

**NASA MUSEUM ALLIANCE CONVERSATION
HUBBLE SCIENCE BRIEFING
Wide-Field Planetary Camera 2: The Camera that Saved Hubble**

**Moderator: Anita Sohus
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Coordinator: Thank you for standing by. Today's conference call is being recorded. If you have any objections, you may disconnect at this time.

If you need assistance during your call, please press star then zero and I will assist you. You may begin.

Anita Sohus: Welcome to the April 2008 Hubble Science Briefing. We have with us this morning Dr. John Trauger from JPL who is the principal investigator on the Wide Field Planetary Camera 2 which is Hubble's workhorse main camera.

So I'm going to without much further ado let John introduce himself and go through the presentation.

I heard - I know that a few of you have had some trouble downloading. I apologize. We'll see if we can troubleshoot that later today for you.

John Trauger: Okay. Well hello everybody. Very happy to do this. I hope that you folks will ask questions as we go along. I've not done one of these before and I could certainly use your guidance if I'm heading in the wrong direction any time.

This is a little bit of a history. It's history and possibly used for the word - for the Hubble Telescope.

The Wide Field Planetary Camera 2 was placed - was launched and installed in the Hubble Telescope nearly 15 years ago.

And so it is the oldest instrument on board. And it's coming home at the end of the year as you know.

So what I think we want to do here is tell the story of WFPC-2 and some of the interest, human interest that went with fixing the Hubble aberration problem and the wonderful outcome and some of the early science results that showed we were on the right track. And I'll do all this in a few slides.

I also sent - so I sent some slides that are in PDF format. And I also sent an

essay which I hope you folks received.

One of them kind of tells the human interest story. The other one is pictures that illustrates the development and early days of Hubble - of the WFPC-2 in Hubble.

Frank Summers: Anita, this is Frank at Space Telescope. We didn't see that on the Web site. Is it there now?

Anita Sohus: Yes.

Frank Summers: Okay, we'll download it.

Anita Sohus: John, do you want to say a little bit more about that? It's a chapter that you and Steve Maran [press officer for American Astronomical Society] were working on for a book.

John Trauger: Oh I don't want to say too much about it. We were - Steve Maran and I were working on a book nearly ten years ago. It didn't get published but I was just looking it over recently and I thought it would be a useful thing to include. And I could happily talk to that later.

Well so some people have the pictures and some people don't. The story all began as I think you're all familiar on the 24th of April 1990 when the whole Hubble mission was set in motion when Discovery launched the Hubble Space Telescope.

We had of course really high hopes. And we still do for all the science that can be done with Hubble.

Primarily we know that Hubble is a telescope that operates above the Earth's atmosphere and allows us to have unparalleled acuity at visible wavelengths, very large fields of view. That's Hubble's special niche.

And it - as we - as it was advertised in advance, a ten-fold increase in spatial resolution over a large field would indicate that we could see ten times deeper in space if we're looking for detail in the astronomical objects they're looking at, for example, stars and galaxies.

And that being the case, we can reach ten times further out into space, extend our - what used to be ground based astronomy outward into space by a factor of ten. That in some ways indicates we not can explore an area or volume of space that's 1000 times larger than was accessible from the ground.

So we had high hopes of - a very large breakthrough in what we could do.

The next slide -- and I have to apologize for those who have slides I did not put numbers on them -- is a cartoon by Gary Larson. It's something that I thought was really appropriate and conveyed the thoughts that were on everyone's mind just before the launch.

It's - maybe I should describe it. Is that a good idea?

Anita Sohus: Yes, you could just briefly.

John Trauger: I don't know if people have it then there's no need. But what we've got is it is three inmates who are burrowing their way out of jail. And they're about to reach what turns out to be the bottom of a lake.

And the first one to reach - just about to break through is saying we're almost free everyone. I just felt the first drop of rain.

What it conveyed was the real sense that once the Hubble mission began, a lot of things would start happening in a hurry -- orbital verification, science verification, finally guaranteed time observing would all begin happening in rapid succession and we knew we would be reacting to whatever went wrong, whatever surprises were there. That was the transition from planning to implementation. Everyone was ready for anything that might happen.

The next slide is one of many that appeared later on in the media. This one is Mr. Magoo. And it says, the caption is "The man who built the Hubble Space telescope". This is something that we discovered we were going to live with for the next three years.

The problem of imaging with the Hubble Telescope was something that nobody anticipated, complete surprise.

The next slide is a picture of the Hubble primary mirror. And as we know with a man standing nearby, as we know, you can't just look at it and see what was the trouble was.

But it had been figured to the wrong prescription. The next slide is a sketch, a cartoon of how it was in error. It was nowhere different or nowhere - well you think of the primary mirror as this cartoon shows as a very shallow bowl, very accurately figured.

But this bowl was to the wrong shape. The shape it should have been deviated from the shape it was by no more than as one way of looking at it, 1/60th - the thickness of a piece of paper. It was very slightly out of shape.

However, that was sufficient to create a range of focal positions for any given - it made the telescope fundamentally unfocusable.

The range of focal positions, the place where a star would image would spread from a point to a line about 4 centimeters long which is to say there was always some kind of a bright core of a star, but a big halo around it everywhere over a range of 4 centimeters.

Man: Now John this is at Space Telescope. We've heard that the error was due to just a small error in the measuring device for the mirror. Can you confirm that?

John Trauger: Yes, and that's one of the really - the really good news. In the sense that if you're going to have an error, this was the one to have.

Since the mirror was made to the wrong kind of constant it had a very precise and predictable shape which was a deviation that went as the radius to the 4th power as you went from the center of the mirror out.

So it was created by an error in the metrology. And so it was made quite perfectly to the wrong prescription.

Now fortunately it was easy to find out what that prescription was because it was such a simple error and to make plans to put that same error but in reverse into the optics of WFPC-2.

Did that answer your question?

Man: Yes.

John Trauger: And that really was the strategy that we hit upon. Because I probably should tell a few words about how this came to be.

One interesting aspect was that the - although we had planned for at least a year before the launch to have a very well orchestrated and carefully planned calibration period before we released any images, in fact it turned out that we found ourselves in a position where the media insisted and NASA agreed to show the very first data that ever came down from Hubble.

And so when the first image actually occurred, the telescope still hadn't even been focused.

The image tape was brought over. It was set up. Jim Westphal [of Caltech], the principal investigator for WFPC-1, the original instrument was there. And images were read out and displayed. They appeared in the New York Times

the next morning on the front page.

But there was a problem and it was that we had a sharp core. You could see a sharp image. But there was a skirt extended light around it.

Someone named Aden Meinel here at JPL who would be familiar to people who - well who spent most of his career at the University of Arizona, wanted to take a look at those images and made a suggestion which we ended up implementing.

And that was that if it was spherical aberration, the name of the aberration, that we would - we could in principle fix it with our second camera [WFPC-2], the camera that was coming along, that was actually in construction at the time of the launch by making a modification of some small mirrors. I've gotten ahead of myself in the slides however.

The next slide is a picture of a rather confused looking spacecraft with rockets going in multiple directions. The cartoon that seemed to come out, that seemed to appear in the media sometime around that - the time of the Hubble problems.

And I'll read this. Len Fisk [NASA Associate Administrator, Office of Space Science and Applications] had a very - a number of really interesting quotes. One of them was the measure of our agency is how rapidly we recover from problems. And I think we all took that as kind of our attitude.

The Hubble Space Telescope as you all know has been designed from the start for periodic replacement of its instruments. So the stage was set to replace an instrument with something that would correct the problem if we could implement it.

As I said though, the WFPC-2, the second version of the camera was already in construction. And the reason it was already in construction is because we had already anticipated that every three years there would be a servicing mission. And in fact, it takes more than three years to build an instrument.

So the idea was to build a camera and have it ready in case anything went wrong in order to guarantee the imaging of Hubble because it was considered to be a critical - a critically important capability on Hubble.

Since we had it well built, it was a matter of making some adjustments and continuing its build on a three year schedule so that we could be ready for the first servicing mission.

The next slide I have here is a depiction of what it looked like or what we

envisioned it would look like replacing the Wide Field and Planetary Camera in Hubble. And it's something where an instrument about the size of a small piano weighing something on the order of 600 pounds is maneuvered by fingertip pressure by the astronauts and slides like a drawer into the side of Hubble.

This is what was envisioned and it's what we ended up in fact doing.

I have an image - or the next one is an image of one of the technicians adjusting the pickoff mirror for the WFPC-2 while it was being built, one of several critical items just as a matter of interest.

So the next picture is the astronaut crew and one of their visits to JPL when they were looking at all of the - at the instrument and all of the tools that they were going to be using to install it and make sure it was installed safely.

There is another slide here which shows Jeff Hoffman, one of the astronauts, in the act of moving WFPC-1, the original WFPC aside so that the second camera could be put in place.

And finally we end with a slide of the Hubble telescope as it appeared following the servicing mission ready to go forward.

How are doing? We're doing fine.

Anita Sohus: Yes.

John Trauger: Okay. Well now - okay maybe I should also say there is a narrative which was also distributed which kind of - which I've just kind of given a synopsis of which you might find interesting if there are any questions about - maybe Anita, you could tell me what I'm missing about the story. I'd like to move on to what we found when Hubble - when WFPC-2 was finally turned on.

Anita Sohus: Anybody have any questions on the first part of the talk?

Man: John, I wasn't here at Space Telescope when this happened. But I've got to say out in the astronomical community, the idea of getting COSTAR to be able to really correct the aberration so carefully - I mean because you had to get down to, you know, tens of nanometers in the positioning of those mirrors and all those step-down motors and whatever you needed to do to do that.

I've got to say there was a lot of skepticism originally. How was it within the team?

John Trauger: Okay, well that's fun. I should begin by saying the timing was such that we

recognized -- and this again is based on Aden Meinel's suggestion -- that we could do the - implement the correction in WFPC-2 with almost no changes to the camera itself. So we felt pretty safe that we could predict - that we could do this on schedule.

And in fact, the - there was a very interesting pivotal dramatic meeting when all of these facts, all the problems and possible solutions were brought together near the end of June just a couple months after the launch.

And at that time we proposed our fix for the Hubble instruments for the WFPC-2, excuse me, not for the other Hubble instruments.

The COSTAR was something that came along later. The Space Telescope Institute. Riccardo Giacconi [founding director of the Space Telescope Science Institute] convened a strategy meeting to review all the options for all of the instruments.

And I think that began, that first meeting was in August I believe. And it reported out in October. But it reported with something that would be a modification of something called the STAR, the Space Telescope Access Replacement. It was a box that had already been built. It was basically an empty box, a placeholder that was meant to be installed in case one of the actual instruments had to be removed. It would fill the space and keep the structure stable.

So it was realized that that box could be used. It could be some extending arms and mirrors could be installed in that. And it would be called - originally it was called Smart Star. It eventually became COSTAR. [COSTAR is designed to optically correct the effects of the primary mirror's aberration on the Faint Object Camera (FOC), the High Resolution Spectrograph (HRS), and the Faint Object Spectrograph (FOS)].
(http://www.stsci.edu/hst/HST_overview/, downloaded 4/27/08)

Now the skepticism I think was not so much whether we could do this with WFPC-2. It fit right into the schedule. In fact we have a very firm schedule for development in - by July of 1990.

It was would we make an error in the prescription? Would we know the error, you know, what we were building it to, accurately enough? And then would we negotiate the really unusual situation where we purposely make an instrument that doesn't focus but doesn't focus in exactly the right way?

In other words, the errors that we were building in to WFPC-2 were just as profound as the errors in Hubble in the first place. And we needed to prove it. It was exactly compatible.

So we did end up with a lot of unusual or unique test procedures which I think have - became - are now commonplace with Hubble instruments because they've all been built since in the same way.

There's a fundamental difference in the way WFPC-2 did the correction. Because it was done really at the right place, at a pupil inside the instrument, it was a complete correction such that we recovered the entire field of view and the exact characteristics that we had hoped for originally.

COSTAR was very different. It did not change the internal workings of any of the instruments that it fixed. Instead it moved the pupils around, changed f/ numbers and so on and was not an appropriate correction for a wide field of view.

So there's very - we make a very big distinction between how the correction was done for WFPC-2 and how COSTAR operated.

All of the instruments since the first service mission have been built with this correction the same way that WFPC-2 was and none of them used external mirrors like COSTAR.

Woman: The COSTAR only corrected the error for some of the instruments.

John Trauger: Well, you know, it was put in place - there were four actual instruments. The high speed photometer was removed and brought home to make room for the COSTAR. And so the COSTAR was literally eyeglasses, lenses put - or mirrors put out in front of the faint object camera, the faint object spectrograph and the high resolution spectrograph -- those three instruments only.

Okay, well a lot of the - let's say the visual impact of what Hubble really did for us, it surprised - interesting statement. We all knew what to expect. We all knew intellectually what to expect when the imaging became what Hubble was capable of.

But I think it nevertheless surprised everyone to actually see it. It was really stunning. I have a number of images that begin to convey that thought and that sensation that we had.

First image is one of the Andromeda galaxy, the Andromeda galaxy, which is known to - known widely. It was the galaxy in which - one of the galaxies in which . . .

Anita Sohus: Somebody is typing. Could you please mute—press star 6--or I will have to

have the operator cut your line. Thank you.

John Trauger: Okay, the idea here is that (unintelligible) Hubble is...

Anita Sohus: Yes, if everybody could please mute or I'll call the operator and see which line is giving us the interference.

I'll go out to Peggy's desk.

John Trauger: Okay. All right. All right so here we have an image of the Andromeda galaxy. It's 2-1/2 million light years away. It is a galaxy that Edwin Hubble observed from Mt. Wilson--which is within sight of my office here-- back in the 20s and in which he was able to discern Cepheid variable stars individually.

And this is a nice illustration of what happens. At 2-1/2 million light years we were Edwin Hubble at the Andromeda galaxy.

The next image is the M100 galaxy, a galaxy considerably more distant, 56 million light years away in which the Wide-Field Planetary Camera-2 image is shown.

In this image within the field of view I can tell you, although the slide certainly does not have the resolution, that one can resolve 40,000 stars in this one frame among which about 40 were Cepheid variable stars. And that - what that meant was that we could in essence, extend Edwin's technique from galaxies that are a few million light years away to ten times further or more from the earth.

And what that did - what that meant was that there was now on the order of 1000 times more galaxies because we're looking ten times as deep into the volume of space to select galaxies that would be most appropriate for calibrating secondary distance standards and ultimately to determine the Hubble constant, a number that came out around 72 kilometers per second per mega parsec which I believe stands to this day and is in general agreement with more recent other determinations such as WMAP [Wilkinson Microwave Anisotropy Probe] (<http://map.gsfc.nasa.gov/> downloaded 4/27/2008).

So this was one of the first indications that indeed everything was working well with Hubble. A second one which I think will stand as one of the most stunning achievements we can point to was the first Hubble Deep Field. This was a period of ten days in December 1995 when WFPC-2 was pointed at a single dark area in the northern sky.

Three hundred forty-two separate WFPC-2 exposures were superimposed in various colors to create an image of what basically would be the tapestry of

the dark sky. On the order of 4000 galaxies could be seen in this field. There are all kinds of things in there, all kinds of galaxies, gravitational lenses -- quite a variety of things.

And it was really the beginning of what became a series of Hubble Deep Fields in deeper fields and even more expansive surveys of this kind with newer instruments as time went on.

The next slide shows just a scattering of other deep fields taken with Chandra and with other observatories, radio observatories and so on that this spot in the sky became very interesting for a number of, let's say multi wavelength and other observatories to kind of get a more comprehensive view of what was in there, what was in the deep background objects.

The next slide is a cartoon of a gravitational lens, a gravitational lens being a galaxy that distorts and amplifies the image of a more distant object.

And the next slide is an image of a galaxy cluster Abell 2218, a really spectacular image absolutely filled with gravitationally lensed more distant galaxies.

Okay, all right. I hope - you know, if you don't have pictures, this isn't going to work so well.

The - it's a - it's really not conceivable to give a good review of all of the images and all of the diversity and interesting things that have been done, the well over 200,000 images that have been taken with WFPC-2.

But one interesting direction to take is in the next slide which is an image of a star-forming region in the galaxy M33. And this slide shows a ground-based image and a little square area in that ground-based image which has been expanded to the WFPC-2 image in color.

And here you see that we are observing star-forming regions, a star-forming region in a galaxy that's 2.7 million light years away. All right, it kind of introduces the idea that star forming is another interesting area besides the distant and oldest areas - most distant reaches of the universe.

The next slide is an artist depiction -- just introduced the idea of where planetary systems come from -- the debris, the dust and gas that's left behind.

When a star forms, eventually it accretes and organizes itself into planets. And this is a cartoon, but then the next slide which is a mosaic of specific to images taken of the Orion Nebula is an example of a nearby star-forming region.

And the details that we saw in there were new. This is about 1500 light years away. The Orion Nebula is an interesting object. It's a very bright cavity within a - what is otherwise a dark molecular cloud.

The cavities are being cleared by some very massive stars embedded in it. And as they clear the nebula away they uncover and blow away the obscuring gas and dust surrounding what turn about to be about 100 small stars with various disks and bubbles of material around them.

Two of those which are within this image are shown as an inset. They both look like little black disks with a star in the middle. One is edge on and one is more like face on.

And the dimensions of these objects are comparable to our solar system. So we're looking at objects that are very young stars surrounded by disks of gas and dust which will be potentially forming planetary systems.

These stars are no more than a million or so years old. And so there's a very early - it's a very early look at where planetary systems come from.

These details - well these details were really quite exciting to see for the first time in 1994.

The next slide is a - another example that - of an object, a young stellar object in this case known as HH30. And in this case it's a dark disk with a young star in the middle. But this time the disk is almost precisely edge on so it blocks the light of the star.

And what we see then are like two little glowing patches above and below a dark line which is the illuminated part of the galaxy, excuse me, of the accretion disk.

And then heading upward and downward in the picture is a very fast jet of ionized material. So here we have on this slide two views of a very young stellar system in the process of forming what could be a planetary system.

One is edge on and the other one is face on with a - back lit in a very unusual way because in the Orion Nebula, the walls of the cavity in the molecular cloud are luminous.

The next slide is another example of a star forming region. This one is HH34. Here we don't see the star but we do see the evidence of the stars there, a flare of light and a powerful jet heading from - in the picture from right to left.

And interestingly somewhat distant, quite a ways over to the left side of the picture is what looks like a shockwave -- brilliant colors where that jet is impinging on a bubble of interstellar material, ionizing it and making it glow.

Yes the reminder that we're lucky to see forming planetary systems at all because normally they're - this sort of thing goes on in the dark in the middle of a dense cloud of gas and dust.

The next slide is one of the more widely known pictures for some aesthetic reason. It's the Eagle Nebula. It's the pillars of gas and dust.

It's - the Eagle Nebula is about 7000 light years away. The phenomenon is very similar to what we see in the Orion Nebula which is considerably closer. But now we're basically looking at it from the other angle. Instead of looking at it from the top down, we're looking at it from the side.

And we see the structures which are eroding away. The most dense regions are resisting - are resisting and still existing. But eventually ultraviolet light from the - from some very massive stars are going to wipe away and blow away the gas and dust that we see and reveal all of the stars that lie hidden within these pillars.

Man:

John, I have a question. We've had beautiful astronomical pictures forever. I mean I grew up with the wonderful pictures from Dave Malin [[Anglo-Australian Observatory](#)] and everything. But for some reason this image caught the public's attention.

I mean is it just the fact that we got such high resolution with WFPC-2 that allowed us to see just enough level of detail or these were processed in some way that that - it seemed to just catch the attention? Or was it the fact that, you know, we had a broken telescope and now it sticks and it's a sense of nationalistic pride? What do you think it was?

John Trauger:

You know, to me it's about as stunning as the Orion picture which came earlier. In my mind they're very similar. And they're - and they're exciting for the same reason.

You can see these structures that are solar system size. They're, you know, within a factor of a few of the size of our solar system in here.

And in the Eagle Nebula you can see some of these stars beginning to poke of the - you know, of the - and so it's the detail. But, you know, exactly which image - there are some other images I'll show you that I've gotten a lot of feedback on that are exciting for different reasons. And I don't think it's predictable.

I think some people see dogs and cats when they look at this. I don't know.

Woman: I think the question, John, was is this image so high resolution, is that due to the camera or is that due to processing after the picture was taken?

John Trauger: Well okay, maybe it's worth saying that the resolution is there in the camera and that's the exciting part.

The colors are often chosen to bring out detail. These are false color and I - and we used to have somewhat of a controversy over, you know, are these real colors or not?

Since these are images of emission lines, often are images of emission lines, we can use them to reveal structures that are related to the ionization state and things like that.

But the colors may be interesting as well. The colors are kind of the artists' choice just - in this case, Jeff Hester's choice of colors.

I don't know it's - maybe it's because it almost looks familiar.

Woman: I call it the alien family -- mama, daddy and baby.

John Trauger: Okay, the next image was one of these things that we were just very lucky to be ready for. In July '94 just a couple months after we'd - well six months after we'd gotten things really going, Comet Shoemaker Levy-9 decided to crash into Jupiter.

And it was rather spectacular. Each of 23 fragments one by one crashed into Jupiter.

This is a picture of Jupiter, a sequence of four images, the first of which shows the - what we saw 5 minutes after the impact of the G fragment.

And the - because of the way things are going, the fragments all crashed into Jupiter just over the horizon from our view.

But what we see in the first image, the first of these four images is the plume that was thrown up by that crash.

So you see the plume peering over the limb in the first picture.

A couple hours later -- 100 seconds later -- 100 minutes later I believe, was the second picture. And there you see the debris field that was left behind by

that fragment. And the following two images show what happened a couple days and then five days later as that structure began to just swirl away in the atmospheric winds.

It's kind of an illustration of how handy it is to be in Earth's orbit but ready to look anywhere in the solar system. There's quite a number of interesting things that happen. The ring crossing, ring plane crossing of Saturn for example, that Hubble was able to observe.

But then moving on, there was an opportunity to learn more about the evolution of solar systems, of stars and their systems, kind of from womb to tomb, the recycling of material from a star back into the galaxy and then the recondensing of that into the next system of stars.

We were just - we've just been looking at what happens when you have a preexisting cloud of gas and dust.

This next picture, the Egg Nebula, is an example of where some of that dust comes from and where a lot of carbon and nitrogen is injected into the galaxy for the next generation of planetary systems.

Here you see once again, a hidden star because it's wrapped in a donut or a Taurus, a cocoon of dust. You don't see the star directly, but you do see its searchlight beams coming out either way, to the top and the bottom, to the left and right.

And illuminated by these searchlight beams from the star are many rings. They look like the rings in a tree rings if you like.

These are shells of material that have been thrown off from the star over the past 10,000 to 20,000 years. So it's very recent in time. And it is a short period of time while the star, Red Giant is throwing material back into the interstellar medium and about to become - uncover the white dwarf star in the center.

When that happens, a lot of ultraviolet light will make it out into the nebula and it will be transformed into a - what's known as a planetary nebula.

The next slide shows an example of that. Nebula Hen-1357 is quite distant -- 1800 light years. What's really interesting about this one is that's it known to have turned on, that is transformed itself into a planetary nebula which is glowing in the ionized radiation from its gases just 40 or so years ago, an example of things that really do happen on short time scales.

It's an indication that the previous slide, the Egg Nebula is an example of a very rare event to see because it doesn't last very long. Ten to twenty thousand

years is a very short time compared to the lifetime of a star.

So here we see the stages of this transition.

The next one is another slide which is - somebody asked has raised a lot of interest because it looks like an eye floating in space. But that's an accident of I can tell you, of colors that were chosen.

This is an image of what we're calling the etched hour glass nebula. And what you can make out if you just imagine for a moment is what looks like an hour glass, one lobe of which is headed in our way and one which is headed more or less in the other direction away from us and etched all around inside the shell of this hour glass are bright emission lines.

There's a central bright area and a star which actually is off center. So there's lots of mysteries about this as well. But that central star is what is radiating the ultraviolet light that in turn powers this whole nebula.

So here we see a mature planetary nebula of which there are many examples. The next one -- and there really are many examples like snowflakes that they're really not very much alike -- is an image of the Eskimo Nebula, another example of a planetary nebula.

Other exotic species that were observed include Eta Carinae which is the next slide. And I know that the - what we saw when we first saw this image it completely reversed what we thought was going on.

If you look at the image, you can imagine - I'm sorry I don't remember the person who suggested this but it's a visualization, a solid object. It looks like a solid object. It's made of dust reminiscent of an ant wearing a tutu, two lobes and something squirting out of the waist.

We didn't know that that's what it was like. I know that the scientists looking at this for the first time had first thought that what now look like two lobes, one coming towards us and one going away looked with lower resolution to be a donut.

And the thing that we now recognize as a tutu was thought to be jets coming out of that donut out of the north and south poles of the donut. This has completely changed our view of it. Certainly an example of what - how instantly a picture can change our view of what's going on.

The last image I'm showing is the Supernova 1987A which is a very distant object. This is a rare event to see a Supernova, especially to see one this young.

Obviously 1987A indicates that it was first observed from the Earth in 1987, but it's 170,000 light years away in the large medulla on a cloud in another galaxy.

What you see is detail that will not be there very long. And that - and it's rings. There's a ring once again, maybe the waist of an hour glass. There's two other rings that are presumably written on the sides of an hour glass and in hydrogen emission lines. And the entire structure's on the order of seven light years across.

What happens and an illustration of two things on the next slide is that some things in astronomy you can watch actually change. And the appearance of that central ring which is brilliant in the light of ionized oxygen is doomed to be swept away as the actual material from the Supernova reaches it and just blows it apart.

And what you see then in the mosaic of pictures, the last picture I have here is the evolution of that ring between September 1994 and November 2003.

And what you see is that the ring begins to illuminate first here and there and then everywhere as the material from the Supernova reaches it and creates the shocks and new emissions.

And in time this whole structure would be blown away and if we go and look we won't see it at all.

This slide also illustrates something else which is interesting. And that is the continuity that's possible with the Hubble telescope. This is - this includes - this is the one slide here that includes WFPC-2 images and images from the Advanced Camera for Surveys which came afterwards.

Advanced Camera for Surveys had approximately the same, somewhat larger field of view as the WFPC-2. But it had a newer generation of CCD sensors, higher quantity efficiency and uniformly smaller pixels. So the resolution and the sensitivity was improved.

Also it's perhaps worth noting, the CCDs, all CCDs that are on the Hubble degrade over time. So the renewal of the - you know, the new instrument with its new sensors is always a good thing.

So this illustrates the continuity of science as you move from one instrument to another. And it also - it's also maybe in anticipation that after 15 years the WFPC-2 is going to be actually removed and replaced with another camera, the Wide Field Camera 3 which will again cover a lot of the imaging tasks that

WFPC-2 and the Advanced Camera for Surveys - let's see, I guess you probably know by now that WFPC-2 is still working.

The Advanced Camera stopped a few years ago and all this is going to be fixed when the next servicing mission occurs, the replacement of WFPC-2 with the Wide Field Camera-3 and the repair of the Advanced Camera for Surveys all are scheduled for later this year.

Okay, I'm very near the end here. I have a cartoon here of WFPC-2 feeling a little bad because he's going home. But after nearly 15 years of operation, I think we need to consider this a great success. And we're looking forward to seeing the new camera, Wide Field Camera-3 in its place. And that's it for my presentation.

Anita Sohus: Great. Thank you John. One question I have is Wide Field Planetary Camera-2 and Wide Field Camera 3, will we be able to take the same kind of planetary pictures with the new camera like the Shoemaker Levy crashing into Jupiter? Will those be possible?

John Trauger: Yes, they should be.

Anita Sohus: Okay, with Wide Field-3?

John Trauger: Yes, Wide Field-3, yes.

Anita Sohus: Okay. All right.

John Trauger: The filter is slightly different. And it's worth pointing out that the wavelength range will be extended the nearest red to 1.7 microns beyond the wavelength range of WFPC-2.

So you could think of Wide Field Camera 3 as a panchromatic camera going all the way from 200 nanometers to one - 1700 nanometers in wavelengths.

Anita Sohus: Anybody have any other questions for John?

Man: Yes, I have a question. Are you expecting with the Webb telescope in a few years, are you expecting another giant increase in our capability of how far we're going to be able to see? Have you worked on any of that?

John Trauger: Yes, very interesting. The James Webb telescope is going to be built - it's main objective is to extend into the longer wavelength range. So it's basically a - that can be used out to - that is a defraction limited camera at 2 micron wavelengths that will work out to, I don't know, 17 microns.

It will not - it does not have higher resolution, spatial resolution than Hubble. It's a larger telescope but its diffraction limited at 2 microns instead of about 1/3 that wavelength. So the actual imaging - image quality will be very similar.

Okay, so the main thing is it's going to the longer wavelength range.

Anita Sohus: Which means it'll see - into one area of time.

John Trauger: It'll see deeper in dusty areas and star forming regions. And the first light in the universe is the mantra.

Man: I have a question John. I'd like to know - I mean you've shown us planetary stuff. You've shown us star stuff and nebula stuff and you've shown us some galaxy stuff and some cosmology stuff.

If you had to pick the greatest achievement of WFPC-2, its legacy of 15 years of service, what would it be?

John Trauger: Well I still think that the first Hubble Deep Field is a stunning thing. We really didn't know -- I mean, you folks at the Institute can correct me -- but we really didn't know what we'd see. And it's just a Rosetta Stone of just about everything in the universe.

So I have a feeling that that's one of the most significant of lasting value accomplishments.

Man: Fair enough.

Anita Sohus: The sound bit or whatever for the Deep Field, it's the size -- correct me John if I'm wrong -- if you held a grain of sand up against the night sky at arm's length...

John Trauger: You could block it.

Anita Sohus: ...you could block the Hubble Deep Field. And yet within that Hubble Deep Field there's what, 3000 galaxies and only two or three stars.

John Trauger: And if you really look there are 26 stars.

Anita Sohus: Twenty-six.

John Trauger: Only a few bright ones. It's a pretty empty area as far as our galaxy's concerned.

Anita Sohus: Are there other questions?

Vanessa Thomas: I have a question. This is Vanessa Thomas from Space Telescope.

Man: I have a question.

Anita Sohus: Let Vanessa go first please.

Vanessa Thomas: What will become of WFPC-2 when it returns to Earth?

John Trauger: What I have heard is it's promised to the Smithsonian to be displayed at the Smithsonian.

Anita Sohus: I'm assuming they have handling equipment onboard the shuttle for strapping it down once they remove it?

John Trauger: Well Wide Field Camera-3 is very similar on the outside for a good reason, it has all the same dimensions and connections, latches and everything as WFPC-2.

So the box that Wide Field Camera-3 is coming up in I presume is the same box that WFPC-2 came up in years and years ago.

And it will clearly - it absolutely positively will fit in. So I mean one interesting possibility is that Wide Field Camera-3 will come home this year. But we don't know what's going to happen to all the rest of Hubble. It doesn't fit into the shuttle bay anymore.

I don't think it would be considered safe even to take pieces off and try to make it fit. So I don't know what the future of the rest of Hubble is, but at least we'll have this artifact here on Earth to remind us of, you know, these early days of Hubble and space astronomy.

Anita Sohus: Right. I think so after this repair mission it's planned for operations at least through 2020 where they would have to start thinking about de-orbit options.

John Trauger: No, that's about the time when the solar max would de-orbit Hubble all by itself.

Anita Sohus: Any other questions?

Man: Yes sir. I have a question. To the general public, I mean obviously to you guys over who built this thing who really worked so hard on it, obviously these pictures when they first came in were really, really exciting.

To the general public however, they don't have the anticipation that you guys had. How would we bring that to them, as a solar system ambassador?

Anita Sohus: We're thinking.

Man: Well we here at Space Telescope would immediately say show them ground-based photographs first.

As John did in his talk he showed you what M100 looks like from the ground and then when you show what it looks like from Hubble, it just changes everything. But that's our first guess here.

Man: So you'd show the ground-based ones first. Thank you very much. That's really helpful.

Anita Sohus: I think a lot of people have grown up with Hubble images and don't realize what a treasure did not exist before now for the last 15 years.

Man: Yes, I know myself that I was one that grew up with those pictures as well. And so even listening to the briefing today, it's been really exciting. It's brought the - a new vision to these pictures myself. And I'd like to bring that to the people I present to as well. Thank you.

John Trauger: Great.

Anita Sohus: Thank you. Yes, we're - I mean it's a remarkable instrument to take both Wide Field and... to correct internally for distortions on the primary mirror. And it's just looked at an amazing array of phenomenon out there that we would not have known about otherwise.

John Trauger: Yes, it fulfilled the promise of Hubble from the beginning.

Anita Sohus: Yes.

Man: No, I couldn't agree more. I sat in my tele astronomy classes when Hubble came out. So maybe I'm dating myself but it sure made a difference to me.

Man: One more question please?

Man: Yes.

Paul Cirillo: This is Paul from New Jersey, another solar system ambassador. Thank you for taking the time to do this. I really appreciate the invite. I particularly like slide Number 20 where you have the drawing of the gravitational lens.

John Trauger: Yes.

Paul Cirillo: And a lot of times when I'm showing the deep space field picture I try to describe what's happening there but I don't think I do a very good job of it.

Could you take another minute with that slide and talk it through a little bit if you could?

Anita Sohus: The gravitational lens?

Paul Cirillo: Yes. I think it was Slide 20.

John Trauger: Yes, okay.

Paul Cirillo: It's a great - I like it because, you know, it has the numbers there, the digits and shows how they're distorted but...

John Trauger: Well I can tell you that this cartoon that you see was - appeared in - I know I saw it in Scientific Americans so I probably am violating some copyright to use this. I'm in trouble now wherever this is. But...

Anita Sohus: There it is. Yes, John's got a printout [of the presentation] so we're looking...

John Trauger: I don't have any page numbers. Oh, here it is. Okay so what it's showing is in the distance, a familiar pattern of numbers, 1, 2, 3, 4, 5.

The galaxy is something that's going to bend the light rays in a way that is very peculiar. It's been described for a single galaxy, a single massive spot centered in front of an object as like looking through the bottom of a wine glass.

It's a peculiar lens. It's not a lens for real imaging. And it's that distortion, it's acting just like a lens except it's made out of gravity. And so it's kind of punching a hole in the pattern as it passes through and you see more or less nothing in the middle of the field and a vastly distorted number 5, 4, 5 and 6.

I don't know if there's a better explanation, but if - when you look at the next image and you see all of these arches that look so much like what happened to the numeral 5, you get a... where that's really what does happen.

In the case of the image there's so many gravitational centers that it's even more confused. There are quite a few galaxies in the field.

Paul Cirillo: The object that's causing the defraction, in this case the galaxy, does any of that come through?

John Trauger: In - well in the case of the image of Abell 2218 which is the next picture, you can see the elliptical galaxies, the yellow blurry. Maybe I didn't make this clear -- the yellow and blurry objects in that image are the lensing galaxies.

And the curving arches are the distorted images of other galaxies that are maybe five or ten times further away.

Paul Cirillo: Okay.

John Trauger: So you're looking right at the lens. And it's possible people have done this to estimate the mass associated with each one of these little - each one of these elliptical galaxies and predict what the lens should be doing and some reconstructions of what's on the other side have been done in some cases.

Paul Cirillo: Very good. Thank you very much.

Anita Sohus: We're a little over our time. Any last questions for John?

Man: I have a question. Can you hear me?

Anita Sohus: Yes.

Man: Yes, I'm sorry. I have laryngitis. Has there been any more talk about bringing the Hubble back to Earth? I know at one point there was and I wasn't aware that it wouldn't fit in the shuttle anymore. Why would that be if that's the way it was carried up?

John Trauger: Well I'm not the one to argue it one way or another. But I have observed there are a number of things. For example, the NICMOS [<http://www.stsci.edu/hst/nicmos/> downloaded 4/27/2008) camera which used to be cooled by a cryogen, you know, a solid...

Man: Right.

John Trauger: Okay, is now cooled with a mechanical chiller. So that's a mass that's attached in a place that is not secure, you know. It's not secure for launch or return.

Man: Yes.

John Trauger: So there's a mass - that's an example of a mass that is not properly mounted for the vibration and forces.

Man: Right.

John Trauger: Furthermore, part of that very same structure is a solar panel or - not - excuse me, a thermal radiative panel which is attached to the outside of the Hubble. So, you know, heat pipes come around and attach to this thing which is now external and has expanded the envelope of where Hubble is.

I think it's - there are two such panels now on the shady side of the Hubble. There are masses that have been added. Now the solar panels have been exchanged. They don't roll up. They're fixed panels. They would need to be thrown away which I presume could be done.

But I really think that we've reached a situation where it would not be considered safe for the astronauts or for the shuttle to have something that could break loose on return and start crashing around in the - I shouldn't even speak this way, but start crashing around in the shuttle bay.

Joel: Well this is Joel from Chicago. The thing we've got to remember too is that there's only so many shuttle missions left. They are ending the shuttle program in 2010. There's even instruments they're not going to be able to bring up to the station that are built on the ground.

So there's going to be no way - there's going to be no shuttle to even pick it up even if we wanted to.

Man: Right. Thank you.

Anita Sohus: Okay, John and Frank, I assume there are going to be another telecon or two this summer about the servicing mission and all the logistics of getting to the Hubble with a second shuttle on the pad in case it needs to go rescue the astronauts -- going to be some high drama this summer.

Frank Summers: Yes, that there will be. And we do plan on doing - on having these briefings every month.

I was going to tell you that Peter McCullough will be our speaker for next month, but then I looked at my email and saw that Peter had rescheduled to June and I forgot who jumped into the May slot.

So May 1st, the Thursday May 1st we will have a speaker. It's in my email, but not with me here in the conference room.

Anita Sohus: Okay, well thank you very much everybody and especially thank you to John for a wonderful talk and showing us what the Hubble has - you know, just a peak at some of the magnificent sights the Hubble, the WFPC has given us over the years.

And we'll see all of you - the next Hubble Science Briefing, first Thursday every month and unless you come on some of the other mission briefings as well. Thank you.

Man: Thank you.

Man: Thank you.

Man: Outstanding job.

Man: Thank you.

Man: Thank you. John, does the name (Bill Rayford) ring a bell with you?

John Trauger: I'm sorry, who?

Man: (Bill Rayford) from (Perkin Elmer) years ago?

John Trauger: I'm not placing the name.

Man: Okay. No, I met him recently and he said he was the main person from (Perkin Elmer) who was working with explaining what happened with (Amera).

John Trauger: Oh gosh. Well I certainly know people at Perkin Elmer- I guess now known as Danbury.

Man: Right.

John Trauger: (Kerry Facey) and others.

Man: I just thought it was coincidental. I was on vacation last week and simply happened to meet him on vacation. He was telling me what he was doing and what he had done. And that was it and now here I'm talking to you.

So I - if you don't recognize his name, then no big deal. But anyway, he's doing fine.

John Trauger: Sure. Okay.

Man: Thank you again.

END