NWX-NASA-JPL-AUDIO-CORE (US)

Moderator: Michael Greene
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8:00 am CT

Coordinator: Welcome and thank you all for standing by. At this time all participants are in a listen only mode until the question and answer session of today's call. At that time you can press star 1 to ask a question.

I would also like to inform all parties that this call is being recorded. If you have any objections, please disconnect at this time. I would now like to turn today's call over to Mr. David Prosper. Thank you Sir, please begin.

David Prosper: Hi everyone it's me, Dave Prosper from the NASA Night Sky Network here at the Astronomical Society of the Pacific's headquarters in San Francisco, California.

I'm very excited to present this teleconference with our guest speaker Dr. Charles Beichman, the Executive Director of NASA's Exoplanet Science Institute at California - at the California Institute of Technology in the jet propulsion labs. His topic is going to be on 50 Years of Exoplanets, the View from 2045.

Before we get started I just want to make sure that you can all view the presentation slides. So if you don't have the slides up in front of you, you can download them at our special URL, bit.ly/nsnexoplanets, all one word, that's bit.ly/nsnexoplanets.

There are two versions; one is in Microsoft PowerPoint and it has some animations and clocks in at around 60 megabytes; the other is a smaller PDF with no animations and clocks in at 4-1/2 megabytes for those with slower connections or no PowerPoint.

And if you have any other problems along the way feel free to email us at nightskyinfo@astrosociety.org.

Now for a brief minute I'd like to hear from the folks joining us tonight where you'll do the introductions a little differently this time. So if you want to say "Hi" to everyone, please press star 1 to enter the queue and then you can let us know your name and tell us where you're calling from and what club you're with. And just so we know who's out there listening in.

Coordinator: And again, to introduce yourself that is star 1 and record a name so I can introduce your line. You can hit star 2 to take your name out of the queue. But again, that is star 1 and record a name so I can introduce your line. One moment.

Okay first up we have Stewart Myers' line. Go ahead, your line is open.

Stewart Myers: Hello, I'm Stewart Myers, I'm from Amateur Astronomers Inc. based in Cranford, New Jersey.

Coordinator: Okay and next up...

David Prosper: Hi Stewart.

Stewart Myers: Hi.

Coordinator: Sorry. Next up we have Lance Ripplinger. Go ahead Lance, your line is open.

Lance Ripplinger: Yes, my name is Lance Ripplinger. I am with the Star Valley Astronomy Club in Star Valley, Wyoming.

Coordinator: Next up we...

David Prosper: Right on the Eclipse path, awesome.

Coordinator: Next up is Linda Prince. Go ahead Linda, your line is open.

Linda Prince: Hello, this is Linda Prince from the Amateur Observers Society of New York. Hi David.

David Prosper: Hi Linda, good talking with you.

Coordinator: Okay and next up is (Edward) Downs. Go ahead (Edward), your line is open.

Ed Downs: My name is Ed Downs, I'm with the Astronomy Club of Tulsa, also a science writer for In Flight USA Magazine.

David Prosper: Hey Ed, thanks. I might have read your - one of your articles recently on the plane.

Coordinator: All right, and next in queue is Bryan Stranahan. Go ahead Bryan, your line is open.

Bryan Stranahan: Hello, I'm Bryan Stranahan from the LAVC, it's the Los Angeles Valley College Astronomy Group.

David Prosper: Hi Bryan. I owe you another phone call by the way, so...

Bryan Stranahan: That's fine.

David Prosper: ...I'll check in with you in a little bit.

Bryan Stranahan: All right, thank you.

David Prosper: You're welcome.

Coordinator: And next in queue is (Arthur Ulch). Go ahead (Arthur), your line is open.

(Arthur Ulch): Hi, my name is (Arthur Ulch). I'm a member of the LA Astronomical Society and an amateur astronomer.

David Prosper: Awesome, hi (Arthur). Thanks for joining.

Coordinator: Next up is Bart Billard. Go ahead Sir, your line is open.

Bart Billard: Hi, I'm Bart Billard. I'm a member of the Rappahannock Astronomy Club and IOTA.

David Prosper: Awesome. Hi Bart.

Bart Billard: Hello.

David Prosper: Glad you could make it. We should probably wrap up the intros for the moment, so we can get going with the rest of our talk for tonight.

Then - so it was really great to hear from everyone so - and for those of you that couldn't make it we'll possibly talk to you later during the Q&A. So if this is your first telecon with us welcome, and if this is your 50th or 100th, welcome as well. So just follow along with the slides and there will be a brief time - a brief little bit of time for a Q&A at the end of our talk.

And also, it was really nice to see some of you at the Astronomical League convention in Las Cruces, New Mexico a few weeks ago. It's always fun to finally put a face on familiar names. And I was happy to have brought along some of our updated Kepler and PlanetQuest materials, and to give out samples and show off some of these new materials to everyone there. And of course our Star Party had a lovely thunderstorm interrupt it, as is the astronomy tradition, but it was beautiful.

And now we have a brief minute for the latest Night Sky Network News for our members.

So we're now halfway through 2015, so that means it's time to log your events from January through June if you've not yet done so. All clubs who log at least four public outreach events during this half of the year remain eligible for new NSN toolkits, as well as qualifying for quarterly prizes, a Night Sky Network Recognition Pin for the year, and NASA Handout Requests, which we're out of right now, but we're expecting to get many more handouts for you all soon.

Our second quarter prize, going to four lucky clubs that have logged at least two events between April through June, is a pocket model of the rocky planets plus our Moon. With the Earth just 2 inches wide, you can fit the whole inner solar system in your pocket. So thanks to the NASA INSITE Mission for donating these. The INSITE probe will be traveling to Mars to learn about its interior through marsquakes and by taking its internal temperature.

Also, if your club has not received a toolkit in some time, you can email us at nightskyinfo@astrosociety.org to inquire as to why you've not recently received one. It's likely that your club has received all of them and so that's why you haven't gotten one, but accidents in shipping do happen as well so remember to check your club's shipping address.

We can save money if we can ship your toolkits to a business address and your shipment will also be more secure. And remember, we prefer not to ship to PO Boxes if possible. And, if you've received all of the toolkits but would like a new one to replace a lost or damaged one, please let us know.

Now it is my great pleasure to introduce our speaker, Dr. Charles Beichman, the Executive Director of NASA's Exoplanet Science Institute at the California Institute of Technology and the Jet Propulsion Lab. His topic is 50 Years of Exoplanets, the View of 2045.

We are especially excited to have Dr. Beichman here as we know there is many exciting exoplanet announcements coming out from NASA. And it's hard to believe that it's only been 20 years since the first confirmed detection of a planet around a typical star.

Since that time we've detected over 1800 planets of all types, big and small, hot and cold, gaseous and rocky. But the best is still to come as we consider new telescopes that detect and characterize the physical properties of these planets including analogs of our own Earth and the habitable zones of nearby stars.

Dr. Beichman will discuss what we've learned about the prevalence and architectures of planetary systems and how that information will help us to look for signs of life on nearby habitable worlds.

Dr. Beichman has been a leader in infrared astronomy and exoplanet science for over 25 years with key membership roles in the IRIS and new mass sky surveys, as well as playing important roles on the instrument teams for the Spitzer Space Telescope and the James Webb Space Telescope.

For the James Webb he leads the exoplanet group within the NIRCam instrument team. As Chief Scientist of Astrophysics at JPL, Dr. Beichman has played a critical role in establishing NASA's Exoplanet Exploration program, serving as head of the Science Working Group for the Terrestrial Planet Finder. And he is presently the Executive Director of NASA's Exoplanet Science Institute.

So Dr. Beichman if you would like to begin.

Dr. Charles Beichman: Okay great, well greetings to all of you from East Coast to West Coast, North to South. And I'll assume that most of you have been able to pull up the slides I sent around earlier; they're both in PowerPoint and in PDF. I'll - the PowerPoint has a couple of fun animations. I won't rely on them too much, but if you can look at them they're quite fun. And but I won't rely on them too much.

So I'll go ahead and get started. And the first slide, which is a picture of the Earth as seen by Apollo, just addresses the fundamental question, "Are there other earths and life in the universe?"

And I want to describe how this is a 2500 year quest still ongoing, and we've made just the most remarkable progress in the last 25 years with a huge amount still to come. So it's an enormously exciting time. And I'm going to sort of give you a lightning tour of some ancient history and move as quickly into the present and then take a look at the future.

So in the next slide I show an image of some ancient Greek philosophers and a quote here from the Greek philosopher Epicurus says that "There are infinite worlds, both like and unlike this world of ours, we must believe that in all worlds there are living creatures and plants and other things we see in this world." So that was 300 B.C., and it's a pretty modern statement of what we think is the case today, except they of course were just doing it through philosophy.

The next slide shows in the medieval period, the early renaissance, a philosopher and troublemaker named Giordano Bruno said that there were "Countless suns and countless earths all rotating around their suns in exactly the same way as the seven planets in our system. The countless worlds in the universe are no worse and no less inhabited than our own Earth." And for his troubles he was burned at the stake. Luckily I'm doing this talk by telephone so you can't get me.

And then we move on the next slide to the sages of the present time, the philosophers of our age. Hollywood producers, and of course modern science fiction is full of ideas about life, particularly intelligent life, occasionally malevolent life, out in the cosmos, and certainly since the 1950s this has been a very active and fertile area for imagination.

One of them, the original The Day the Earth Stood Still, the aliens come to Earth and tell us to live in peace or "Pursue your present course and face obliteration; the decision rests with you."

So we have popular fiction, we have philosophy, going back many, many years. And on the next slide we get to what's called the Drake Equation after Frank Drake, where we now start to try and quantify what modern science, and still some speculation, can do.

This is a picture of the Drake Equation as posted on the wall of the Green Bank telescope where Frank Drake first made his searches for radio signals from other civilizations. And it relates to number of communicating civilizations that might be out there to a couple of parameters that you just multiply together.

So there's the rate of formation of stars, that's our star; the fraction of those stars with planets; the number of earthlike worlds per planetary system -- these are all things where we've made enormous progress in the last 20 years, but which were mostly unknown when Frank Drake started his work.

We then get into an area where we know less; the fraction of earthlike planets where life develops. This is a topic of ongoing and near-term future research.

Then we become somewhat more speculative; the fraction of the planets with life where intelligence develops.

And the fraction of those planets that start to communicate.

And then probably the biggest unknown; the lifetime of communicating civilizations.

You multiply all those together you get some idea of how many communicating civilizations might be out there willing to talk to us or at least something we could listen to.

So the terms in yellow and the one in blue, are ones where we can talk with some authority about the science that's either happened or will happen in the near future. The stuff in green is more speculative, and I'll touch on that at the end.

So 25 years ago we knew of no planets beyond our solar system and today we're up to a number around 1900, almost 2000, of which almost more than - almost 1/3 are actual multiple systems.

So I'll go through, very quickly, the techniques that people are using, starting at the top is the radio velocity technique. We look for the wobble of the star's motion as induced by the presence of an unseen planet. Image here of the Keck telescope where many of these initial discoveries were made.

The transit technique started out as a follow-up to radio velocity systems. And in fact, used a very small telescope in the parking lot of a Science Institute in Colorado to confirm the first transiting system where a planet crosses the face of its star and makes just a very small dip in the brightness in the star for a couple of hours. But that could be measured.

And as you'll see, we learn an awful lot about that, first from the ground, and then from space with the Kepler mission and the Spitzer Space Telescope.

We've got more than 1200 planets, almost 5000 candidates, 300 or 400 of those in the habitable zone. And of the ones in the habitable zone, there's a baker's dozen which have sizes smaller than or comparable to the radius of the Earth.

So that's starting to be a very powerful technique. And this is to a great extent due to the huge success of the Kepler mission.

There's a hodgepodge of other techniques; there's imaging with the Hubble telescope, the Keck telescope, the telescopes the Europeans use down in Chile. And you can see in the bottom left a planet that pops into view in 2003 around the star Beta Pictoris and then a couple of years later after its gone, come out from the glare of its star, it pops up again in another part of the image. We're starting to see more and more of these imaging systems as we put instruments called chronographs on bigger and better telescopes.

Another technique is called microlensing -- we'll touch on that a bit -- where you can use the gravitational effect of light-bending by an intervening star to detect planets.

And then there's a hodgepodge of other techniques that have found (unintelligible) ten other systems. So it's really been quite remarkable how much we've learned.

So an important question to address, and we have conferences on it, we just had a European conference on this topic, "What makes a planet habitable?"

The key thing is it's distant from its host star. If you have a big hot star you can be further out, just imagine it being a hot campfire, you have to sit well away from it to be at a comfortable temperature. A smaller, cooler star you have to move in closer, that's the point of that first graphic.

You also want to have a pretty circular orbit so your temperature is pretty stable; you don't want to be bounced around by the planets in the system; and you don't want to be bombarded by lots of comets and meteors and asteroids and so on, that would ruin your day.

The planet shouldn't be too big or too small; you need to retain an atmosphere, you want a bit of a magnetic field, you might want to have some active plate tectonics to help maintain the atmosphere at a stable configuration.

And of course for a habitable planet, you'd like to have water and the various chemicals that we know are very abundant in the volatile elements in our own solar system.

And maybe you want to have a solid surface to initiate life. Although we don't know that that is an actual requirement.

So the last image just shows the goldilocks zone. It's an image of - I think it's off the shores of Hawaii, and its' all about finding beachfront property, not too cold, not too hot, not too big, not too small, just the right place.

The next slide describes some of the most important results from the Kepler mission. I'll spend a couple of minutes on that. This has really, really revolutionized the field. We have Kepler 11which is a system with six planets all on orbits interior to Venus equivalent in our system. Multiple systems in a nice flat planer configuration. One of the first to be found of that kind other than our own solar system.

The next graphic shows the - another representation of the - what we call the habitable zone; the temperature of the star going cold to hot, going vertically, where is the - how much heat does the planet get from its star; and then a bunch of different planets popped in there.

And if you're too close, if you get towards the red area you start getting too hot and you probably start to have a runaway greenhouse effect.

If you go out too far to the right you're probably going to be too cold, you'll be like Mars and you may never warm up enough to have any possibility for life forming.

But if you're in that sort of yellowish-green area in the middle where we see the Earth and a number of other Kepler planets and other planets situated, those are places that might be quite favorable and Kepler's starting to find quite a few of these systems.

If we click through again we see the origin of the science fiction planet Tatooine actually has a grounding in reality, unbeknownst to the makers of the first Star Wars movie. This is a real Tatooine like system. It's a planet orbiting two suns; a yellow one and quite a reddish one. And Kepler's found quite a lot of these as well.

If you go to the next slide, those of you who have the PowerPoint and are looking at in full screen mode, this is one of our animations. And it's what is called the Kepler Orrery.

(Dan Fabricki) at the University of Chicago took many of the planets found by Kepler, I think this may be the - a full sample of a couple maybe a year, year and a half ago, and showed them in orbit around their host stars. And if you click on the animation you'll see all the planets orbiting their Sun; the size is relevant, the temperature is encoded in the color, some move slow, some move fast, some are multiple.

And if you don't have it in your PowerPoint or in the PDF, I encourage you to go onto YouTube and you just type in the words Kepler Orrery, and there are a number of them available. And it's quite accurate scientifically. And it's a wonderful thing to be looking at. If you get the right one, you get the Flight of the Valkyrie's as the music. So I do hope you get a chance to look at that. It's easily found on YouTube.

So what have we then learned? The next slide is titled Planet Characteristics. And it just gives you a sense of the very broad range that we have. So we have gas giants like Jupiter and Saturn. And you can see there are some that are bigger than Jupiter. The four sort of orange colored ones are one to two times bigger than Jupiter itself. We have ice giants like Neptune and Uranus. And then we have rocky planets that are of order of the size of the Earth or a little bit bigger.

We've found that as you go to smaller and smaller planets, there are more and more stars that have such planets. And depending on how you do the statistics, perhaps 10 to 15% of all stars, particularly solar type stars and even lower mass stars, have rocky planets of order of the size of the Earth or a little bit bigger in orbit around them.

There may be Earth analogs in the habitable zone of something like 10% of all stars, even more for the cooler M stars. So there are a lot of planets out there. Any star you look at with the naked eye, if it's a standard main sequence star, the odds are it has a planet or two or more.

And so the last box on this page just highlights some of the characteristics that we've been able to find; mass from an Earth-mass up to many times the mass of Jupiter; radius now in fact down to 1, even a little bit smaller than the radius of the Earth.

There's one planet in very close that has something like the radius of Mars; densities from Styrofoam to led; Orbital distances from in very close out to in fact from imaging, hundreds of astronomical units with temperatures of the planet from very, very hot down to you know, well below freezing.

So what can we learn from transiting systems? Well it's interesting; the next slide will give us an idea of what we're learning now about planets, particularly from transits or transits in combination with other data.

Over 180 years ago, a quiet August, pardon the pun, philosopher and scientist August Comte said on the subject of stars, we'd never learn their chemical composition. Well of course the advent of spectroscopy in the 20th century showed that in fact we could learn about the composition of stars. And you might have said, "Well gee, we'll never learn about the composition of planets," but in fact we are, and we're learning a lot.

So from transits we can get information like the Orbital distance, the inclination of the orbit. If you combine the transit measurement, which gives you a radius, with a radial velocity measurement which gives you a mass, you can get the density, and in fact the composition of the planet.

So if you look to the right, this plot is showing planet mass horizontally. On the left is all the planets we've been finding, and on the right is sort of a zoomed in version where you're just looking at Earth masses from 1 to 10 Earth masses.

If we look first at the plot that has the wider scale, going up to Jupiter masses, we see that the planets with the biggest radius, vertical axis, have a lot of hydrogen envelope, they're quite low density. And as we start moving to smaller radius planets, their density starts to increase and we're looking instead of hydrogen-based planets, ones that are composed more of water, rock, and eventually in fact, iron cores like we have on the Earth.

So this is very much an evolving topic as we put together data from the various missions. And we just learn a whole lot about the presence of things like rings and moons, atmospheric structure.

If we combine transiting systems with observations from telescopes like Spitzer and Hubble, the bottom plot here shows the signal from the planet, the transiting planet, as a function of wavelength. And you start to see that we can pick out absorption features due to methanes, carbon monoxide, carbon dioxide, water, more methane, and even estimates of what the structure - temperature structure is of the atmosphere. As you go higher up in the atmosphere of the system you may even have evidence for temperature inversions.

So we're starting to piece together an enormous amount of information from planets that we can barely see. So we're learning a lot and there's much more to come.

If we go to the next slide entitled Mapping Weather on the Transiting Planet HD 189733, those of you who can look at the animation should just click on the image there which shows a, basically it's a 2D map, a projection of a planet with a hot spot on it that's located just off of center of the sub-stellar point.

So this was an infrared heat map taken by Spitzer during a whole orbit of the transiting planet, and it shows that there's a hot spot that's a little bit displaced from the sub-solar point. And there are just super-heated winds going around this planet.

So if you click on the animation you'll see how this map wraps around the planet. And we can see the planet orbiting around its star. And Spitzer was able to study the planet through its whole orbit and from looking at it when it's in front of the star, around to the side, back behind the planet and back out again, one is able to piece together the heat map.

The next animation is called the James Webb Space Telescope. And again, I won't spend a lot of time on the animation, but if you click it you'll see how the James Webb Space Telescope goes up in its rocket all in a very compact configuration and then it starts to deploy over a period of a week or ten days.

If you remember the Mars landers had what they called Seven Minutes of Terror as the lander came down through the atmosphere. Well this is about two weeks of terror as the James Webb Space Telescope, a successor to Hubble operating in the infrared, deploys the heat shields, followed by the deployment of the mirror itself as it goes through a very carefully laid out sequence of events.

The whole telescope is cooled down by blocking all the radiation from the Sun using a series of Sun shields that have to deploy, all choreographed very carefully; then the mirrors of the telescope themselves deploy.

And certainly I recommend people take some time to look at this video. Again, there are a number of them on YouTube that give more or less detail.

Some are you know, over an hour long showing you in great detail all the steps that happen. And JWST will be launching in 2018 and it is indeed NASA's next very big thing, and will do an enormous amount of science of which I'll get on to now.

So the sort of things we'll do with James Webb Space Telescope on exoplanets is shown on the next slide where we'll do imaging of - using a - what we call a coronagraph to block the light of the Central star and start to reveal planets. This is an image of a system detected by ground based telescopes, but we'll be actually able to push to fainter levels, get down to Saturn levels of planets and measure the spectra of many of these systems.

We'll also be able to pursue this transit technique, getting spectra of the planets as they go in front of or behind their host stars, and again picking out in great detail, species like methane, water, CO_2 and so on, and push probably all the way down to super-earths. They're probably not down to the level of actual Earth analogs; the stars are still just too bright and they add too much noise into the measurements.

Beyond JWST there are a number of missions that are either already going on, funding targets for James Webb, the Kepler mission is proceeding at pace, the repurposed satellite is doing a great job finding new planets no longer in one field, but moving around the ecliptic plane looking for new planets, and is expected to find hundreds of planets, many down to the level of super-earths orbiting nearby stars suitable for study.

East will be launching, has launched the GAIA Satellite that will look for the positional wobble of stars due to the presence of planets. And it'll survey all the way out to a few hundred light years finding Jupiters and smaller planets around all these systems.

And NASA will soon launch the TESS Satellite to look at the whole sky for transiting systems, finding many much brighter planets - brighter host stars than Kepler, which was forced to look at just one piece of sky in detail.

So there's a lot of exciting new missions coming on in the next couple of years that will feed into James Webb.

There's another mission on the books that'll launch sometime in the mid-2020s called the WFIRST Satellite. It will use this microlensing technique where a lens star increases the brightness of a background star due to the bending of light at the intermediate star actually operates like a real lens.

But if there happens to be a planet orbiting the lens star you get an extra little blip from the defect in this lens if you will, due to the planet, and it can actually let you learn a lot about the population of planets out in a very interesting region, where the planets - many of the gas giants are thought to form.

We're also equipping WFIRST with a coronagraph that should make the first direct images of gas and ice giants in reflected light. The previous images I've been showing were hot, young planets, only a few tens of millions of years old. WFIRST will actually look at planets in their reflective light. And now we're starting to look at planets much like those in our own system.

So we now look at this next slide is a star field from the 2Mass survey, and there are 100 billion to 200 billion stars in our galaxy. We know the vast majority of them have planets. So there must be billions of habitable planets in the galaxy. Even if only a few percent of planets around stars are in the habitable zone and of a size like the Earth, that's still billions of habitable planets. So we want to know on our real final frontier, is finding habitable planets and life.

So the next slide is a close-up of the Earth. And then if you click again there's two spectra taken of the Earth from the Galileo satellite many years ago, Carl Sagan did this, looking back at the Earth with the Galileo spectrometer, which would eventually be used at Jupiter, but to show that there was water and oxygen in the atmosphere of our own Earth.

Looking back from one of the Mars satellites at Earth, again you can see evidence for water, ozone, carbon dioxide, showing that the Earth is indeed a round, warm ball with an atmosphere and with oxygen and ozone present. There's a strong, at least circumstantial case to be made for the presence of life. Oxygen is really very hard to produce without life somewhere in the system.

So if we look 50 years beyond the detection of the first planets, so now we're looking at the year 2045, maybe that's too late, maybe I'm being pessimistic, maybe I'm being optimistic, but one of the sorts of telescopes listed on this slide, a visible light chronograph, an infrared interferometer or an external star shade, all equipped with one kind of technique or another to block out the starlight, will be capable of looking at a few dozens or tens or maybe even hundreds of nearby stars, block out the light, find planets.

And then do spectroscopy of those systems, and look for the sort of things we see in the figures at the bottom; evidence for oxygen, the Oxygen A Band; water, the Oxygen B Band; or in the infrared wavelength, CO2, ozone and water. And if we find those in the right combinations on the right sized planets, we'll have very strong circumstantial evidence for life.

Is that enough? Well maybe 2045 the history books will say that 3 out of 10 habitable planets show evidence for photosynthetic life. And that could be as early as 50 years after we discovered the first planets outside of our solar system.

If we look a little bit beyond we could imagine explorers on Mars drilling deep into the subsurface areas on Mars and perhaps finding life, non-DNA based life, forming deep below the Martian surface. Or perhaps the search for extraterrestrial intelligence finally bears fruit and radio astronomer, you know a relation of Jill Tarter, or Jodi Foster shown here from the movie Contact, is picking up one of the first SETI signals from a distant star.

And you may have seen in today's paper, a very large donation by a Russian Silicon Valley benefactor who's giving $100 million to start the very active search for SETI.

So any number of these techniques might bear fruit. And the last slide I have is a picture taken by the Voyager spacecraft looking back from Earth when it was four billion miles away. And you can see there, that pale blue dot; we're trying to find more pale blue dots, not from four billion miles but from tens of light years away.

I'll end just with a poem from T.S. Eliot that, "We shall not cease from exploration, and the end of all of our exploring will be to arrive where we started and to know the place for the first time, when the last of Earth left to discover is that which was the beginning." By studying other pale blue dots we learn a great deal about our own place in the universe.

So I'll stop there. I've gone through a lot of material very fast. I'm certainly happy to answer some questions so I'll turn it back over to the moderator.

David Prosper: Thank you so much Dr. Beichman. So yes, operator if you could tell people how to dial in?

Coordinator: Yes Sir, will do. If you would like to ask a question, please un-mute your phone first, press star 1 and record your name. I do require your name to introduce your question. If you would like to withdraw your question you can press star 2.

But again, to ask a question please un-mute your phone first, press star 1 and record your name. It does take a few moments for the questions to come through however so please stand by.

David Prosper: While we wait for questions I actually have a question for you. What's the status of the Terrestrial Planet Finder Mission? I've heard it's been off and on for a while.

Dr. Charles Beichman: It continues to go off and on. We had quite a big push in the late-90s and early '00s. And then the astronomy community moved on to the James Webb Telescope. And that's really occupied us for the last couple of years.

There's starting to again be a big push for a mission that might be, you know reviewed by the National Academy, you know, during their next review of priorities for astronomy, for missions that would start in the 2020s. And there are a couple of missions there under consideration that actually would have the power to do some number of Earth-like planets; block out the light of the star and push into actually doing spectroscopy of those planets looking for life.

So I don't know, 2030 we could have one? Stick around.

David Prosper: Cool.

Dr. Charles Beichman: The goal is there, the technology is there, it takes will and a fair amount of money.

David Prosper: Definitely, thank you.

Coordinator: And I am showing no questions in the queue at this time. Just a reminder, that is star 1 if you would like to ask a question.

David Prosper: And another thing, for the K2 mission, is it just looking for exoplanets or is there - I've heard there might be some other extra science that it's doing as well in addition?

Dr. Charles Beichman: Yes. No, it absolutely is pursuing both, you know its primary goal of exoplanets, which it can now pursue for a fair number of other kinds of stars than just the ones in the first Kepler field; it can do young stars and other kinds of stars as well. So it'll do exoplanets in many different environments, but it can also use this incredible precision in measuring the brightness of stars to learn about stars themselves.

There's a technique called asteroseismology, that by studying the vibrations of stars you could learn about their density, composition and age. So yes, it's a very powerful - going to be very powerful.

David Prosper: Very cool. Okay.

Coordinator: All right, and we do have a few questions in the queue right now. Let's see our first question here comes from (Jeffrey Cassoff). Go ahead Sir, your line is open.

(Jeffrey Cassoff): Hello, I had really two questions. One was about that helioseismology?

Dr. Charles Beichman: Yes.

(Jeffrey Cassoff): I had read during the Kepler opening release, I guess back in February of maybe 2013 or 12, that it was a big issue as to whether stars were stable enough to distinguish between transits and variations in the star. Is that an ongoing problem and are there preferred star sizes in the main sequence that are as stable as our Sun or more stable?

And the other question I had was, in your presentation when you were talking about mapping weather, I think I had also read about how these tidally locked planets that always have one face to the Sun, like mercury has one face, that the atmosphere will distribute the heat uniformly or more uniformly around the planet. Is that slide supporting that concept or is it refuting that concept if there's a hot spot?

Dr. Charles Beichman: Okay, let me take the first one first. The question as to the stability of stars which, you know, have a little flickering, you know, at the parts per million level or 100 parts per million level, that can indeed mask a transit of a, particularly a very small planet. And in fact on average, stars turn to be - turned out to be somewhat noisy, more flickery, then our Sun was, or just a bit more active than we'd expected by maybe a factor of 2 or so.

And there's a distribution. Some are as indeed as quiet as our Sun or even quieter. And it has to do with, we think, the age of the star. It could be that the younger stars are slightly more active, then they quiet down as they get old, or they're just a slightly different composition, or a variety of things that people are investigating that cause that increased noise.

So probably about 1/3 of the stars are quiet enough to actually be able to pull out an Earth of a solar type G star. As you go to smaller stars, the relative signal that you get when an Earth-sized planet passes in front of it, gets bigger. The transit signal is simply the size of it is - goes like the square of the radius ratio. So a smaller star, same sized planet, you get a bigger transit and that can - is one reason people are focusing on smaller stars, the K stars and the M stars, it's just easier to pull an Earth out from those.

(Jeffrey Cassoff): Okay.

Dr. Charles Beichman: Second question about the heat maps, indeed the Spitzer map that I showed in the movie, the temperatures from the hot side to the cold side is absolutely moderated by these winds that are very powerful, you know 10,000 kilometers per hour, that move the heat around the whole planet.

So for a gas giant it's pretty straightforward. I mean the winds are there, there's a lot of gas, and that helps moderate the hot/cold side temperature a lot.

As you get to smaller planets, rocky planets, the atmospheres are thinner and there's more of a question as to how hot the hot side would be and how cold the cold side would be. And so a rocky planet might have a much higher contrast between the hot and the cold side.

But certainly the ones where we've been actually able to do the mapping, which are bigger planets, they have enough gas there that they can really redistribute the heat a lot.

(Jeffrey Cassoff): And even those large planets would be tidally locked to generate that kind of asymmetry?

Dr. Charles Beichman: Typically they are, yes. I mean once you're inside the orbit of mercury, you tidally lock pretty quickly.

(Jeffrey Cassoff): Okay. Okay, well thank you.

Coordinator: All right, and next in queue we have (Edward) Downs. Go ahead Sir, your line is open.

Ed Downs: Thank you very much. My question is actually hardware related, regarding the James Webb Telescope. I'm curious as to given the complexity of deployment with the James Webb, is it intended to be a serviceable telescope as was the Hubble? And is it dependent upon some of the Orion development and SLS development that's underway right now or? Well, those are the two questions primarily.

Dr. Charles Beichman: Yes, so James Webb was designed, and is being constructed and will be launched in an area where we did not expect to have any manned capability far away from the Earth. James Webb will actually orbit at a, well it's called the L2 Point, it's about a million miles away from the Earth on the - away from the Sun in sort of a stable orbit, very far away. So there's no real ability for it to be serviced at all.

You know, people have talked in the future about at some point being able to, you know, send a robot out to L2, bring a spacecraft back, repair it closer to Earth or actually setup, you know, some sort of you know, deep space capability to do that. But all that is still very far in the future. And that does depend on the future directions for the manned program; Orion, SLS and so on.

But Webb was designed with the expectation that none of that would be available. So all that stuff has to work.

Ed Downs: Okay, thank you very much.

Coordinator: All right, next question comes from Linda Prince. Go ahead Linda, your line is open.

Linda Prince: Hello. I was wondering about the WFIRST Satellite that is going to use microlensing technique. So there's a foreground star with a planet, and then there's a farther star. I'm just wondering how a little tiny planet compared to this massive star can be seen? Are there going to be - is data going to be collected when the - as the star moves in different positions around the planet? Is that how we can see the - detect the presence of the planet?

Dr. Charles Beichman: Yes, I mean microlensing is sort of an odd technique. You'll - we will wind up staring at something like 100 million stars continuously towards a very, very densely populated part of the galaxy. In fact the background image on my slide is above the 2 Mass Sky Survey. But it just shows an enormous density of stars.

So WFIRST has quite a large field of view camera and will just stare at one field continuously for three or four months. And by doing that, even though any individual occurrence is pretty rare, you star at that many stars and send down data every couple of minutes on all of those stars, you have the chance of seeing one of those nice smooth curves that I showed on that microlensing slide.

And we see these from the ground. This has been done very regularly from ground based telescopes in the Southern hemisphere looking at the bulge of the galaxy. And every once in a while that if the lens star has a planet in the right place, you'll get a fairly short, maybe five, ten hours, blip due to the presence of a planet.

And again, we've done this from the ground. And having enough coverage to make that work is challenging because you actually have to get people. And many amateurs are involved in doing this. Unfortunately they're all in the Southern hemisphere so it's hard for U.S. astronomers to participate.

But there's a global network of professional and amateur astronomers that wants, once one of these big, long, slow microlensing events is discovered, which might take a 20 or 30 day period, people will start to look at it in much more detail if there's a hint of a planet, and be able to zoom in on that blip and you can get a lot from the - about the population of planets that are out there.

So it takes a wide field telescope and it takes continuous coverage, but that's what WFIRST will be doing.

Linda Prince: Very good, thanks.

Dr. Charles Beichman: The down side, by the way, of the microlensing technique is once it's over, it's over. There's no follow-up, you can't go back and say, "That's a great System, I want to study it, look for spectroscopy, characterize the planet," it's a one shot event. But we should get many thousands of them down to the level of seeing things like the size of Mars or smaller, at a range of distances from the star which are hard for any of our other techniques to work with.

Coordinator: Okay. And the last question of the night comes from (John Tulic). Go ahead Sir, your line is open.

Dr. Charles Beichman: You just answered it Sir. Thank you very much. Last question was relative to mine and it was answered. Thank you Doctor.

David Prosper: Well then, okay. So we're almost out of time this evening. But I wanted to thank everyone here who called in. Thank you, all the members that are listening in, for your excellent questions. And I also wanted to give a huge thanks to Dr. Beichman for giving us so much of your time and for your excellent presentation on the future of exoplanet science.

Dr. Charles Beichman: Well it was pleasure talking to everybody.

David Prosper: Yes. And we have one more last note for the exoplanet lovers out here, and that's to say that the wonderful NASA PlanetQuest Web site has now been updated with a 20 Years of Exoplanets page. And it's being updated with many new sharable images of planet profiles, those wonderful exoplanet travel posters done in that old fashioned style that look fantastic, and a lot more.

And there's also resources, just from all the different missions that are looking for exoplanets, as Dr. Beichman was making light of earlier. So you can find them at planetquest.jpl.nasa.gov and a quick direct link to the page in question is another bit.ly link, bit.ly/planetquest20years, and that's 20 as a two-zero. So bit.ly/planetquest20years.

And that is it for tonight. You can find this telecon, along with many others, on the Night Sky Network under Astronomy Activities. Just do a search for

Telecon. So tonight's presentation with the full audio and written transcript will be posted by the end of this week.

And goodnight everyone, and keep looking up.

Coordinator: That does conclude the call for today. Thank you all for participating. You may disconnect at this time.

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