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Moderator: Heather Doyle
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Heather Doyle: Thank you. Welcome everyone. We're really excited today to hear from Dr. Bolton. Again my name is Heather Doyle from the Solar System Ambassadors program. So we have some large slides. As I mentioned earlier if you need any help, please email Kay Ferrari. She will help you with that. So please remember to mute your phones. It's star six if you're not sure how to mute your phone and please do not put us on hold because sometimes phones have hold music. So that will disrupt the talk. But I'll turn it over to Courtney O'Connor now. She's the public engagement lead for the Juno mission and she's going to introduce Dr. Bolton for us. So Courtney, please take it away.

Courtney O'Connor: Hi everyone. Thanks for joining us today for our Juno science update. So as Heather said, my name is Courtney O'Connor and I'm the public engagement lead as you know. So although this will be wrapping up around 1:00 pm Pacific, I will stay on after if there are any questions about technical issues or products that we can send out to your upcoming events. So without any further ado, I'd like to turn it over to the principle investigator of the Juno mission, Dr. Scott Bolton. Scott, take it away.

Scott Bolton: All right. Thanks Courtney. Hi everybody. So I'm Scott Bolton. I'm what NASA calls the principle investigator, which is just a term to describe the leadership and management for the Juno mission which is currently orbiting Jupiter. So to talk a little bit what it was about and some of the results we're getting and show you some of the images and a couple little movies I hope you'll enjoy. If you have the PowerPoint that you loaded already, then you can start on the first slide and that first slide just says Juno up in the left-hand corner and then my name and the Juno team on the bottom right hand corner and a picture of an unrecognizable planet in the middle.

And so the first thing I want to draw your attention to is what you're looking at is actually a picture of Jupiter. It doesn't look anything like the Jupiter that we all know and love and that we grew up with and that's because you're looking at it from the North Pole. So this is the North Pole or maybe actually it's the South Pole. No this is the north pole of Jupiter. And this was the first time we got a close look at it or any look at it at all and it doesn't look at all like Jupiter. It doesn't have the features that you normally would see, the zones and belts and the stripes and of course the great red spot.

And so this is sort of a lesson a little bit in general science. I think that any time you take a look at something in nature from a new perspective, a different perspective than you're used to, you're likely to learn something fundamental about that. You're going to see it from a different view and you're going to see something maybe that you've never seen before and that's common in almost all fields of science or even, common everyday life if you just look at anything from another view, you learn.

And that's of course part of how NASA explores is we send the spacecraft and that was one of Juno's missions was to go over the poles of Jupiter which had never really been explored before and we carried a camera so we could take a look and see what it looked like. I can say that nobody expected it to look like this. If anybody had actually shown me this picture five years ago, I never would have guessed it was Jupiter. And I don't think very many people would have.

You see a whole series of cyclones all over the place and really giant, very long storms swirling around. The bluish hues are real. The pole looks very different. The other thing that's important to realize about this particular picture is any time you look at the pole of a planet, at least in our solar system, the sun is in what we call the ecliptic plane. So it's shining on the equator of a planet just like at the Earth. And if you were to look at Earth's pole or Jupiter's, it would always be only half lit of the planet would be at nighttime and half of it would be daytime.

And yet this picture is all lit and the reason is is that some amateur or fan of Juno because we post our pictures online -- we actually post the raw data and they make their own pictures -- they took a series of three different pictures, each one being half lit but showing a different part of Jupiter lit and then they pasted them together so that we could see what it looked like completely lit. Of course, you would only see this if the sun was over the pole of Jupiter but it was all fascinating. And when the science team first saw this picture, we were all amazed because nobody had thought of even doing something like that and it's part of the advantage of sharing your data with the public. They come up with ideas that we might not. And so the more people involved, the more ideas get expressed and so we got this fantastic picture.

Okay. I'm going to jump to the next slide [2], which is actually a movie. So if you're computer works like mine, inside PowerPoint you're seeing just sort of a piece of a half lit Jupiter pole. You move your mouse around. You should get a play button. You should see some sort of an arrow that shows like you can play a video. I'll take a second and wait and make sure people can try to do that. And then if you push that play button, this video is also on YouTube and Courtney can send you the links in case you can't figure it out through my PowerPoint. But if you play that, that video will start playing.

This is a video made by an amateur that processed the data himself -- or it's actually two people on missionjuno.com's Web site. And what you see they put it to music. If you turn on the sound, it's music from the movie 2001 A Space Odyssey. But the amazing thing about this movie is you're coming in close. So we go over the pole and then we scrape by Jupiter really close. We're screaming past it moving about 150,000 miles an hour and we get right up close. So you quickly see the movie to the point where you see something that you can't even tell it's a planet because you're looking so close. You're looking at a little tiny piece of the planet.

You'll see incredible swirls. I mean Jupiter is like a piece of art, like a Van Gogh painting or something. And you'll also see not only the stripes but you see little white dots sometimes in the whitish clouds. Those are thunderstorms we believe. They're sitting above the cloud base. They look like tiny dots but they're 50 to 60 kilometers across a piece. And those are storms of probably ammonia and water ice. This is probably where it's raining or hailing on Jupiter. And then you'll see it'll go down and you'll see some of the reddish stripes. These colors are probably enhanced by the person that made the picture, but they're probably not far from true color. They're just probably exaggerated a little bit.

And then as we go over across the south pole, you'll see that you start to get far enough away from the planet where you can see a piece of the curvature of the sphere and you start to recognize that it's actually a planet. And you're now coming across and seeing the south polar region. So on my computer, this movie is just about done but I'll wait a little bit because some people might have started a little bit later than I did.

But you'll see that Jupiter is basically just a swarm of incredible storms swirling around, different colors. They're very circular white storms that almost look like they're evenly spaced. We don't really understand the source of any of these. These storms at the poles are all newly discovered. We're still struggling with theories to explain how you make those kinds of things, why the North and South Pole look a little bit different. But generally, these are cyclones. They're like tornadoes and many of the cyclones are 1/3 the size of the Earth.

Some of these longer swirling storms that are not exactly shaped like a symmetrical cyclone but they're stretched out. Those things could be half the size of the Earth or even as big as the Earth. Of course, the great red spot is about 1.3 or 1.4 times the size of the Earth and you'll see some closer pictures. There is the people that made the images, Jerald and Sean. And you can go to our Web site and see lots of these.

Okay so assuming that most of the movie is done, I'm going to go onto the next slide [3], which now I'm going to talk a little bit about well why did Juno go to Jupiter. What is its main scientific goals? Although we're very happy to take a picture of the poles and see what everything looks like, that wasn't our main science objective and in fact we put the camera on board mainly to allow the public and ourselves to see what Jupiter really looked like up close and personal.

So now you're looking at a galaxy. This is a Hubble image from a galaxy. It's a little bit from the side. Normally galaxies you might look at look like the Milky Way. We look at one that you're looking from the pole of it. Here, you're looking from the side. Galaxies are sometimes a little bit different but they're all a compilation of a huge number of stars and gas and dust and between the stars. And you're looking at-- our galaxy is about 100,000 light years across. So it's very, very large. A light year is the distance that light travels in one year. And light is moving really, really fast. And so you're looking at dimensions that are quite large.

Okay so the next slide [4] is another Hubble image called the Pillars of Creation. So what you're looking at here is if you're on the right slide with me, you see sort of a very colorful picture with three prongs sticking up. Those are the Pillars. This is a dusty gas nebula out in the galaxy, our galaxy. And it's where we believe stars form. So inside of these dusty materials, you'll see some of the dust. You'll see little bright lights scattered in there. Those are new, young stars that are forming out of the clouds that are in this.

And we believe our solar system formed out of something like this. And so the cloud collapses. The star is born out of it. Most of these clouds of dust are hydrogen and helium. That's what most of the universe's ordinary matter is. That's what the sun is mostly made out of and in fact that's what Jupiter is mostly made out of. And so the belief is that Jupiter formed early, shortly after the sun formed while that hydrogen and helium from the nebula were still around. From looking at pictures like this, we've learned that after a star forms-- it's not long after that that the gas part of the nebula, the hydrogen and helium, get blown away. And so if you're going to form a giant planet like Jupiter, you've got to form it pretty soon.

And one of the goals of Juno is to try to understand how Jupiter did form. Because it is so massive and so large, we believe it was the first planet to form. And so we're really trying to learn how do solar systems get made in general and Jupiter's a key piece to that puzzle because it represents the first step of planetary formation. Something happens that's different after the star forms, our sun, to allow all the planets to form.

Okay so the next slide [5] is a little bit of a text about the history of the solar system. And on the right-hand side, you see a picture. This is an artist's concept of what the early solar system might look like. You're looking down from a pole. The bright spot on the left-hand side is the young new sun that was formed. These little specks are the gas and dust that are left over after that star is formed. And the swirls on the right-hand side is sort of the artist's idea of how maybe the first planet is forming. So this is supposed to be a snapshot in the early solar system when the first planet is forming.

And the reason I'm showing you this is that when we study Jupiter, we've learned that it's like the sun in the sense that it's mostly hydrogen and helium but it is different in a very significant way besides the fact that it's not as big as the sun. It has an enrichment in what cosmologists call heavy elements. Those are all of the atoms that are heavier than helium. So the universe is mostly hydrogen and helium and then everything if you remember your old chemistry table, everything beyond helium is heavier. We call that a heavy element. It's it's a heavier atom.

And we don't know how Jupiter got that and we'd like to learn about that. It's one of the key things to tell us how planets are made and it sort of sets up the Earth. And the reason is is that the stuff that Jupiter is enriched in is what the Earth is made out of. So whatever process was going on that allows the Earth and the other planets to form started right away with Jupiter. Jupiter forms out of the same material. We know it's pretty early because it has the hydrogen and helium, but it has this enrichment.

So whatever is going on that allows that enrichment to happen in a planet started with Jupiter and of course that leads to the process that eventually gives you all of the planets and the terrestrial planets are almost no hydrogen and helium. They're almost all heavy elements. And of course, life itself is made out of these. These heavy elements are what's needed for organics to grow. So this is part of the reason why the formation of Jupiter is so important to us to understand is it goes back and tells us about our own history not just the general history of how solar systems are made.

Okay. So the next slide [6] is a chemistry table from sort of a high school chemistry class. And this shows the periodic table of the elements. The top two, the green and the orange, are hydrogen and helium. And I just put this out so that you could see that everything except for those hydrogen and helium, everything beyond the number two is basically a heavy element. So some of the ones that you might be more familiar with is six, seven and eight which is carbon, nitrogen and oxygen.

The ones on the far right that are kind of orangey. Those are called noble gases. They don't do much chemistry. They don't change much. So when we measure those in the solar system, we think we're measuring stuff that hasn't been altered through chemistry. So you can learn a lot about the origin of elements in a particular body by looking at the measurement of those. But there's other elements in here, aluminum, titanium. They're all in here. And the point is that everything pretty much beyond helium is a heavy element. And so that's what we're mostly made out of is this other stuff and that's what organic molecules are made out of. And so this is of interest to us to learn how Jupiter got this.

So the next slide [7] is NASA's first attempt at trying to learn the composition of Jupiter for the reasons that I already laid out. This is called the Galileo probe and it was a spacecraft that was launched in 1989. And in 1995, it dropped a little probe into the atmosphere of Jupiter. This is an artist's rendering of what it might look like for that probe to drop into Jupiter's atmosphere. So it's dropping off its heat shield. The probe is attached to a parachute and it drops down and measured the composition.

The next picture [slide 8] is actually a real photo of the probe. And I show this because it kind of looks like it's something out of a 1950’s science fiction film. This is a submarine but a submarine made for Jupiter. And so it's got all of these little vessels and different things on it to hold the pressure and be able to survive great pressures as it drops into Jupiter's atmosphere. And some of the sensors for instruments are sticking out on the end so that it could measure how much wind, it looked for lightning. And but the main objective of it was to measure how much of each element was in the atmosphere.

Okay, now the next chart [slide 9] shows this is a little bit of a technical chart. It's the science results from that probe. And so let me just explain briefly what this is. On the horizontal scale -- going sideways -- is you see argon, krypton, xenon. Those are the noble gases. And then you see carbon, nitrogen, sulfur and oxygen which is really measuring water. The oxygen is tied up in water in Jupiter. And then on the vertical scale, you see the numbers that go from .1, 1, 10, 20. So this is the ratio of the abundance of those elements compared to the sun.

So if all of the measurements showed up on a horizontal line that's the -between the dark and the light, which is right at one on the vertical scale, that would mean that Jupiter had identical composition to the sun. The ratio of each of these elements compared to hydrogen is the exact same on Jupiter as on the sun if all those numbers came out on one. But what you can see is that none of them come out at one. They all come out at about three to four. This is a little bit of a complicated scale because it's called a log scale. So the numbers don't look completely linear.

But the fact that all those came out enriched by about a factor of three or four and we were unable to make the measurement of oxygen. So you see yellow arrows instead. Basically, in the 20 to 30 minutes that it took to make these measurements, all the theories of solar system formation were proven wrong. No theory could explain why all those were enriched about the same. There are two big puzzles to this. One is is that they're all enriched about the same and we expected some differences based on the temperature and pressure that Jupiter would have formed at.

And the other puzzle is that the measurement we did make for oxygen was really low. And the reason that's a puzzle is that the theories of how Jupiter got enriched is that water ice was formed in the early solar system and carried in these other elements. And the fact that the water was below the solar meant that our theories really were screwed up because that was the thing that was supposed to carry it in. There should have been more water than anything else. So most scientists believed that that was a measurement error that we just unluckily dropped the probe into the Sahara Desert of Jupiter and had we dropped it in anywhere else, we would have got water in a way that we could explain it. But we didn't really know.

And so one of the key measurements that Juno is making is to measure the water all over the planet so that we can learn if this measurement is right or wrong and also learn how much water is in there. Most theories now about the formation of Jupiter and the solar system vary partly based on how much water is in Jupiter. So we'll be able to constrain those theories and learn something about this.

Okay so the next slide [10] I want to show is basically another picture of Jupiter with the Juno spacecraft attached to it. This is again made by another amateur that goes onto our Web site. And they decided to put the picture of Juno on it, which is great. And these are what you can see on Juno's picture is that there's three giant solar arrays. Juno is very, very large. Each one of those solar arrays is about 25 feet long and there's three of them. And Juno goes through space cartwheeling. It's spinning around. The whole thing is spinning about twice a minute.

And so and with all those giant solar arrays even because Jupiter is so far from the sun, we only get about 600 watts of power and it's about the power of a microwave oven. And so we twirl over. You see another view of Jupiter here. This is a little bit of the south pole. But you can see the great red spot in this picture. And it's one of the many pictures that are available on our Web site. I'll show you some more at the end as well.

Okay so the next slide [11] is really getting back to how Juno investigates the origin of Jupiter. So we have two measurements that are very important when learning about Jupiter. One is done through what we call gravity science. We're measuring the gravity field very carefully and very precisely. And what we're look for is is there a core in the middle of Jupiter. In other words, is there a core made of rocky material in the center, sort of Earth size or a little bit bigger than the Earth.

And that would tell us about the early formation period, because if there is a core in the middle of Jupiter it probably started that way. You wouldn't be able to dump rocks into Jupiter once it's made and make a core. They would melt and evaporate in the - and burn up in the atmosphere and then kind of mix around. And so if there is a core in the center of it, it means it started that way and that means that rocks formed in the early solar system before Jupiter did. The next measurement is the water abundance, which I've already kind of covered.

Okay I'm going to go to the next slide [12]. This is a picture of a can of Campbell's soup. And the reason I show this is that to emphasize the aspect that what Juno is really after is learning about the recipe to make a solar system. And of course, most of us are familiar with Campbell's chicken noodle soup. And some of you when you first tried it or your kids like it, you know, you might have wanted to make some like it. And if you opened up and you saw this can and you decided you liked it, what you would do is if you wanted to learn how to make chicken soup, the first thing you'd do is just turn the can around because on the back side is the ingredient list. And while that's not the recipe, it's the beginning of learning the recipe.

And that's exactly what NASA's doing when we explore the solar system is we're trying to get the recipe to build the solar system but we're doing it by figuring out the ingredient list of all of the different objects. And so you first get the ingredient list of Jupiter. That's part of what Juno's doing. But you'd like to get the ingredients in comets and asteroids and all of the different planets. And eventually, you kind of put together the idea of how to do the recipe.

Okay. So I'm going to go to the next slide [13] which is our science objectives are not just the origin of Jupiter but we actually look at the interior structure, not just whether there's a core but how is it all built inside. How is the magnetic field made? How is it spinning and rotating inside? What's the source of the winds and the zones and belt structure that we see on the outside?

We want to learn about the atmosphere, the dynamics, the deep atmosphere. We have special instruments that can see through the clouds. So we'll see that for the first time. And then we also look at the polar magnetosphere. And on the bottom, you see a Hubble image of Jupiter's aurora. So we're looking at the aurora borealis or the northern and southern lights of Jupiter. These are Hubble images of them but Juno's going really close and making close-up measurements of the aurora.

So we look at science in all of those areas and they're all very important to us. The origin is probably the most fundamental and most important thing that Juno's doing but all of this is very important science and we're also realizing that we need to learn about those other three topics in order to figure out the origin. So they're all connected if you will.

Okay. So the next one [slide 14] is how did we get there, Juno's flight plan. And so here you see a little map of sort of the solar system looking down. And you can see that Juno launched on August 5 from the Earth, 2011. We didn't have a big enough rocket to get us all the way out to Jupiter. So we went around the sun going out a little bit past Mars' orbit. That's the red circle. The blue is Earth's orbit. And then we came around and got sped up and kind of exchanged some momentum with the Earth and used that flyby to fling us out even faster and farther.

And so we eventually reached Jupiter on July 4 last year, 2016. These tick marks are 30 days a piece. The thing I think that's important to kind of take away from this trajectory is when you launch a rocket from the Earth and you get away from the Earth, you're not actually just flying through the solar system free. You're in orbit around the sun just like all the other planets. And so when you get away from the Earth, you're still trapped by the sun and that's why we went around and if you go faster, you can go around the sun farther away. But Jupiter is moving faster than the Earth is, so it's orbit is farther away from the sun than the Earth's is.

And so we're trying to gain enough speed so our orbit will go out as far as Jupiter. And the whole trick that the navigation engineers do is they get it into a trajectory so that the speed gets fast enough to reach out to Jupiter's orbit. You're still trapped by the sun. And then you've got to make sure Jupiter is there when you get there. So you've got to time everything just right. And then when we finally got near Jupiter, we wanted to change our speed. We wanted to speed up with respect to the sun and slow down with respect to Jupiter so that we would make a transition from being in orbit around the sun to actually being in orbit around Jupiter.

We became a satellite of Jupiter. We're still trapped by the sun. We're going around the sun now with Jupiter just like one of its moons. So that's how trajectories work and you navigate through all of this with something called star cameras which are just like the ships use to navigate across the seas. Is we're taking pictures of the stars trying to figure out where we are in space. And I'll show you an example of that later.

So here the next slide [15] is a close-up of the spacecraft. I won't go through all of these. You can look at this on your own but there's a number of different instruments. We do the gravity science. We have this microwave that kind of sees through the atmosphere. We have a bunch of instruments that look at the polar magnetosphere and we have cameras that look in the ultraviolet, the infrared and the visible light. And you'll see examples of data from all of those.

It's a big spacecraft as I pointed out because you can see sort of a picture of a guy next to it that represents about six feet or so. And in the middle of the spacecraft is something we call a radiation vault because Jupiter is very, very hazardous. So basically there's a box in the middle that's made out of titanium that all the electronics are inside being protected from the harshness of Jupiter's environment.

Okay next slide [16] shows you another picture of the trajectory. We go flying by Jupiter really close. This is almost to scale. I mean the spacecraft isn't to scale but we're actually going that close to Jupiter. We go over the poles. These time ticks are one hour now. You see Io is one of the inner most moons of Jupiter. It has volcanoes on it. There's other moons in there that are closer but they're much smaller and not as well known. You see those listed in yellow. The point to make on this is that as Juno comes by, it goes from north pole to south pole in just two hours. Jupiter is really big, ten times the size of the Earth. So it's about 1000 Earths fit inside Jupiter.

For us to go past it in two hours, we're screaming. We're doing that because we don't want to stay there very long because we'll get burned up by the radiation. But we're also getting pulled in by Jupiter. So every time we go by, we're sort of almost setting the human speed record. I think the first time we did it and then each time is a little bit slower. But we're moving close to 125-150,000 miles an hour as we speed by Jupiter every time. So we're really cooking.

Okay next slide [17] shows you how we orbit. So what Juno is trying to do is make a map of Jupiter. We want to go over all of Jupiter. We go over the poles each time. And of course if you want to make a map, you try to go over every longitude. So if I was making a map of the Earth, I'd want to go over one time over New York, another time over California, another time over the Pacific Ocean, another one over Africa. Slowly you would make a map of the Earth. And so this shows you how we make our map is flying each one to go over a different longitude and eventually when we're done with 32 orbits, we've made a whole map and we can really measure everything around Jupiter and learn about how it works inside and out. And so that's the goal for Juno.

Okay so the next picture [slide 18] is an artist's concept of what it looks like in the middle. So this is sort of just a cutout of Jupiter. Juno really looks inside of Jupiter every way we know how scientifically. So there's three different ways. One of them is through microwave radiation and it kind of looks at the little top part that's cut out that's called the radiative zone or the meteorological layer.

On the right-hand side, you see something called bars. That's a unit of pressure. So one bar of pressure is basically what you feel on the Earth at sea level. So if you go to the beach to go swimming and you're outside in the air at the beach, you're feeling one bar of pressure. That's all the atmosphere of the Earth pushing down on you at the beach or at sea level.

And of course, if you dive into a pool or go into the ocean ten feet or more you'll feel it on your ears. And that's because you're going into higher pressure. Now you have the water on top of the air pushing down on you. So Jupiter is quite big. Its pressure is quite large. So just even in this top part, it goes down several thousand bars of pressure in just about 1000 kilometers in distance which is hardly scratching the surface of Jupiter.

Then we go down further and we get to a place where the hydrogen in Jupiter almost behaves like a metal. And we believe that somewhere in there the magnetic field is getting created. That's the two mega bars of pressure. Finally down at the bottom, you might have a core and the middle of Jupiter is probably 40 mega bars of pressure. We look at the gravity field we can see data all the way down to the middle. The magnetic field sees into this metallic hydrogen region maybe or just above it. And then we look at the deep atmosphere as the third way. And so one thing to point out is if there is an ice rock core in Jupiter, it's not like the ice rocks, you know. In fact, it's under 40 mega bars of pressure. So it's not behaving like anything we understand or can see or ever have seen. We can't even make something like that in the laboratory.

Okay so the next picture [slide 19] is a cake that somebody sent a picture of, a Jupiter cake. And it looked pretty good. I didn't get a chance to taste this cake but I was impressed with the way they made it. And they cut it open to show me the inside. And the reason I show you this is that we've started getting our data and I had to inform this person that their cake was wrong already. I already knew that the cake was wrong, that the middle of Jupiter did not look like that, which actually looked a little bit like the picture I showed on the previous slide, the blue being maybe the metallic hydrogen and then having two sorts of cores, this white and it must have been vanilla and chocolate.

And I don't know what the right answer is yet about Jupiter because we haven't finished the mapping. But I can tell you that the chocolate and vanilla part are probably wrong. A more likely answer is it might be mocha. It might be the science of the whole white mixed together. So the core we're seeing or the indications are that the core could be quite large, maybe half the size of the planet or larger. We're not sure yet because we haven't analyzed all the data and we still need to get more data. But it doesn't look like it's very compact.

Okay so the next picture [slide 20] is how the deep atmosphere sensing works. So we have something that is a microwave instrument. We call it MWR and it sees through the atmosphere. In the middle, you see a little picture of Jupiter with some little circles running up and down. That's sort of the footprint or the resolution of the instrument. So when we're over the equator in the middle, those little circles get really small because we're close. And so we see very fine detail. When you get out toward the north and south poles, you're farther away. So the pixel size or the resolution goes down and that's what those circles kind of show.

We have six different instruments that look at radio emission that's in the microwave. And on the right-hand side, you see a little sketch of Jupiter with the pressure again. It went down to 1000 bars pressure. And as you go down, you see what we think are layers where there might be ammonia clouds or water clouds. And then you see the six different channels from this instrument. The one that's higher frequency doesn't see very deep. It only sees down to the ammonia cloud. And the other ones can each see deeper and eventually the longest one goes all the way down to about 1000 bars pressure.

So this instrument is brand new. It was invented for Juno. And what it’s goal is is to look at Jupiter and measure the temperature at all of these different depths at the same exact time. And we can do that and we can learn how much ammonia and water is in Jupiter at each of these spots because the thing that's deciding how far you can see down is what we call the opacity or how transparent the atmosphere is at that frequency, which is all dependent on water and ammonia. So if there's a bunch of water and ammonia in the atmosphere, then the atmosphere is pretty opaque and we can't see in it very far. If we can see really deep, then it means there's less.

And so we look at how deep we can see and we can invert that and figure out how much water and ammonia must have been in the way. It's sort of like the way your microwave oven works. If you put a container of water in there and you turn it on, eventually the water will boil and that's because the microwaves are being absorbed by the water molecules. So that happens in Jupiter's atmosphere.

And so if theoretically I knew the power of your microwave oven exactly and we stuck a container of water in there and it took exactly let's say one minute for it to boil, I could then calculate how much water you must have put in the microwave oven. Because if you had put in more water, it would have taken longer to boil. And so that's not exactly how our instrument works, but it's a close analogy that you can understand because everybody is used to microwave ovens and probably heating up water or spaghetti.

Okay so the next slide [21] shows you some of the data from this new instrument. So here we're looking at different frequencies, right. So we see down to different layers. And so these are sort of onion skin layers of Jupiter. The top one is the one you're used to, visible light. You see the zones and belts and the great red spot sort of what you're used to. And then the next layers show that while those zones and belts don't stay exactly the same all the way down, in fact they disappear quite quickly, they are replaced by some other kind of structure. And so Jupiter's structure in its atmosphere goes pretty deep. It's not just at the very top part of the veneer. And so this was our first look at the deep atmosphere. And of course, we're trying to map it out and we only have a few of these stripes. And slowly we're getting more and more data.

This July 11, we went right over the great red spot with this instrument to see if we could see if the roots to the great red spot looked different than the other parts of Jupiter. And while I can't report right now exactly what we saw yet because we're still analyzing it, I can tell you that it did look different than anywhere else on Jupiter. And so soon we'll probably have a press release or something on that as soon as we stop arguing about what we saw. Because we have a lot of scientists trying to figure out what it means.

Okay. So the next picture [slide 22] is an infrared map of Jupiter. This is also another movie. If you move your mouse a little bit, you should be able to play this movie. This one has no sound but it shows you sort of an infrared map of Jupiter. The dark means it's cooler. The yellow and the reddish mean it's warmer. So when you watch this go by, the first thing you can see is a lot of these storms are cooler. That means they're either sitting up high in the atmosphere or for some reason they're made out of something a little bit different than the other parts. The whole zones and belts seem to change temperature as you can see. So this is something that was known a little bit before we got there, but nobody had made a map quite like this before.

Okay then the next picture [slide 23] is quite amazing. This is the south pole of Jupiter. This is with infrared. Again we went over the south pole and we took a picture of it. And this is before we saw the visible light where somebody had stitched together all of the different. So we'd only seen a half lit Jupiter before this. When we looked at this, we were all startled. The crosshairs kind of represent where the south pole is. And you can see that there's an organization of cyclonic storms that seem to be circling the center of the pole. And so this was of course not ever known before and is quite remarkable. We're still working on theories of how these storms get created and maintained. And over time we'll measure whether they're stable or not. But they're quite beautiful.

And so the next picture [slide 24] is the same thing but looking at the north pole. And the amazing thing is a similar set of features is there but it's a different number of storms. Instead of five, it looks like there's eight. Normally most theories would have predicted that north and south would be symmetrical. So for some reason they're not. Whether this is just a state that it's going through or this is stable, we'll only learn with Juno over time in the next year or two.

But you can see that Jupiter's full of incredible swirling clouds that are quite beautiful and very artistic. And so the next picture [slide 25] is one that somebody sent me reminding me that somehow Van Gogh had a vision of Jupiter. And here you see the starry night and amazingly of course this is

Earth's but it's almost as if he was painting Jupiter's atmosphere. So I show that to you just for fun, a little bit of art mixed with the science.

Next slide [26] is Jupiter's aurora. This is in the ultraviolet. This is the northern aurora. And over in the upper right-hand corner, you see a picture of the Earth to scale with its aurora. And so this of course you can see that Jupiter's aurora is actually quite large, much bigger than the Earth itself even. And this is the first time we'd ever seen the aurora completely all the way around because you have to get over the pole to get this view. If we look from the Hubble telescope, we only get little pieces of the aurora. We never see the whole thing. Now you've got to be right over the pole. So this is one of the things that Juno's doing on every orbit.

The next picture [slide 27] is our first view of the southern aurora in infrared. So this is the first time. You can't see hardly any of an aurora from Hubble telescope or from the Earth telescopes. So this is our first view of that. And it's considerably more complex than the north, which is still being studied to understand.

The next one [slide 28] I'm going to show you is we have an instrument on board that's like flying a radio called the plasma wave instrument. And what you see here is some data from that. This is another movie. On the horizontal scale is time. Those are hours. And on the vertical scale, it's just frequency. So think of this as listening to radio in your car and you can change channels which is changing frequencies. And so this shows a range of frequencies roughly from ten kilohertz to 100 kilohertz. That's actually beyond human hearing range but I can play a mathematical game and just divide all of this data by some number and make it so that it falls within our hearing range. And so that's what I'm going to play for you hear is an audio file of this data.

Now the colors that you see, they're called amplitude or spectral density but you can think of them as just volume. So this - I'll let somebody play. That's okay. You just put the play button and you play it. It's about a minute long or a couple minutes. It sounds scary and eerie. So we have a lot of these files. This one came down at the end of August. It sounded eerie enough that I ended up using as part of my Halloween decoration and scared a lot of children with it. So we have a little bit of an evil streak in our family where we like to dress up and make our house very scary and this recording helped.

The next one [slide 29] I'm going to play for you is another recording. This one sounds very different. It sounds almost like musical tones rather than and you only hear this when we're very, very close to Jupiter. So you can play this as well the same way. You'll hear static but then after it starts at about maybe 12 hours 48 minutes, you'll start to hear very discrete tones. So I'm not playing these for you over the phone because I didn't want to interfere with whatever your computer is playing.

So I'm going to go on and assume that you guys are close to listening to that whole thing. So the next picture [slide 30] is actually from our star camera navigating through space. This is an interesting picture because it's very close to Jupiter and looking out and the line you see going across is actually the rings of Jupiter, but we've imaged it from the inside looking out. And then you see all the other stars. These are navigation stars. And the ones on the right-hand side, you'll see three in a line. That's Orion's Belt. It looks the same as we see it from the Earth. It's a zodiacal sign, right. So this is from that star camera.

The next slide [slide 31] is a snapshot from a Web site for Juno cam. This is actually an old version. These are all working. It says coming in fall but this is an old picture. But you can go there and you can process data, make your own pictures. You can actually get students to go in and help vote on where we take pictures of. You can discuss what's important about different pictures, different parts of Jupiter. And amateur pictures of Jupiter are also loaded up on there. And so I encourage everybody to go take a look at that.

The next one [slide 32] I'm going to show you is a short film that we made on approach to Jupiter. And it shows the satellites going around. You have to start the movie the same way as the others. This is the first image or movie showing motion of heavenly bodies that I know of, I mean a lot of motion. But we're seeing it starts off with computer graphics looking through Galileo's laboratory. But basically, the data is untouched once you start seeing the Jupiter data. It's not manipulated by me at all. And it shows the moons of Jupiter orbiting Jupiter from afar.

So what we did was we took a picture every 15 minutes and then collapsed it into a two or three minute movie and you're seeing the four Galilean moons going around Jupiter. The inner one has a period of a day and 3/4. That's Io. Then Europa takes a little bit longer to go around and then you have Ganymede and Callisto finally. And they're all going around at different speeds. But this is basically how nature works. This is the motion, this is how our solar system must look if you went far enough way. Jupiter's like its own mini solar system.

This is how the planets going around our star look. It's how our moon must look going around our planet. This is how the stars going around galaxies. You know, they orbit the middle of the galaxy to some extent. Not exactly but nature works like this at all scales, small and big. Everything's sort of cyclic motion. And this is our first shot at really seeing nature's motion on a very large scale. And so I think it's a significant thing for us to take a look at because it kind of bridges the idea of how nature must really work.

Galileo saw this but he obviously didn't see the motion. He just looked each night and saw the stars changing position near Jupiter. But from that, he must have imagined that they were going around. And that of course profoundly changed our society because he realized that Earth was not the center with everything going around it. Here was this other object with its own moons. And he got into some trouble with the Vatican for that. But eventually everybody bought into it.

Okay. So the next ones I'm just going to show you a series of pictures. These are all off of our Web site. These are all made by amateurs and artists, any, you know, schoolchildren. Anybody that wants to go on can learn how to make a picture from the raw data. I'll just go through them. The first slide [33] is Jupiter in very false color but very beautiful. The next one's a close up of stuff. The next one [slide 34] shows you sort of a full frame. [Slide 35] Our camera is spinning. As it spins by and takes pictures, you know, where we're close up we don't see as far - a wide a view. And in the north and south, we see a little bit wider. So the images in raw form kind of look hourglass shaped.

[Slide 36] Then you see a close-up of one of the storms, [slide 36] a half-lit Jupiter, [slide 38] a full lit, the one I started with. More images, I'll just let you look through these yourself. And if you've downloaded the PowerPoint, you have them all. You can find many, many more pictures on our Web site. These are just a few that I selected. [Slide 41] Here's a cyclone that compares to the size of the Earth. [Slide 42] Something else that almost looks like sand art. I mean Jupiter's very artistic. [Slide 43 - 45] You see half of these are art. And so what I'm watching as we share this with the public and they're expressing themselves when they make these pictures, which is great.

And then finally the last shots [slide 46]. You see the most recent shots we got of the great red spot, a sequence of four pictures showing different details of the great red spot close up. You can blow these up on your computer and see more detail. [Slide 47] And then some people use their imagination like an astronaut floating above Jupiter or even maybe what Jupiter looks like from one of its moons [slide 48].

And the last couple slides [49] are showing the Lego mini figures that are on board to help connect with the. So we've got three Lego mini figures, Galileo, Juno and Jupiter and they're made by Lego out of spacecraft grade aluminum and they're stuck on our spacecraft along with a plaque dedicating and honoring Galileo, the scientist. And then you find our Web site. And that's all I have.

Heather Doyle: Wow. That's great. Do you have some time to take a few questions?

Scott Bolton: Sure.

Heather Doyle: Wonderful. Ambassadors, do you have any questions or anybody else from Museum Alliance on the line?

Man: Hi. Yes I have a question.

Scott Bolton: Go ahead.

Man: This is from San Diego. So your first is the main goal to measure the water abundance. But the first result come out for Juno as the public case is about the ammonia, specifically for the ammonia content. Why did you start with ammonia and not the pressure of the water? And is it in position for the ammonia results actually you guys actually presented in some of the articles and papers.

Scott Bolton: Yes. Sorry I was hearing a lot of echo, but I think your question had to do with what did we discover about the ammonia. Is that right?

Man: Correct. Basically what if any results actually from the water. Because actually all the data you available on the internet is about the ammonia results but there's not much about the water.

Scott Bolton: What about the water? So we haven't released anything on the water yet because we're still working on the data. And the reason is is water is a very difficult thing to pull out. And we need to understand the ammonia and how the atmosphere works before we can go in and put into the models to pull out and analyze the data to pull out the water abundance. And so we were so surprised at the ammonia features and the dynamics that were happening inside of Jupiter's atmosphere that we're first working on that. And so we probably won't be able to say much about the water for quite some time. We need to collect more data and get the analysis more mature. So it's probably many months before we'll announce anything on water.

Man: Thank you.

Man 2: Dr. Bolton, that celestial video is absolutely excellent. I'm so glad you made it.

Scott Bolton: Thanks. We were too. We were surprised at how great it came out. We realized it's something but we weren't sure how it would work.

Man 2: It's a bit hit every time I show it. Quick question. About how much is it sped up? And when I see the moons flickering, is that just the effect of the pictures or am I seeing them rotate real fast?

Scott Bolton: You're not seeing them rotate. So what's happening is there's two phenomenon going on. One is they're blinking on and off because they actually pass into Jupiter's shadow. So you can see they'll all go blink on and off in the same spot when they're on the night side part of Jupiter. Because we're coming in from the side, so Jupiter's half lit, right. So they go over to the night side. So they're passing into the shadow.

The other part you see Callisto blink on and off a lot and that's because Callisto turns out not to be very bright. And it was basically like one pixel. And so in the raw data, it seemed to flicker on and off and I made a decision not to clean that up and process it further because I wanted this to be non-Hollywood-like and really be raw data. You can go in and other people have gone into the raw data, which we've actually put on the web, and fixed that and made it smoother. But I wanted this one to be shown more raw.

Now the way it's sped up is the pictures are every 15 minutes and it takes about 2 1/2 weeks to make that movie. I don't remember the exact ratio but I turned it into something like two minutes of film. So you'd have to calculate that. I don't have that off the top of my head, but it's sped up quite a bit. If it was in real time, you would have been sitting there watching it for 2 1/2 weeks.

Man 2: That's just fine. Thank you. And again, my compliments.

Krishnadas Kootale: Dr. Bolton, this is Krishnadas from New Jersey. There were a couple of images that showed an hourglass shape and I guess you explained in one of them the cause of it. I think it is the slide number 35. If you could say that once again. I didn't quite catch that.

Scott Bolton: Sure. So keep in mind that our spacecraft is spinning twice a minute. And so the way the camera works is it builds up an image while the spacecraft spins by Jupiter, right. So if you can imagine that the spacecraft is near the equator, for example, and if the camera were to look straight at the equator you would only see a little piece of Jupiter, right, because we're not far enough away that you could see the globe. You would just see some little postage stamp part of near the equator. But if I took the same camera and I just looked up north, I would see a wider piece of Jupiter because I would be looking at an object that was a little bit further away. Right? It's a projection. And so that's what you're seeing is the north and the south have a projection effect on them. So I see a little bit wider piece of Jupiter than I do in the middle.

Krishnadas Kootale: Got it. Now there was the slide or the picture showing the aurora of Jupiter in relation to Earth which had some sort of a concave hourglass type of effect. Is that also due to the same effect?

Scott Bolton: A little bit although that camera is an ultraviolet camera that builds up images in a different way than the visible light camera. It's counting photons and it has a mirror that lets it look at different angles. But that one you should think of more of as a snapshot but the frame is not a square like you normally would think of it as. It's a slit that builds up. That one's a little harder to explain I'm afraid. Just send me an email. I might be able to send you a sketch of it. But it's hard to describe over the phone.

Krishnadas Kootale: Okay. The same picture also has strips or tiles kind of artifacts on that. Is that perhaps the surface of Jupiter under different lighting or under different frequencies?

Scott Bolton: No that same image in the ultraviolet is only ultraviolet but you are seeing different affects and you also see noise and stray light in there. But you're seeing different kinds of ultraviolet emission basically or scattering.

Krishnadas Kootale: Okay. That's one unrelated, no I want to mention that at the launch ceremony I was there the previous night and you had attended that dinner and the meeting with the whole project team and you brought your family. I believe it was your mother. She was extremely proud. I cannot forget her gleaming face in that event. My regards to her.

Scott Bolton: Yes. Well thanks. My mom - yes I remember that. And she is pretty happy with everything as you might expect.

Krishnadas Kootale: Thank you.

Man 2: Dr. Bolton just a quick question on that same image of the aurora with Earth for scale. Is that the north polar aurora or south polar aurora?

Scott Bolton: I think that's the north polar aurora.

Man 2: Okay. Thank you.

Man 3: Question. Yes. Can you vector us to the scientific articles like in the review of scientific instruments that really peel the onion on the internal workings of the various instruments on Juno.

Scott Bolton: Sure. So there's a series of articles that are published online in a journal called *Space Science Reviews*. And there's one for every instrument. And we're about to close that publication and you'll be able to buy a book of it. But you can go online and look at every instrument.

Man 3: Thank you.

Man 4: Hi, a question. So is there a plan to go back to the 14 days orbits or like this particularly we're going to stick with 53 days orbits?

Scott Bolton: No we will stay in the 53 day orbits. We made that decision because the plumbing system for the rocket motor wasn't behaving properly and we could basically get the same exact science with a 53-day orbit as we were with the 14. So we decided to just leave it alone because everything worked. So we won't change the orbit.

Jeff Nee: Hi Dr. Bolton. On slide 22, what's the temperature difference between the dark parts and the brightest parts of that infrared movie?

Scott Bolton: I don't know that off the top of my head. We'll have to get back to you on that one.

Jeff Nee: Okay thank you.

Man 6: You mentioned that the core was larger than was maybe thought earlier in the presentation. I'm wondering is that thought to be maybe rocky iron type core or does it have a different composition?

Scott Bolton: It's too early to tell. We don't know the composition yet. We're just looking for, you know, how big a density change and where that might occur. So the assumption would be is that it was heavy elements, not necessarily iron, you know, carbon, nitrogen. The two most abundant heavy elements after hydrogen and helium are oxygen and carbon. So those would be the dominant pieces of it. But there'd be a little bit of everything in there is my guess. But it's too early for us to tell exactly that kind of detail.

Man 6: Okay. Do you have a rough sense of the density? I realize it's under high pressure, so.

Scott Bolton: Right. It's under incredible pressure. So it's hard to quote anything there. But I mean all we know is the density of Jupiter as an average. We haven't gone in and calculated this. But there's still some argument going among the science team of what that core is, whether how compact it could be or how diffuse or fuzzy it might be. So, you know, I'm giving you sort of early results, but they're not very definitive yet.

Man 6: Right. Well thank you. That's helpful.

Man 7: I have a quick question as well. Is there any change to what's going to happen at the end of the mission for the de-orbit burn now that we're going to be in the 53-day orbit for the entire duration?

Scott Bolton: No. We still have the same mechanism. We didn't use the rocket motor to de-orbit. We used these little thrusters, which we have still full use of. So that plan is unchanged. It's just a matter of when you would do it and right now we're thinking we'd just do it at the very end as we always did at the end of the 32 or 34, 53-day orbits. But if the spacecraft wasn't healthy, we could do it earlier.

Man 7: Okay. Thank you.

Scott Bolton: Okay. It sounds like that's about it.

Man 8: Actually one more question about some of the YouTube videos actually show that the early results shows that it's maybe actually the magnetic field actually it is much closer to the surface. So any update on the magnetic field projector?

Scott Bolton: Just what you said. We see hints that it might be being created closer to the surface than we thought. But to really say anything definitively, we need to finish the map of the magnetic field. And so what we've seen is hints that that's the case which unfortunately that also indicates if it is closer to the surface that we need more flybys. Not more than we originally planned but it just means we need to finish off the mission in order to really understand it because the more orbits you get, the closer your longitudinal spacing is as you can imagine. And the closer the field is being created to the surface, the more you want that fine grid to correspond to roughly the depth of the field being created. So I probably won't be able to say a lot about that for at least another year or two.

Heather Doyle: Well thank you so much for taking the time to speak with us. This was fascinating and I know you're very busy. So we have to let you go. But I believe Courtney said she had a few things to talk to us about as well. But thanks again so much for all this great information and for the amazing pictures and videos.

Scott Bolton: Thank you and if there's anything you guys need that Courtney doesn't have, just have her ask me and we'll try to put it together for you.

Heather Doyle: Thank you so much. Courtney, we'd love to hear from you.

Courtney O'Connor: Sure. Well really I don't have anything formal to add other than that if folks are going to be hosting Juno themed events in their areas, we are happy to send out any of our detailed posters. We also have lesson plans and activities. Of course as Scott mentioned, we have all of our videos and animations. So I'm assuming Heather that they would get in touch with you and then we can provide them with those resources?

Heather Doyle: Absolutely. So the ambassadors can fill out a materials request and then we can go from there. And then Juno cam obviously is something they can just go over to anytime online correct?

Courtney O'Connor: That's correct. Yes. So go to the mission Web site which is missionjuno.com. If you click on the Juno cam section, that's how you can participate in the citizen science campaign. And there are different levels of participation anywhere from the amateur astronomer to image processors to the voting section, which is the easiest for the public to participate in because you really don't need to have that image processing skills in order to vote in the Juno cam section. I also want to recommend following up on social media. We are @NASAJuno on Facebook, Twitter and Instagram. And that's where you can find the latest images, press releases, features and videos. So that's about all that I have here but if there are any questions for me, please feel free to ask them now.

Jeff Nee: Courtney no Juno fidget spinners in the works?

Courtney O'Connor: There is an unofficial Juno spinner on one of the 3D modeling spaces that I could send over a link too but it's not going to be something we'll do officially from the mission.

Jeff Nee: I'd still love to have that link. Thanks.

Heather Doyle: All right. Well if that's it, Courtney thanks so much for helping to set up this presentation. Courtney was the one that set this up for us all. So the next telecom we have will be on August 3 and that's the Universe of Learning's Cosmic Beacons: 50 Years of Pulsar Discoveries. So I hope that you all can join us then. Thank you so much for calling in and have a great rest of your day.

Coordinator: This concludes today's conference. Thank you for participating. You may disconnect at this time.

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