NASA Museum Alliance Conversation
Hubble Servicing Mission 4
Dr. Frank Summers, Space Telescope Science Institute

Moderator: Anita Sohus
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Coordinator: This is the conference coordinator. At this time, I need to remind all parties that today's conference is being recorded. If you have any objections to this recording, now would be the time to disconnect. Ma'am, you can start your conference. Thank you.

Anita Sohus: Thank you and welcome everybody to Hubble Servicing Mission 4 Overview, with Frank Summers at the Space Telescope Science Institute there in Baltimore. I would like to remind everyone that unless you have a question, please do mute your phone, either using your mute button or *6 on your keypad. And do not put it on hold because sometimes that plays lovely music that we really don't want to hear!

So Frank, I'm going to turn it over to you. Was everybody able to download the presentation?

Frank Summers: Okay, hello everybody, this is Frank Summers from the Space Telescope Science Institute. And just to finish Anita's thought there, if anyone has problems downloading the presentation, now is the time to speak up.

Okay, great. So I'll assume everyone has the presentation in front of you. Today, we're going to try and prepare you guys for Servicing Mission 4, which is nominally scheduled to take place May 12th of next month.

Now if you've looked at the presentation, you'll see there are 71 slides in the presentation and there's no way I can possibly go through all 71 in detail. My intention is not to go on for three hours here. But instead, most of the beginning slides are slides that I think that people will - it will provide you with information if you want to answer your visitors' questions about Hubble's background, etcetera.

And so I'm going to go pretty quickly through the first 10 or 20 or so slides, maybe even 30 slides. And then I will slow down as I get to the more distinctive SM4 material, okay?

All right, so let's move on to Slide 2 which says, A Space Telescope. And then quickly move on to Slide 3. On the left hand side, you see the Hubble Space Telescope going through its shake test in California. And the guy in the bunny suit there for scale. On the right at the top is the launch of the Hubble Space Telescope back in 1990. And at the bottom right is the deployment of the Hubble Space Telescope, just to show where it came from and where it went.

And on Slide 4 is an important misconception that a lot of the public has. On the left is an artist's illustration [of Hubble in orbit]. I found out after I started doing - presenting this in my talk as the wrong thing to do that it [this slide] was actually created here at Space Telescope (oops - egg on our face). But it was done not in a purpose that was meant be scientifically accurate.

And on the right is a photograph from the space shuttle. And the most important point about this - these two illustrations, the illustration versus the photograph -- is the curvature of the Earth on the left hand side. You can see how far Hubble would have to be away from Earth in order for the curvature of Earth to appear like that, whereas in the photograph on the right you can see what a very slight curvature you can see from shuttle orbit. And if you sort of fill out the size of Earth, you can get a feeling for how high Hubble is above Earth's surface.

Moving on to Slide 5, you can see a rough diagram of it, as good a diagram as you can do in PowerPoint really. And whereas you have the size of Earth being 6,400 kilometers, the Earth's atmosphere being 100 kilometers, 1/64 of that radius and Hubble hovering over it 600 kilometers above the surface. And I find this slide is actually quite good for resetting people's perspective on where Hubble is. It's just really skimming above Earth's atmosphere.

Okay, moving onto Slide 6, here is that shot of Hubble above Earth's atmosphere. And if you move on again to Slide 7, you see it compared to a size of a school bus which you can joke with kids is the magic school bus. That usually gets them giggling just a little bit.

And a bunch of the basic information about Hubble is here on this slide, its launch, length, weight, altitude, orbits every 97 minutes at 1,700 miles per hour. And the power usage of 100 watts, the easy way to present that to people is that an average computer has about 300 watt power supply. So this is about the size of eight computers in terms of its power usage.

All right, moving on to Slide 8, it says some Hubble history. And let me pause here. Are there any questions on those first seven slides that I've presented?

Anita Sohus: Laptop computers or towers?

Frank Summers: Well, your laptop computer generally has a 200 to 250 watt power supply because they don't want a lot of power in your laptop. Your tower computers, your really big beefy tower computers, can have up to a 600 watt power supply. So I was thinking sort of, you know, a medium sized tower, a small - or a small sized tower with a 300 watt power supply. You can check the power supply in your own computer and substitute your own numbers there, okay? Other questions?

Okay, let's move on to Slide 9 in our Hubble history. And this is just to show you that it goes all the way back to 1946 when the gentleman on the right, Lyman Spitzer, proposed the idea of a space telescope, long before we'd even been into space. It's pretty obvious that if you get up above Earth's atmosphere, a space telescope would have advantages.

It was - at the beginning of the space age-- it was recommended by the National Academy of Sciences. But nothing really went going until - got fully going until mid-70s when NASA and the European Space Agency collaborated. It was funded almost immediately after that collaboration began because there were a lot of things that went on in the interim.

And then in '85, construction was complete, ready to go. And of course, in 1986, we had the Challenger accident with the space shuttle.

Moving on to the next slide, in 1990, it was finally launched. In ’93 and ’97 were servicing missions. And at that time, the mission was extended to - from 15 - from its original 15 years to 20 years. And then in 1999 and 2002, we had more servicing missions - I’ll go into those in a little more detail later.

And in 2003 we had the Columbia accident. So you can see that the space shuttle accidents have played a significant role in the history of Hubble, simply because they’ve changed when Hubble - when we can go to Hubble and how we go to Hubble because it is the only way we get to Hubble. And if the shuttle’s not flying, we can’t service Hubble.

So in 2004 was the decision by then NASA administrator, Sean O’Keefe, that we would not go back to Hubble, which fortunately proved for us here at Space Telescope proved to be wildly unpopular. In 2005, we went to what we call to gyro mode - and I’ll explain that a little later - but basically it’s a way to prolong the life of Hubble while we’re waiting to see if we can get a servicing mission.

And in 2006, the new NASA administrator decided, yes, we’ll make one final house call to Hubble. And it was scheduled to originally go in 2008, actually, I mean, this original servicing mission was originally scheduled for 2005. It was delayed to 2008 by the Columbia accident. And then of course in 2008 we had the hardware delay which again, we’ll talk about later.

All right, so that’s the basic synopsis of Hubble history. What’s on the next slide - what makes Hubble so great. So let me pause there; are there any questions about Hubble history that I can answer? I know that’s brief and fast but, you know, I want to get - this early stuff is just preliminary for you to have as background material.

Anita Sohus: And much appreciated.

Frank Summers: Okay, I’m glad. A lot of people like these slides and ask me for them. So I figured I’d just throw them in this talk as well.

All right, Slide 11 - it says, What Makes Hubble So Great? And I have four slides on the answers. Number 1 is on the next slide, Slide 12, clear view that is located above the blurring effects of the atmosphere. This, by the way, is my favorite image of Hubble just hanging over the atmosphere. It's just a gorgeous image and sort of, you know, Hubble's looking out into the universe.

But what it really indicates is, you know, that thin atmosphere get's off of it. Get above that, you get above the twinkle, twinkle little star and it can - has the clearest view of any optical telescope. Now notice that it does not have a clearer view than things like radio telescopes, the Very Large Baseline Array has much, much higher resolution so it's not the highest resolution of any telescope as of any optical telescope.

All right, the second reason why it's so great is that it is serviceable. Honestly, as an astronomer, I thought that putting it in Low Earth Orbit was a real pain in the as**, okay. Because you got this earth there that's in the way, okay? You can't observe because the Earth blocks a lot of your view. It's, you know, it's inside the Van Allen radiation belt and such and you get small problems with the South American anomaly and the magnetic field. And there are problems with being in Low Earth Orbit.

But the huge advantage is that you can then get to it with the shuttle and that makes it serviceable. And you know, here's a computer analogy. I bought my - a computer back in the early 90s. And since then, I have upgraded that over and over and over again. I've swapped out the motherboard, swapped out the hard disc, put in a new one, pulled out the CD-ROM drive, thrown in a DVD-ROM drive. You know, upgraded the memory.

And each time you do that - so the chassis of the computer remains the same but it feels like a brand new computer because you've swapped out the really important electronics parts. Well, with Hubble we get to do the same sort of thing is that we go up with - in the shuttle, we pull out the old instruments, we put in a new instrument, and each time we service it, we feel like we've got a brand new telescope. It has new capabilities. And that's an analogy I find works reasonably well with folks who survey.

This is why Hubble, even though it's a 20-year-old telescope - or 19-year-old telescope - it still is doing cutting edge science because it gets a refresh of its instruments every few years. It still is a cutting edge telescope.

All right, moving forward to Slide 14, the - and the third reason is that Hubble is public. A very important point about Hubble is that when you apply to get Hubble time and Hubble - and it's very competitive, it's oversubscribed at a 10 to 1 ratio. But once you get Hubble time and Hubble takes your images, you get an email saying your images are now in the archive. And you get one year - the clock starts right then - you get one year of exclusive access to that data.

And then after that one year, everybody in the world can get access to that data, including your fiercest rival, okay. So your fiercest research competitor will go out and grab your data and scoop you on it if you don't do your research. Furthermore, if you don't do your research on your previous Hubble time that you've got, you're not going to get time with Hubble the next time you apply.

So by being public, the data gets out to everybody and you get a very strong incentive for people to really do the research that they've proposed to do with the telescope, not just sit on their data as, you know, astronomers have done over the centuries.

Finally, moving to Slide 15, this is the slide where I get to credit the wonderful people who work here at Space Telescope. I'm in the Office of Public Outreach here so I don't provide direct support to the scientists. But the software programmers, the instrument folks here at Space Telescope really do provide fantastic support to the scientists.

As a matter of fact, this model was brand new with Hubble, with the Space Telescope Science Institute, was a brand new model of how to support a telescope with an entire building full of people whose jobs were - half to do research for the astronomers and half to do just support of the telescope. And this is the model that has been replicated for other space observatories, Spitzer and Chandra, and for many other telescope projects since this; it's proven to be a very good working model.

All right, so Slide 16 we'll stop here. So those are the four reasons I think Hubble - make Hubble so great. Any questions on that section?

Okay - yeah.

David DelMonte: Hi, this is David DelMonte, Solar System Ambassador from down the street from you in D.C. How long will Hubble be great? What can we hope for?

Frank Summers: Well, the official NASA line on that is that after Servicing Mission 4, Hubble should have at least five years of continued life, okay. The unofficial line - and you didn't hear it from me - is that most of the people I talk to hope that Hubble will last for a full decade after Servicing Mission 4.

David DelMonte: Okay.

Frank Summers: Okay?

David DelMonte: Wonderful, thank you.

Man: Yes, I'd like to ask something about Slide 12.

Frank Summers: Sure, go ahead.

Man: Does Hubble work on the night - on the day side of the earth? In other words, is it open - if I understand, the instruments are sensitive to light.

Frank Summers: Yeah, Hubble has certain areas that it can point to when it's - when the - and there has to be a certain angle pointed away from the sun. And so there's only a certain amount of the orbit where it can take data. It can take data when it's on the day side of the orbit as long as it's, you know, as it's pointed fully away from the sun and is shielded from the sun. The light leaks are not - the light leaks are all patched. There are no - you can't have light leaks on Hubble, okay?

So being on the day side or the night side of Earth, it still can take data. Especially at the early parts of Hubble, you could not take data where it was crossing the terminator because the solar panels started to wiggle as it crosses the terminator. I don't know if that's still a problem here 19 years later but I know it was a problem in the beginning.

And as I said, there’s certain areas in the Earth’s magnetic field - one area called the South American anomaly where the electronics goes a little funky and we don’t take data during that as well.

Man: Thank you.

Frank Summers: Okay, let’s move on. We’re on Slide 16, Houston, we have a problem. We’ll move onto Slide 17 and this is one of our first releases from the Hubble Space Telescope. And on the left is a ground-based image of a double star. Astronomers can immediately tell it’s a double star because it’s elongated and stars on good - for good telescopes - this is a good telescope by the way - would appear circular.

On the right with Hubble you can see the double stars resolve. And this is a slide to show that look, you know, even without any correction to the telescope, it had better resolution than ground-based telescopes, all right? A lot of people think it had horrible misconceptions that Hubble was totally broken after the start - no, it wasn’t totally broken. It just wasn’t meeting specifications.

And on the next slide, where it says comparative use of the star, on the left side is what a point source looked like before we put in the Corrective Optics. That’s what COSTAR stands for - Corrective Optics Space Telescopes - yada yada - I can’t remember all it. [Corrective Optics Space Telescope Axial Replacement]

But anyways, so you can see how it’s a big splotch of light. Well, if you go to the next slide, you can see after COSTAR, all of that light is then down into basically a pin point. And so the first servicing mission put in COSTAR and got it from its - the fuzzy image on the left to the refined image on the right. And that’s how we got Hubble fixed. [Hubble's "workhorse" instrument — the Wide Field and Planetary Camera 2 (WFPC2) — is behind most of the famous Hubble pictures. Specially designed small mirrors within WFPC2 correct for Hubble's spherical aberration, while COSTAR was designed to optically correct the effects of the primary mirror's aberration on three other instruments, the Faint Object Camera (FOC), the High Resolution Spectrograph (HRS), and the Faint Object Spectrograph (FOS).]

And we move to the next slide for the M100 galactic nucleus. We can see this sort of fuzzy image on the left for using Wide Field Planetary Camera 1 of the center of M100.

And if you go to the next slide, you can see Wide Field Planetary Camera 2 image of the same thing. And you can see how much finer resolution. It's just a blurring of a light - all those individual point sources get spread out. So it may be blurring on the left and on the right to achieve its design specification, okay? And so these are the images I like to show to say look, you know, they did it. They really did it. They got it right in fixing the problem.

Okay, any questions on the initial telescope problem on those four slides? Great, all right, we'll move on to Slide 22, the Hubble servicing missions.

Okay, Slide 23, Servicing Mission 1 was in December 1993 and its main mission was to put in COSTAR. And it also installed Wide Field Planetary Camera 2. Now this is kind of special because when [JPL] built the Wide Field Planetary Camera 1, it was just called Wide Field Planetary Camera at that time.

[JPL] also built an exact duplicate [in anticipation of the next servicing mission] because somebody was just being cautious. Well, because we had this exact duplicate, because [engineers] could figure out the exact problem with the optics in the telescope, [JPL] modified Wide Field Planetary Camera 2 to adjust for the flaw in [Hubble's] mirror with Wide Field Planetary Camera 2.

So what we did on Servicing Mission 1 is we just pulled out Wide Field Planetary Camera and dropped in Wide Field Planetary Camera 2, a direct replacement. And it had the correction in it and produced those beautiful images of M100s that you just saw.

We also replaced the solar arrays - remember I always said the solar arrays were wiggling as we were coming across the terminator going from day to night. Those solar arrays were replaced. It didn't fully fix the problem as I remember it. We also replaced gyroscopes. Gyros are moving parts, okay? They are spinning tops basically in order to point the telescope. So they spin to process of inertia and they maintain their direction in space.

And you cannot make space age gyroscopes because things that are in motion, things that move, eventually wear down. Gyroscopes will be a very important problem that I'll discuss later under Servicing Mission 4.

All right - and so by the way, the image in the upper left is the actual image of them replacing Wide Field Planetary Camera 1 with Wide Field Planetary Camera 2. I'm not sure which one it is because they basically look identical so I can't tell.

All right. Moving on to Slide 24, Servicing Mission 2 was in February of 1997. And here's where we started putting in new instruments that we had previously planned to develop and put in. WFPC2 was really sort of a target of opportunity in new instrument. NICMOS which is the Near Infrared Camera, Multi-Optic Spectrograph and the STIS, is the Space Telescope Imaging Spectrograph.

Those were two new instruments, NICMOS being an infrared camera, STIS being a spectrograph to replace what was the previous spectrograph, the Goddard High Resolution Spectrograph that went up at launch.

We also replaced one of the fine guidance sensors; this is how Hubble points itself. The Solid State Recorder, this is actually cool. It wasn't until 1997 that Hubble was recording onto digital discs basically digitally, okay. It was recording analog mode up and through 1997. The Hubble finally got a digital recorder in 1997 and the Reaction Wheel Assembly which I don't know much about so I won't say much more.

Okay, any questions on those first two servicing missions? Great, I'll move forward, Slide 25. Servicing Mission 3A was one that had to go earlier than expected because we had a gyroscope failure in November 1999. And it was - well basically without enough gyroscopes, you can't point Hubble. So Hubble could not do science.

And so we - the decision was made to make an early - to split Servicing Mission 3 into two components. Servicing Mission 3A was basically maintenance of the telescope, okay?

As you can see at the bottom of this slide, the computer, the data recorder, another fine guidance sensor, electronics improvement and thermal protection, all sorts of things that improved the telescope but we didn't change out any instruments. So we didn't change the science capabilities of Hubble in Servicing Mission 3A. It was more of a visit to the shop, bring the car in, do a brake and a lube job and so on and so forth for 3A in 1999.

The changeout of instruments happened in Servicing Mission 3B in March of 2002. And this is where we put in Hubble's most powerful camera to date, which is ACS, the Advanced Camera for Surveys. ACS was a significant improvement over Wide Field Planetary Camera 2. It had, you know, ten times the discovery space is what they like to say.

Basically it had, you know, really high resolution and much better detectors in it. And actually, you know, one of the really cool things about it was the optics, the codings on the optics in ACS really were such an improvement, they had- they provided several orders of magnitude - not orders of magnitude, several, yeah, several multiplier effect in terms of the sensitivity of the camera.

We also of course did do maintenance stuff, again, solar arrays. Now this is one, NICMOS cooling system was a repair of NICMOS. NICMOS, the cooling system didn't function as long as we had hoped it would be. And they devised a backup version. And this was really cool because this was where we started to get very inventive in how we handle Hubble and that the astronauts were very confident that they could do repairs in space that really had never been expected to be done in space.

And so the NICMOS cooling system and in particular the power control unit were two repairs that the astronauts had to train for very carefully. And when we replaced the power control unit, the guy at NASA said "Hubble is now without a heartbeat." Hubble was basically without power for several hours while they changed the power control unit back out. But it came up just fine after Servicing Mission 3B.

All right. And so we finally get to Servicing Mission 4, currently scheduled for next month, May 2009, where we will install two new instruments, Wide Field Camera 3 and the Cosmic Origin Spectrograph - I'll tell you a little more about those later. And there's a whole suite of maintenance things, the ACS repair, the STIS repair, gyros, batteries, Fine Guidance Sensor and thermal blankets and the DO remodel. Again, I'll tell you all about that later.

This is the standard photograph of the astronauts as they, you know, standard publicity photograph. But of course, they had some fun with it. On Slide 28, you can see the Atlantis 2025 picture which for those of you who don't get the reference, this is like the Ocean's 11, I think, or Ocean's 12, one of those movie posters. So kind of cool for that.

All right, on our next slide, it shows you the - well, let me just stop there. Any questions on the servicing mission quick overview that I just gave?

Man: Yes, question. The camera, a lot of times people refer to cameras at home with the number of megapixels. Is there an equivalent for this?

Frank Summers: Yes. For the Advanced Camera for Surveys, it's a 16-megapixel camera. And the word camera is really kind of misleading because the public then starts to think about it well, it's like you just take snapshots which of course is totally wrong. I mean, Hubble is meant - is a scientific instrument that's meant to see much, much more than the human eye can see whereas a standard digital camera is meant to show you what the human eye can see.

So if the camera is a catch phrase that we use for simplicity's sake. But they are detailed scientific instruments. And ACS with 16-megapixels, WFPC2 is 1,600 x 1,600. So what does that make it, 2.5 megapixels. Okay?

Man: I have one quick question for you. Was the Hubble Ultra Deep Field picture taken with the ACS?

Frank Summers: Yes, the Hubble Deep Field, the first one in 1996, was taken with WFPC2. And the Hubble Ultra Deep Field was taken with the Advanced Camera for Surveys. It was taken relatively soon after ACS was installed to make sure that we got it done and that ACS was operating at its peak efficiency as these detectors tend to degrade over the course of time.

There is question as to whether when we put in Wide Field Camera 3, whether we shall take yet another deep field, Wide Field Camera 3 will have more sensitivity than ACS. But that's questionable how much more sensitivity that will provide enough science case for doing another Ultra Deep Field. That's being debated within the building right now.

Man: Put in a vote from me to do it.

Frank Summers: Okay. I will pass that along. Any other questions before we move on?

All right, great. So the next slide is a view of the focal plane of Hubble from 1990 through - and how it's changed over the various servicing missions. So in deployment, you can see the three Fine Guidance Sensors, which is sort of the banana shaped things around the edge. And then the various instruments where they are located on Hubble's focal plan when Hubble was launched.

In 1993, you can see the changes that we went with so WFPC2 is the major change there. In 1997, you can see there was no - or SM2 - actually NICMOS wasn't there in 1993. Yeah, no I'm sorry - no, SM2 we added in NICMOS, I take that back. And NICMOS had just come in 1997, it's 1999 when things didn't change with WFPC2 and NICMOS and STIS there.

And you'll notice that the Fine Guidance Sensors as they get changed out, they get changed - their numbers from FGS2 to FGS2r, etcetera. In 2002 with Servicing Mission 3B, we added ACS. And in SM4, which this slide says 2008 because it was produced last summer and I didn't get it changed for this talk. It actually should be 2009 of course. We'll add in WFC3 and COS. And hopefully we'll have a repaired STIS and a repaired ACS.

I don't really like looking at the focal plane but a lot of geeks really enjoy it. I prefer these diagrams that were made here in the Office of Public Outreach. So on Slide 30, you see the four axial instruments, the four along the axis. Those are the telephone booth sized ones. And then if - down bottom is the radial instrument which is the Wide Field Planetary Camera 2 - Wide Field Planetary Camera.

And in 1993, we swapped out WFPC2 and added in COSTAR - that's the yellow box. The yellow telephone booth is COSTAR; the red triangular shaped one is WFPC2.

Moving on to Slide 32, you see in 1997 the addition of NICMOS and STIS. And in 2002, which is Servicing Mission 3D because 3A we didn't change anything, we added an ACS. And in 2009, we will put in WFC3 which is the yellow box, taking out COSTAR which is no longer used, by the way. And Wide Field Camera 3 replacing Wide Field Planetary Camera 2.

All right, so those diagrams are usually pretty good for helping to understand where the instruments are in the telescope. Okay - what?

(Vanessa): (Unintelligible).

Frank Summers: I'm sorry, the yellow box is COS. Did I say something different? Okay, I'm sorry. All right, thank you. Vanessa is here at the table with me and she's corrected me. The yellow box is COS; the red triangular thing is WFC3 in this last diagram. Okay, any other mistakes I made? Sometimes you just don't hear yourself speak when you're talking.

All right, so any questions about those last few things on the things before we move on to the anomaly of last year?

All right, great. The next slide says, Hubble, we have an anomaly. All right - and moving forward, this is the picture of the space shuttle on the launch pad 39A and 39B at Kennedy Space Center in late September of 2008. Let's see, Atlantis is in the foreground. What's the one in the background? You guys remember, is that...?

Woman: (Unintelligible).

Frank Summers: Endeavor. I believe it was Endeavor. Atlantis is in the foreground which carries the instruments for Hubble and Endeavor is in the background as a possible backup mission in case there is severe problems with Atlantis, they needed to have another space shuttle on - ready on the launch pad just in case a rescue mission was required.

Unfortunately, in the beginning of October on the next slide, you see the Science Instrument Control and Data Handling Unit. This is not the one on Hubble; this is the one on the ground. And this instrument had an electronics failure late September, early October 2008, just two weeks before launch.

And basically this unit is the unit that talks to the science instruments. That's why it's called the Science Instrument Control and Data Handling Unit. I'm sorry - control and - SIC and DHS - right. I've got to get my acronyms right - SIC and DH here.

And so the data comes off those scientific instruments that I just showed you, goes through this unit and gets formatted and then gets sent - and then is prepped to be able to send down to the ground, okay? So if this instrument - this piece of hardware isn't working, then you can't get data off the instrument. So the data can take all the data off - the instruments can take all the data they want, it's never going to get to the ground.

Now this piece has two - like everything on Hubble basically - has redundancy to it. It has an A-side to electronics and a B-side to the electronics. The A-side operated fine for 18 years and then it went kaput. So then we very quickly switched to the B-side but that of course gives us a single point of failure.

And since we had a virtually identical - not absolutely identical - but very close to identical unit on the ground, the decision was quickly made to that we were going to delay the servicing mission from October of last year in to 2009. And at the same time, we're then going to add to the manifest for Servicing Mission 4, a replacement of this unit.

So a lot of the reasons for the delay until May of this year is because they had to flight qualify the SIC and DH that's sitting on the ground. They have - it wasn't - as I said, it wasn't absolutely identical. Close to identical but the hardware in it had to be space qualified, okay, it had to make sure it can handle the atmosphere, the radiation that is (unintelligible) actually the radiation fields that are in Low Earth Orbit.

And so that was shown, you know, they originally thought they were going to be able to get it done in February - by February of 2009. That was pretty quickly shown not to be the case. And so that's why it's not going until May of 2009, okay.

And so if I remember correctly, the individual component on the SIC and DH is called a CUSDF, which is the Control Unit Science Data Formatter. So you got to learn your acronyms if you want to work at NASA.

And so the CUSDF had - there were two pieces to it and so one of them failed and so they switched to the other one. And that's what we're operating on right now. We're operating on what we call the B side of the CUSDF of Hubble right now. This whole thing will be replaced during Servicing Mission 4.

Okay, any questions on the anomaly as they called it back in late 2008?

Okay, great. Let's move forward. And now we're going to get to the really serious stuff, SM4. They have quite an ambitious workload. And this is a direct quote from one of the higher up - very high up folks at NASA. It says this final mission will be without doubt the most complicated and challenging that NASA has ever mounted.

You remember how we talked about the NICMOS cryo cooler replacement and the power unit changeout in Servicing Mission 3B? Well, those are, you know, relatively simple - those were really challenging at the time but they came up with even greater challenges for Servicing Mission 4. But you know, you listen to the astronauts and they came here to the Space Telescope and talked about this.

And to them it's like the greatest thing because it's really - if they get a challenges but they have various practices, they're going to practice it and they'll have - they say by the time they get up there, it'll be clockwork. So let's hope it goes as wonderful as they say it will.

So what are the major goals for Servicing Mission 4? Those are outlined on Slide 40. And they are basically enhance the scientific capabilities which is put in the new instrument, restore capability which is to repair failed electronics on STIS, the Space Telescope Imaging Spectrograph and the failed electronics on ACS. ACS unfortunately failed on - a few years ago and we've been working. We're back with WFPC2 by the way as our main workhorse camera right now and has been for almost two years now.

And then upgrade - this is to do all the maintenance stuff in terms of the Fine Guidance Sensors, etcetera, you can read it there. And the big statement at the bottom is if successful, HST will be at the height of its power with six working complementary science instruments and, you know, it'll be the best it's ever been.

How are we going to get it to be the best it's ever been? Well, let's go forward to Slide 41 - oops, let's not go to Slide 41. Let's go back on Slide 40 and ask for any questions on this before I move on because the next one's a little complicated slide. Any questions out there right now?

Rick Varner: Yes, this is Rick Varner. I was wondering if the replacements of the data processing, if that comes before this workload or after it.

Frank Summers: The replacement of the SIC DH is part of this workload. This slide was produced last year. So it would go into the upgrade or -piece of it. So I didn't actually include that because I just talked about it in this talk. But I'll mention that, yeah, this is part of it.

And it has a higher priority in my understanding - and I'm going to say I'm not a NASA spokesman so you can't quote me on this. But in my understanding, it has a higher priority than either the STIS repair or the ACS repair. But perhaps not as high priority or equivalent priority as with WFC3 and COS instrument installations, okay?

All right, Slide 41 is the EVA timeline - EVA standing for Extravehicular Activity and it's basically our space walk time line. But note this is as of July 21, 2008. Again, I didn't get the - I prepared this talk last year and I didn't bother to get the new one because the new one is going to be like this. And this gives you the character of it.

But the point is, is that there are five space walks and they are quite full, each of them as you can see lasting six and a half hours for your time walk - your space walks. They have the battery modules, they have the WFC3, they have COS and STIS and ACS repairs, etcetera. And you can see the ACS repair is broken up into two different parts and the Fine Guidance Sensor and various things.

So they plan their space walks extremely carefully. As I said, they practice them and they figure out the time that they expect and need for them and pad that, of course. So what's not included in this of course would be the SIC and DH repair, a swap out. But the astronauts say that's basically really easy because they're only, you know, four to ten - four major bolts and about six minor bolts that need to be taken off.

And so for one of these repairs, you'll see there's over 100 screws that need to be changed out. So they consider SIC and DH, you know, a very simple thing compared to some of the other things. The other things are much more complicated and I'll get to those in just a minute.

Moving forward to the next slide, let's talk a little bit about Wide Field Camera 3 because this is going to have new science capabilities and really become the next workhorse camera for Hubble.

On Slide 42 you see a picture of it. And again, it's that same sort of triangular shape that goes in as the radial instrument in Hubble.

Slide 43 is just tech - is the information about it. It has two cameras in it, one that is near ultraviolet and optical - that's what they call UVIS - the UVIS channel. And the infrared camera, the near infrared camera. What makes this special is that it really does go from the ultraviolet through the visible to the infrared. And that's the phrase in the center saying, that's the first truly panchromatic camera.

We've had cameras that can go from ultraviolet through the visible and only a tiny bit into the infrared really before. And vice versa, we didn't get the ultraviolet. This one goes across all three band passes that Hubble is capable of looking at.

And it is significant improvement on the previous instruments. The UVIS channel is over 30 times the discovery power of Wide Field Planetary Camera 2, a little less on ACS. And I'll show you some graphs in a second that will make that clear. And the IR channel is a huge improvement on NICMOS, especially in the near infrared.

So moving forward to Slide 44, this is the graph of the limiting magnitudes that you can get to with the cameras. It's a little complicated here but let's start on the left side. And you can see that dark blue line, okay; at the top it says WFC3 UVIS. Okay, so that's the UVIS camera on WFC3. And higher is better here, okay?

The green line beneath it that says ACS HRC, okay, shows you what the high resolution channel could do. And this is on the left hand side; you're getting into the ultraviolet. And you can see there's a huge difference, okay? UVIS can get, you know, almost two orders of magnitude greater sensitivity than HRC in the ultraviolet, you know, WFPC2 can't even really go as far into the ultraviolet as UVIS channel can.

So we will be getting brand new capabilities in the ultraviolet for imaging with this - WFC3. We'll really be able to see ultraviolet and if you don't know, ultraviolet's extremely important when you're looking at star formation regions. Young stars, especially the most massive stars that only live for a short amount of time, radiate copiously in the ultraviolet.

You can find - you want to study star formation regions, you want to study these young stars. You really want to be able to look in the ultraviolet. This will have brand new capabilities for Hubble in the ultraviolet WFC3.

On the right side of that same plot, you can see that from say out 500 nanometers up to 800 nanometers, the difference between WFC3 and the ACS wide field camera, ACS/WFC, really isn't that much different, okay. And even the HRC at ACS.

So from about 500 nanometers to about 800 nanometers, WFC3 isn't going to provide a huge improvement over what we could see with ACS, although it will provide a huge improvement over WFPC2, the same sort of improvement that ACS provided over WFPC2. And remember, we are currently observing with WFPC2. So if ACS doesn't get repaired and we'll have a similar jump from WFPC2 up to Wide Field Camera 3 after this instrument.

Finally, on the right hand side, going from about 1,000 nanometers to about 2,000 nanometers, you can see the infrared part of the spectrum. And so the red line represents NICMOS and the blue - dark blue line represents WFC3, the infrared camera. And again, you see that you get, you know, half the magnitude or so in the infrared.

And again, you're getting new capabilities in the near infrared around 1,000 nanometers that NICMOS couldn't go to. So we're getting significant improvement both in the ultraviolet and in the infrared WFC3, although for most of the visible, we're just restoring back to the capabilities of ACS.

Let me stop here and ask if there are any questions on this. Okay, great, let's move forward.

Slide 45; the other new instrument that we are inserting is called the Cosmic Origin Spectrograph. And again, it is - this is the picture of the telephone booth and the clean room as it was being readied for shipment to the Cape.

Slide 40 - what happened to Slide 46? It went directly from Slide 45 to 47. Did I miss one here? All right, well if there's a hidden one, I apologize. Slide 47 now - all right, this is too much information on this, okay. But I took this directly so that those of you who wanted all the detailed information could get it.

The most important points are, you know, this is going to be an ultraviolet spectrograph, okay? You can do spectroscopy from the ground, okay? And you can do it really well on things like the Keck [Telescope] where you can just do an - collect an awful lot of photons. Spectroscopy needs an awful lot of photons.

But what you cannot do from the ground is ultraviolet observations. Ultraviolet photons are just absorbed by Earth's atmosphere. So the optimization for cost was to do spectroscopy in the ultraviolet, okay? So we have the two channels, the far ultraviolet channel and the near ultraviolet channel.

This is the same ultraviolet region where WFC3 will provide such a marked improvement over the previous imaging cameras, will evolve to have a (?) imaging spectroscopy improvement in the ultraviolet. Let's see - the cool thing about the far ultraviolet channel is that we're able to basically learn from NASA's FUSE mission - the Far Ultraviolet Spectrographic Explorer, FUSE, and learn from that.

And a lot of people who worked on FUSE are across the street at Johns Hopkins University. Space Telescope [Science Institute] and they were able to provide their expertise in helping design Cosmic Origins Spectrograph as well.

And then in the near, ultraviolet channel - nothing particular jumps out at me except for the - for both of these channels, recognizing that it records the arrival time of every detected photon which is kind of cool.

If you think about detecting your photons and then tagging each and every one of them with their arrival time, that gives you a lot of information that you can work with when you're trying to deconvolve this data and trying to figure out what's going on. Most of this is probably going to be gibberish to most of you but it's there if you need it.

Okay, moving on to Slide 48. Here is the part that actually makes a lot of sense to most people. Again, these are graphs. And on this graph, lower is better because this is the flux, this is the minimal amount of life that you can observe with something. And so the green line is STIS, one of the detectors on STIS. The red line is another detector on STIS and then the purple and blue lines or pink and blue lines are what we would get with COS.

And again, we're looking at factors of three to factors of ten improvements with COS. And you can see that this wave length range is in angstroms. I apologize; astronomers like to use angstroms instead of nanometers. But to get - to go from angstroms to nanometers, just divide by ten. So really you're going from about 110 nanometers on the left hand side of this plot to 180 nanometers on the right side of the plot. So this is heavily in the ultraviolet region, okay?

So even though we call it left side one far ultraviolet in the near one - near ultraviolet, we're still nowhere near the 400 nanometers which is where the ultraviolet turns into violet light and visible light.

Okay, so we're looking definitely - heavily in the ultraviolet here and we're getting factors of three to factors of ten improvements in our ability to detect photons with the spectrograph.

All right, any questions on COS or WFC3? All right, wonderful.

Let's move forward to Slide 49 where it says the ACS repair. And so ACS failed as I said about two years ago in January of 2007. This repair is to me the most dangerous thing that they're going to do. Again, ACS was never meant to be serviced in space. But it's provided a ton of really cool science. As somebody noted, the Hubble Ultra Deep Field was taken with ACS. So we'd really love to have this back.

And again, if the electronics has shorted out. But in order to access the electronics, they actually have to cut through a grill, all right. And they have to be able to cut through the grill and the astronaut has to reach in and replace something inside that.

And when you're wearing a space suit and you cut through a grill, you just naturally think that there are going to be sharp edges to things all around on that. So just the description of it just sort of frightens me at having to do it. But once again, the astronauts who visited Space Telescope said, you know, yes it's going to be difficult. But again, they can handle it. They've designed everything that need to do to be able to do it carefully.

Now the reason why we want to repair ACS - you may look at the previous graphs and say, well wait a minute, WFC3 is going to do everything that ACS can do, right? Well, true but not true. The important point is that each of these cameras has different filter selections on it. In order to optimize the science that you want done with the instruments, you choose the filters that you put in front of the light to, you know, to bring through only red light or yellow light or green light.

Well, actually, in Hubble we, have these very narrow band filters that only let through a very specific wavelength light. And the filter set selection on ACS is going to be different, similar in some respects but different from what's on WFC3.

And there are certain science that we've already started using on ACS and had to stop when it failed that would be best served if we could also have access to those filters on ACS and continue to - the continuing observations with the same set of filters on ACS for under - for consistency in the scientific data analysis and being able to compare apples to apples.

There are programs that were done with ACS that we would really like to continue with ACS if possible. And there's slightly different capabilities with those filters so ACS can do a slightly different set of science than WFC3.

So it won't be - if ACS is not repaired. It will cripple Hubble. But if it is repaired, it will give it, you know, a, you know, a bit extra capability. Restore some capability that we had and we will do an - and it will enlarge the scientific questions we can't address. Any questions on the ACS repair?

Okay, let's move forward to Slide 50. We also want to repair the Space Telescope Imaging Spectrograph. This one failed back in August of 2002. Now this is really funky because there are over 100 fasteners - basically screws - that the astronauts need to take out.

And you think about, you know, pulling out 100 screws. All right, when you do it at home, right, you pick them up, you put them on the table, you clear a space on the table, you drop all your screws down and then you try and make sure you still have all of them when you have to put them back together at the end of it, you know?

But the thing about doing it in space, when all those screws could float off, well of course they can't do it like that. So what they designed is a capture plate that they put on top of STIS and they pull out the screws and the screws drop into this capture plate. And they aren't going to actually be put back on.

They analyzed the design of it and they said, you know what, we overdesigned this by putting 100, 110 fasteners here. We can get away with doing like, you know, ten or something like that, okay? So they're going to take off 100 fasteners, drop them all into the capture plate. And then they're - when they replace the panel on STIS, they're only going to put in less than 10 fasteners and that should hold it.

So you know, they're recognizing that had they designed STIS to be repairable in space, they would have designed it differently. And of course they didn't design it to be repairable in space but they've come up with the solution in the meantime.

Now once again, STIS does have similar capabilities to CO, COS will do a lot of the science that STIS was designed to do. But again, there are slight differences in the design of it that will increase our ability to do more science if we have STIS alive as well.

So it would be again, it's all about maximizing the amount of science we can do with Hubble and increasing - keeping our capabilities and options open because, you know, you never know what astronomical problems are going to arise.

I mean, back in 1990 when Hubble was launched, we had not observed any extra solar planets. I mean, none, not a single extra solar planet had been observed. And Hubble, these days, has actually taken spectra of the atmospheres of extra solar planets, okay? How cool is that, okay?

I mean, to go from science that was never envisioned to being able to, you know, look at the atmospheres of planets. So that just shows you how much science can change over 20 years. So it's good to have as much capability as you can to answer as many questions as you can.

All right, any questions on the STIS repair? All right.

Anita Sohus: This is Anita. We're coming up on the one hour point.

Frank Summers: We are? Okay.

Anita Sohus: You can stay or others can stay but I thought I'd mention it.

Frank Summers: I figured I had about ten minutes left.

Anita Sohus: Okay.

Frank Summers: But I see I only had five minutes. All right, that's usual for me. I tend to enjoy my talks...

Anita Sohus: We have the line if people - if you want to continue and people can stay . . .

Frank Summers: Okay. The next slides will go pretty quickly, okay? The gyros, the - when Hubble was launched, three gyros was the nominal operating mode. As I said, we went to two gyro mode in 2005 in order to sort of preserve the gyros waiting for this servicing mission. Currently on Hubble, three of them have failed, two of them are operating and one of them is turned off as a spare.

We move to Slide 52, you see a graph of the gyros and their failure modes. On the left is the gyros as the completion of Servicing Mission 1. And you can see that most of them failed by this FL mean, where they had read that's a flex lead failure.

On the right are the gyros that were installed in SM3A. And you can see, one had failed by this flex lead failure, two of them have a rotor restriction failure, two of them are still on and one of them is off. You'll notice the one that is off is right around the 75% failure probability, okay, so that's the reason for turning it off.

While D6, as you can see over on the far right is way down low in terms of its run time in years. Whereas G1 is the one we would be really worried about because it's hitting its 50% failure probability. So this is the reason why we want to replace these six gyros.

The ones on the left hand side of the - the G1 through the G6 on the left hand side are the ones long ago that were replaced. And so the ones on the right are the ones that we are currently in Hubble and that we are worried about, okay? And these are the ones that will be replaced. This is why we need to replace them because they do fail after, you know, 50% failure probability after five and half years of operation, okay?

Man: All six of them will be replaced?

Frank Summers: Yes, all six of the gyroscopes will be replaced. Other questions? All right, moving forward, the batteries - Slide 53. You just can't point without batteries. Yes, Hubble does have solar panels where it gets energy but those solar panels basically are served to recharge the batteries. Hubble does go through night.

And when it’s in night, it doesn’t have any light shining on those solar panels. And so it then drains the batteries. It doesn’t drain them fully but, you know, has a charge and discharge cycle as it goes from day to night.

And so it’s gone through about 100,000 charge/discharge cycles because Hubble has made over 100,000 orbits, okay? So on Slide 54, we show you the problem with the batteries.

Now as you may notice from your own camera - your batteries for your digital camera or such that as you take these rechargeable batteries and use them and recharge them and use them recharge them, use them and recharge them, the maximum capacity of those batteries goes down over time.

And so this plot here starts in 1990 and shows the total battery charge slowly decreasing. And then in about 2002, it starts to decrease on a faster rate. And this red dotted line extrapolates that, the saying that would get below, you know, around 200 to 100 ampere hours which is a critical point where the NASA engineers say look, you can’t operate below that, okay, because we just can’t - if Hubble loses all its battery charge, then it could start tumbling. And once Hubble starts tumbling, it’s gone. You cannot catch a tumbling satellite.

Fortunately, they have a complete set of these batteries on the ground that have also gone through these 100,000 charge/discharge cycles. This is amazing foresight, okay? On the ground, they take the same - a relatively identical set of batteries, they charge them and discharge them, charge them and discharge them - just like is happening on Hubble.

And so they’re able to study them and figure out, well, how can we reverse this slide, how can we slow down this slide of the total battery charge? And so they figured out a new method for doing things with batteries. And on Slide 55, you can see in 2006 that they’re able to actually reverse the decrease in the total battery charge and get it back up to 300 ampere hours or so.

And that is one of the saving graces because, you know, we originally predicted the batteries to fail by 2009 and have a reasonable rate of failure by 2009 and here we are in 2009. So basically changing the way we handle the batteries allowed us to wait this long to be able to do this servicing mission, a very important point.

All right, moving forward. On Slide 56 is the Bay 8 thermal situation slide. And during Servicing Mission 3B on the left, you can see Bay 8 and Bay 9. And on the right, you can see the close up of Bay 8 and you can see the thermal protection for Bay 8 has - was degraded. Slide 57 shows you the patches that we put on Bay 8. We put patches on them during Servicing Mission 2 and the - we expect however that these patches will be degraded, okay?

So we are expected to repair and repatch Bay 8. Now you may not think well, what does this matter, why is this extremely important? It's just, you know, the blanket on top of it.

Well, this is a complex graph on the next slide. Well here, actually this one is really easy - it explains - it's basically the average temperature - the maximum temperature over 12 hours over the course of time. The left hand side of it is 1991; right hand side of it is 2007. And this basically shows you the trend is to go - the temperature is to increase in Bay 8 over time, okay? It goes up, comes back down after patching goes up and it's getting up towards what they call the yellow alarm limit, all right?

And so if Bay 8 gets too hot, it actually can cause us to lose the ability to point the telescope where we want it to.

We move forward to Slide 59. The blue dots represent where we - the attitude of Hubble when we have pointed it. The X axis is the roll and the Y axis is the sun angle. And so all those blue dots are where we have - the attitude of Hubble when we pointed it in previous observations.

If Bay 8 - if we can't have Bay 8 pointing directly towards the sun, if Bay 8 has to be on an angle to the sun, we have a 30 degree instance which is the small circle, a 60 degree instance which is the next larger circle and a - I'm sorry - 45 degree instance is the next larger circle and 60 degrees is the next larger circle. Everything inside those circles would be excluded if Bay 8 continues to have problems, okay?

If we get over the red limit and we say look, we can't - we have to be able to - we have to point Hubble so that Bay 8 is not directly towards the sun and has to be at a significant level, you lose an awful lot of your pointings, okay? So while this is, you know, just the thermal insulation, we're replacing the thermal insulation in the attic of Hubble, it actually has a huge impact on the science - the scheduling of where we can point - how we point Hubble, okay?

So this - I always thought this was like, okay, yeah, they're just patching things. And it actually has a much larger implication than even I thought.

Any questions on Bay 8 here or other things? All right, moving forward to 60. This is just a series of slides to show you that the preparations we've already done for SM4. And again, these slides are from last year. I didn't update them because it's the same stuff they're doing this year.

Okay, Slide 61 is the high fidelity mock up of Hubble on the ground and all the folks in their bunny suits, all right? This is not just a model of Hubble; it's an exact model of Hubble that exists in the clean room, okay? So when we create instruments for Hubble and we each want to test new things with Hubble, this is the high fidelity mock up where we can do - where we can almost replicate exactly what will happen on Hubble.

Everything that is before we send things up to Hubble to be done there, even, you know, software stuff, we test it here first.

On the next slide, we have the fit check. This is the actual piece of hardware for WFC3, going into the high fidelity mock up to make sure that it fits in exactly as it is predicted to, okay? So they put - they practice multiple times making sure that WFC3 will fit in the way they expect it in high fidelity mockup before they get it up into orbit.

On the next slide, we have the same thing for COS. This is the-- they insured COS was built to the specifications it's supposed to and fits into the high fidelity mock up so that we don't get any surprises when we get up there in space trying to do the same thing.

Slide 64, the ASIPE fit check - and I really - I look at this today and go, man, I don't remember what ASIPE stands for. [Axial Science Instrument Protective Enclosure] But basically these are the boxes that will be in the shuttle cargo bay, okay? Because before you put things into Hubble, of course you have to put them into the shuttle and so have to make sure the instruments fit and are secured as they should be in the cargo bay.

So before they send them down to the Cape, they test them again in the clean room to make sure that they will fit in the cargo bay the way they're supposed to.

Slide 65 shows the astronauts in the neutral buoyancy lab. Okay, now the neutral buoyancy lab is basically a giant swimming pool. And in that swimming pool, the astronauts are in their space suits.

And you'll notice there's some bulkiness around the space - around the legs of the space suit? Those are weights put on the astronauts so that they are what's called neutral buoyant. Basically they float in this. They don't go up, they don't go down. They float in the swimming pool as if - and it's the best way of simulating what will happen in space.

So in the neutral buoyancy lab, they also go through all the procedures with the same sort of feeling as if they were in space. Of course it's not exactly the same but the astronauts tell us that it's a really good approximation. It really gets you used to do all things.

So they get a full mock up of the shuttle cargo bay in the neutral buoyancy lab. Here they're pulling the WFC3 out of the storage container in the cargo bay. And on the next slide - Slide 66 - you can see an astronomer - I'm sorry - an astronaut on the end of the robotic arm. And he is being taken over to the mock up of Hubble (unintelligible) lab to perform that.

Note that the robotic arm is being controlled by another astronaut who is in a mock up of the shuttle cabin and he's looking through that same tiny little hole - tiny little window that he gets to look through on the shuttle. So they really do mock up everything the way it is done in space so that they really have a great - so but, you know, this is - they practice and practice and practice it so that the runthroughs in space will err in just repeating what they've already done many times over.

Finally, on 67, this slide here is to - this is the completed battery module, okay, it's one of the two battery modules - I take it back. There are two battery modules that will be replaced.

And this is the completed battery module here on Slide 68. This is pictures of the equipment as it is at Kennedy Space Center in Florida - the upper left is COS, the lower left is WFC3. And on the right I believe that's battery module - one of the battery modules.

So they're in the clean rooms. Actually right now they're in the shuttle Atlantis which is already on the launch pad. The shuttle Atlantis rolled out to the launch pad on Tuesday. So two days ago, shuttle Atlantis went out to launch pad so all this equipment that you see here is on the launch pad right now awaiting that May 12th launch.

Slide 69 - well that's May 12th, 2009, that's the target date. Of course, you know how things do slip. But hopefully, on Slide 70, this is what we will see May 12th and we'll see the space shuttle go up and we'll have a marvelous and wonderful repair mission to Hubble.

And finally, a few months after that, we'll get what we see on Slide 71, Hubble images on the cover of the New York Times announcing that Hubble is back, Hubble has new cameras, Hubble returning to taking great science which is our early release observations.

All right, that's it for my talk and I will let you guys ask any questions you have.

Tibi Marin: Tibi Marin from [NASA] Dryden, I have a question for you.

David DelMonte: David DelMonte here. Oh, go ahead, I'm sorry.

Kay Ferrari: Go ahead, Tibi.

Tibi Marin: Okay, Tibi from Dryden. I'm going to be conducting a professional development workshop on the Hubble, just very close to the time of the Hubble's launch. May I have permission to use some of your slides?

Frank Summers: Yes, this is one of the reasons why I included so many slides here is that many people have asked me for these slides and so I want you to use them, okay? Please use them and if you need - if you have any questions on them, I'm happy to answer questions to see if improvements can be made on some of these.

Tibi Marin: Thank you very much. I appreciate that.

Frank Summers: Next question.

David DelMonte: Hi, it's David DelMonte here. Two questions; if you mentioned this, I apologize. I really enjoyed your presentation. Will there be a back up shuttle in place for this launch?

Frank Summers: Yes, the picture that I showed you from late September is pretty much exactly what it will look like this month at the Kennedy Space Center. So we'll have Atlantis on Launch Pad 39A and Endeavor on 39B ready for the back up.

David DelMonte: Okay, thanks. The second part of the question is, a couple of weeks ago there was an accident; a debris field was created when an Iridium and a Russian craft collided. There was some thought that that could affect the launch. Has that now been cleared?

Frank Summers: To my knowledge, yes, that has been cleared. But let me just specify that the old Russian - the defunct Russian satellite and the Iridium satellite collided a couple hundred miles above the orbit of Hubble. So it is disparate - it's distinctly far away in space, especially when you think of it in two - in three dimensions.

It does, of course, raise problems. But you know, the - I'm told there are like, 30,000 pieces of space junk out there - maybe even 100,000 that people are following. So NASA always, always does a complete review of any possible hazard from space junk for any of these missions, any shuttle mission.

And the official quote from NASA was we will, of course, review this as part of our standard review and take it into account and make sure that it does not pose a serious threat. They would have done that by now and my opinion - I don't know for sure because I don't pay that strict attention to it - when decisions get made. But it sounds like they did - they would have included it in their analysis and it appears to me that they have concluded that it does not pose an unacceptable risk.

David DelMonte: Okay, thanks. And just let me speak for probably for all of us the same, thank you so much for doing this and we look forward to the other side.

Frank Summers: We definitely look forward to the other side here at Space Telescope. We've been on pins and needles since, gosh, what, 2005 - ever since Sean O'Keefe, you know, canceled things, we've been on pins and needles.

David DelMonte: It's been interesting the public outcry. I mean, that's been wonderful.

Frank Summers: Yeah, it was very heartwarming for us here to have a second grader in Ohio run a lemonade stand to raise money to service Hubble.

David DelMonte: Yep.

Frank Summers: Okay. Doesn't that just pull on your heartstrings?

David DelMonte: Right.

Frank Summers: I mean, that was just wonderful. Other questions?

Tibi Marin: Tibi. About the thermal protection terms you have there for the Hubble. When you're making all the protection, what kind of materials are you using in there? I'm interested because as I train teachers, I'm trying to encourage them to use everything technology and chemistry and what kind of materials are you using for the thermal protection on the Hubble?

And if you have pieces left, you know, after you fix it like, you know, when you're sewing. It would be nice to have some samples of those and show it to the teachers as we do - I do a lot of professional development workshops in California and Arizona.

Frank Summers: Okay, I'm not an expert on this. I do know that NASA does have the sewing shop, if you want to call it, for getting these blankets made, etcetera. I'd have to research that. Does anybody on the call know better than I do?

Kay Ferrari: Yes, Frank...

Frank Summers: Speak up.

Kay Ferrari: This is Kay at JPL. Tibi, a few years ago, we sent blanketing material to all [Solar System] Ambassadors. You should have received some - sample blanketing material.

Tibi Marin: Never got one. Do you still have some extra.

Kay Ferrari: We still have some, yes. I can send you some.

Tibi Marin: That's fantastic because (unintelligible) Hubble up in space and we get all this...

Kay Ferrari: It's not Hubble blanketing material.

Tibi Marin: I know.

Kay Ferrari: It's blanketing materials similar to - well what it is, is it's scraps that are being made - the scraps left over from the blanketing material that's made for our spacecraft.

Tibi Marin: Exactly. But when the Hubble shoots into space and lowers the temperature, the coldness and the hotness...

Kay Ferrari: Yeah.

Tibi Marin: Of the space, it's important for the teachers and the kids to understand and relay those someway (unintelligible).

Kay Ferrari: Yeah, that's why we sent the blanketing material to everybody when we had it. And I believe we still have some scraps left over.

Tibi Marin: That would be great.

Kay Ferrari: Somewhere in the storeroom.

Tibi Marin: And I really appreciate your presentation as well because it’s very informative and what I needed for my workshop.

Kay Ferrari: Tibi, it went out with the Columbia pins. It was in that same package.

Tibi Marin: I got that...

Kay Ferrari: I know you got the pins.

Tibi Marin: I got the pin but I don’t recall because I keep every - all my space stuff with me.

Kay Ferrari: It was in the - it was in a poster tube. There was a poster, the pin and the blanketing material.

Anita Sohus: Can we deal with that offline please?

Kay Ferrari: Okay.

Frank Summers: Okay. And somebody here at Space Telescope passed me a note that said that it is a type of Mylar which is of course what you’d expect, looking at the - is it really just Mylar? And then say - and gold.

Kay Ferrari: There’s Mylar and the outer layer is aluminized Kapton.

Frank Summers: There you go.

Woman: But during the servicing mission we’re actually replacing - we’re covering - I don’t know if we’re - whether we’re - we’re facing or covering it up. But we’re using (unintelligible) stainless steel panels I think?

Frank Summers: Oh, that's cool. That's another - did you guys hear that piece of information, that we're using solid panels to cover up Bay 8 during the servicing mission. All right any other questions?

Man: You spoke very good about all the equipment that's going to be replaced and the status of it. What about the mirror? How's the mirror held up all these years? Any micro-meteor damage or anything like that?

Frank Summers: You get the standard cosmic ray hits that you get through all the detectors and everything. I can't imagine micro-meteorite damage to the mirror. Yeah, I could - I guess I could image it. But it is protected by being inside the tube with the telescope and all that stuff blanketing around it.

You know, the [power arm?] mirror has been around for, you know, 100 years and it's still doing wonderful things. Mirrors tend not to need a lot of servicing once they're polished. So the - I guess I really don't worry about the mirrors. I really - we worry a lot more compared to the worries that we have about the electronics and the instruments that take the data, they're much, much higher probability of problems going on there.

Man: Okay, thank you very much.

Frank Summers: Any more questions? All right, folks, thank you very much for listening, thanks for coming to this Hubble Science briefing. And we will see you again at a future briefing. Take care.

Woman: Thanks.

Woman: Good luck to you.

Frank Summers: Thank you.

Man: Good luck, thank you very much.

Man: Thank you.

Tibi Marin: Kay, can you stay on the line?

Man: Thank you.

Tibi Marin: Kay, can you stay on the line?

Kay? Kay?

Frank Summers: I’m still on the line. Did you want me to stay on the line?

Tibi Marin: If you would like to.

Frank Summers: I was just wondering...

Tibi Marin: Fantastic, fantastic, fantastic presentation. I appreciate that. And as a scientist taking your time for us is wonderful.

Frank Summers: All right. Well take care. Have a good - have a great day.

Tibi Marin: Thank you too.

Frank Summers: Bye.

Tibi Marin: Bye. Kay, you still there? Okay.

END