before that, the original plan was they'd launch Hubble in the space shuttle, carry it up, grab it periodically, bring it down to Earth, do what they needed, take it back up and that got ditched fairly quickly. They figured out how to do on-orbit repairs.

After Challenger it was also the let's revisit safety and is it safe to land with something the size of a school bus in the back of the space shuttle. The space shuttle has never actually brought something that big back down other than they had a space lab that the Europeans built that they took up a couple of times.

Fraser: It already flies like a brick.

Pamela: So for safety reasons the original plan of bringing Hubble back down and sticking in the Smithsonian was taken away. Then there was the thought of crashing it into the ocean and then there's the no, no, no let's boost it into a higher orbit. Not that I'd know what you would do with it when it's in a higher orbit and dead, but it's always hard to watch a friend die and Hubble's been around for a long time.

It's been the heart and soul of many different careers. It's hard to imagine that some day we are going to take it on a controlled destruction path and plunge it through the atmosphere so that it's bits fall into the ocean, but that's probably what's going to happen someday.

Fraser: How does Hubble stack up to the latest technology? I think that a lot of people have this emotional response to it as one of the greatest pieces of scientific engineering. One of the greatest instruments ever built for the purposes of science.

You could place that side by side with any of the best particle accelerators, genetic experiments, you name it; Hubble has given us some of the most important discoveries in cosmology and astronomy. I know that when NASA was starting to say, well, maybe we aren't going to bring Hubble, maybe we're just going to let it crash, and that's kind of that for Hubble. They already had the work going on for the James Webb Telescope which is going to be a monster, way bigger, way more powerful. It won't see any invisible light; it's definitely not the successor to Hubble.

It's going to be an infrared observatory. People had a very emotional response to save Hubble no matter what we've got to keep that telescope going. I wonder financially if you can take the same amount of money that is being spent a repair mission and just built a new telescope and launched that instead with the latest greatest technology. Would you get more bang for your buck?

Pamela: It's unclear if you'd get more bang for your buck because at a certain level you have to restart a lot of the, oh we haven't built one of those for twenty years programs and redesign things and so there's R & D that goes into it. There's also the risk of a burden to the pot vs. one that you have to go out and catch. You go with the one that you already have in the pot.

Hubble is launched, it is functioning, and it is in a stable orbit. All of these are good things. Every time you launch a mission you hold your breath and hope that it's going to live and not all of them do. When you do the risk assessment, it's better to go out and catch Hubble and stick new instruments in it then to just build a new 2.4 meter telescope every few years.

If you can guarantee each of those new telescopes would be a hundred percent functional and would launch successfully then the equation changes and it might make more sense to just build a new one periodically. There are capabilities that we're just going to lose when Hubble is de-orbited. Its' ultraviolet abilities, we don't have something else to match.

Fraser: Aren't there ultraviolet observatories?

Pamela: Hubble has a unique set of instruments. It's spectrograph that it's going to have is going to allow us to see things that we can't see. I don't think that there's currently a working ultraviolet telescope on orbit.

Fraser: With the same capability?

Pamela: Yeah. We're also not going to have the visible light capabilities anymore. This is where the emotions give in. If you look at Jupiter through a backyard telescope you see fuzzy blob with stripes, sometimes-fuzzy blob with stripes and red dot or maybe two red dots.

When you look at Jupiter through a ground based telescope you see the same thing but now with more details. When you look at it with the Hubble Space Telescope, you are then taking that image and giving more details to it. You can see how that Hubble Space Telescope image and that image you see with your eyes are the exact same thing. There's no guesswork at play.

Well, you look at Jupiter in the x-ray and you see weird stuff at the pole. You look at Jupiter in the infrared and you see something entirely different. The emotions come from looking at Hubble images and going, “Wow, that’s what I would see with my eyes if only I were close enough or if only I were on orbit, or if only my telescope was big enough. That’s what I would see with my eyes.”

Frazer: Or if only I could aim my eyes at something for three straight days and collect every photon that arrived.

Pamela: Yeah. So we’re losing that visible, we’re losing that ultraviolet, but the questions that are out there waiting for us in the infrared universe, the questions that Spitzer is just not quite big enough to answer. James Webb is going to go out there and chase down the origins of galaxies, chase down planets around other stars. It’s going to give us a glimpse into a whole new part of the universe that Hubble just can’t get to.

Fraser: All right, well I think we’re going to have to do a whole separate show just on the James Webb telescope as well. I know it’s going to be another few years before it even launches so maybe we can give people a preview of what its going to be.

Pamela: We have the GLAST (Gamma ray Large Area Synoptic Telescope) that’s going to be going up soon and we might be able sneak in a show about that as well if it launches healthy.

Fraser: There are just so many amazing missions that are going to be going up over the next few months. Well I think that covered the Hubble Space Telescope. It’s one of those situations where the greatest part is the pictures, but since this is a pod cast you have to go to our website and get links to pictures or come to Universe Today and we have lots of pictures from Hubble all the time.

It was great to just tell the story so thanks a lot for that Pamela.

This transcript is not an exact match to the audio file. It has been edited for clarity. Transcription and editing by Cindy Leonard.