Heidi (00:14):

Welcome, everyone. Today we have with us, Josh Adamson, he's from Northrop Grumman. He has been a spacecraft thermal and design engineer for Northrop Grumman in Redondo Beach since 2008, working on the James Webb Telescope since that time. He received a master's degree in engineering and space systems engineering at the University of Michigan. His advisor, Thomas Zurbuchen, is now the associate administrator of NASA's Science Mission Directorate, and he is now part of the mission systems engineering team for Webb flight operations. And he's been a former student of mine from way back in Fargo, North Dakota, many, many years ago. So I really appreciate the time he's taking today to speak to us all on the James Webb Telescope, as we get ready for the launch, hopefully at the end of the month.

Josh Adamson (01:06):

Thank you for having me. We are basically on track to a December 22nd launch at the moment, which is actually my sister's birthday. So it can be a good birthday present for her. This presentation that I got here is a derivative of something that's been handed down through the project for quite a few years. We call it by the numbers. There's so many different numbers that are associated with JWST, or Webb, both big and small, it's kind of crazy what this program go or what this project does, but yeah, let's just get into it then. So a little bit about me really quick, numbers associate with me. As Heidi said, I'm originally from Fargo, North Dakota. She was my biology teacher way back in the day for high school. I went to North Dakota state, in that whole area has about 100,000 people thereabouts.

For graduate school or for a master's degree, I went to the university of Michigan. And yeah, the current science mission directorate associated administrator is my advisor from that time. And again, that town, little bit bigger than Fargo, 120,000 in Ann Arbor. And then I got a job working for Northrop Grumman. What are you now? Space systems, I think. We've gone through many different organizations in the past, whatever 14 years that, yeah, we went from 100,000 added a couple more zeros. Now I'm in an area of 10 million people. And it takes a while to get out of town, let's just say that. There's a picture of me with my family. We got two boys, my wife and we, right before as they were assembling the JWST, they had picture day and you can see the essentially completed satellite behind us in a almost fully deployed state, which will have show a bigger picture in a little while down the line.

So again, this is a by the numbers presentations. So the first number we have is 13.5 billion. And so when we give these talks with live audiences, we'll ask what unit to measure, what does this represent? So since we're doing this over Zoom, we'll just tell you it's light years. So JWST is essentially in the successor, in the astrophysics world to the Hubble Space Telescope. And in some ways also another one called Spitzer, which is an infrared telescope. JWST is also an infrared telescope while Hubble is a visible telescope. And because Hubble looks at those wavelengths in the visible, it can only look so far into the deep, deep, past, and distance in the universe.

And so it can, you can see in this graphic about how far, how many billion light years away you can get out of Hubble. That 0.4 to 0.5 billion doesn't seem like much, but I guess when you ask the astrophysics folks and scientists, they're really excited about that 0.1 or 0.2, that we might get. You can see first galaxies and stars form, cosmic dark ages. So yeah, that's the scienty part of it. And that's all I'm going to talk about there because I'm the engineer side of things. So I only know a little bit about the science stuff. But anyways, so that's a really, really big number to start with.

And next we'll start with this or go to a slightly smaller number, 1.5 Million. And in this case, this is kilometers. So here again, we have a comparison back to Hubble again, and this is the distance from the earth that our orbit is. You can see the earth on the left and the moon next to it, and then Hubble, this is now definitely not to scale, but you have Hubble that's about say 570 kilometers. That's like 400, 350 miles above the earth and over several couple, what is it, couple decades the astronauts went up and fixed it four different times to upgraded it and replaced things that were not working anymore.

But it's relatively close to earth. And now we got the moon is next and this is in kilometers. The moon's a quarter of a million miles away, 250,000 miles away thereabouts, or 384,400 kilometers away. But yeah, no, that's the moon, that's the furthest that people have ever been. And here we are, JWST 1.5 million kilometers away, so a million miles. And we're out here in L2 for basically reasons for the telescope that we'll get into in a minute. But one of the key things about being in the L2 orbit is that we never go in and out of the earth's or the moon's shadows for an eclipse. Whereas Hubble in most space, however, most satellites that you have around the earth go in and out of eclipse, depending on what kind of orbit they're in or what season of the year it is.

But yeah, we have a specific requirement on the whole 10.5, 11 year mission to never be in the shadow cones of either the earth or the moon. And the interesting thing is that once we come off the earth, as the rocket goes up and the faring comes off of the top of the nose cone of the rocket, we'll never see darkness again, we'll always be in some form or fashion from then on forever and ever. Now the next one is 6.5. So this is a lot smaller than the last two, and what this one represents is meters. And this is the last time I'll rag on Hubble in a comparison between JWST and us or JWST and Hubble. But here you see, this is a cool infographic that you could find on NASA's flicker page. But yeah, we're a 6.5 meter diameter telescope versus Hubble's 2.4 meter telescope.

So that's seven times the collecting area thereabouts, you can see a person of average height, six foot person there next to it. And from the graphic, you can see that Hubble is a single monolithic mirror, whereas we have on our primary mirror, 18 different segments that act independently. Well, no, they don't act independently, they are controlled independently to align and be calibrated such that the whole array of segments act as one giant mirror. And that's an interesting feed in itself. And for those of you that are aware of adaptive optics, it is something that's been done on ground telescopes, both small, and I think very, very large, but this will be the first time that there's a segmented telescope in space.

And unlike on the ground where the ground there, they need the adaptive optics for the air as the air bumbles around to adjust for that turbulence, our need for adjustment is a lot less. So they're doing every... I think they're on the tele hertz range, or sometimes I think adjusting hundreds or thousands of times per second, those mirrors on the ground. But here we're going to probably adjust ourselves, I think, two weeks or three weeks, every so often, just as temperature gradings develop and just things get slightly out of range. But as we have on orbit data and we'll see how often we actually have to do that. The other thing that's kind of fun in this infographic is along the bottom there, you have two lines of the color spectrums. You got Hubble, which now talks to or reads a little bit in the ultraviolet whole range of visible and a little bit in the infrared.

And well, Webb will be starting in the near infrared and going into the mid infrared, and that's there. For those of you that know your wavelengths, where you are from 0.6 to 28 microns. Next set of numbers get into one of the crazy things, one of the crazier things about JWST. And this is the numbers 40 and 178. So for those of you who know at least anything, a little bit about JWST is you might know that we're a giant transformer. And let me cycle through these things. So we have 40 deployable structures, 40 things that move in some form or fashion and 178 release devices, pins, or plates, or just any kind of joint that's held together for the launch loads so that we survive and keep together and things, stay happy relative to each other that need to release, let go of each other so that we can go through all those 40 deployments, all those multiple deployment pieces.

And so, yeah, you can see here on the going from left to right, you've got us packaged away inside the faring of the rocket, and then it's all tightly packaged. And then we are released from the launch vehicle, and then about 30 minutes into the mission we are into the flight from launch. We deploy the solar array, and actually from that point on, once we deploy the solar array, we no longer use a battery. The battery is there basically just to make it through launch and in that section. So as I said before, we'll always be in the sun from the moment when that faring comes off of the rocket. So then we go through, you could see two pallet structures, one in the front and one in the back.

And then when that opens, those are the structures that hold the sun shield, which we'll get to in a second. And then after that, we pull the telescope about a meter and a half away from the rest of this area here, the central core of the structure. And then let's see, then we start deploying the sun shield. So, like I said, we'll get into in a little while, but yeah, we've got five layers of this large sun shield that we start expanding. So first we got to pull out the left and the right sides and then the next thing is to pull the layers apart, there are five layers. And then after that, we get into the telescope itself and deploying. You can see the mirrors are folded in this one and here they're unfolded there.

So, yeah, it's a very complicated, very complex deployment sequence. And if you've ever read much about JWST online over the years, you'll inevitably find statements in there about all the deployments and things like that. But they've gone through rigorous testing, both at component level and at the integrated observatory level, across all sorts of conditions, to make sure that the motors work, that everything separates, that the release device is released and so on and so forth. Additionally, one of the reasons Northrop Grumman was selected for this mission way back in the days is because of our success in past on orbit deployments. There's a long history of that from what used to be a company called TRW, which was purchased back in early two thousands by NASA. That's where we built this [inaudible 00:13:26]. Our next two are frankly my favorite two numbers -388 and 185.

And if you caught, what was the intro, I am a thermal design engineer. So we have two major zones of temperature on this observatory. You got the sun facing side, the hot side, which is the left bottom side, that's on the order of 150, 185 degrees, depending on what side you're looking at or what part you're looking at. And then you have the sun shield, which is blocking all the sunlight and all the heat that comes from that to the cold telescope. And so there, we're on the order of -400 degrees Fahrenheit, which is on the order of 40 Kelvin. So extremely cold. For those of you that follow your infrared or your electric maintenance spectrum, infrared wavelengths are essentially heat that all black body, all surfaces emit in some way, if it's got a temperature over zero.

And so we're in the near infrared, as well as the mid infrared. And so in order to keep the mission going, you've got to be cold. If the telescope itself is too warm, it would be akin to going outside at night, training a flashlight in your eyes and trying to see the stars. A little the joke that I make here in LA is that you try and go outside in the middle of LA at night and trying to see the stars, there's just so much light pollution, so many people everywhere. So yeah, we cool the observatory so itself is not in the way of the images that we're trying to take of the sky. So backside, so here again is the 18 segments of mirrors. The primary mirror light comes from long, long, deep, deep, far away, bounces off that, gets to the secondary mirror and then goes right through here through this after optics subsystem that has a couple more mirrors in there that send it finally into the science instruments themselves.

Now there are three science instruments there, oh, sorry, four science instruments, three of them are near infrared, and those ones need to be on the order of 30 to 40 Calvin. So nice and cold. But then the mid infrared instrument, that guy needs to be extra cold, because it's a different range of the infrared spectrum. So he actually goes down to six column. So that's on the order of 450 degrees below zero. And that's done by a special refrigerator that's on board called a cryo cooler. And down here, you got your sun shield again and then down here below, you've got your regular spacecraft stuff. You've got your computer, you've got your navigation, you've got your communications and you've got your power generation, all the guts that make the payload, the telescope itself work and all that stuff.

So yeah, again from the thermal design side of things for a spacecraft, at least not only is it difficult to keep something cryogenic cold and continually cold, especially when you're so close to something so hot, but actually conversely with this one specifically that the spacecraft bus part, was another difficult thermal challenge to deal with because this large sun shield here blocks a lot of the cooling view to this kind of a normal spacecraft would have. And not only that, but it also creates its own high temperature background, infrared back load. So both sides have their extreme challenges to deal with. And again going back to the numbers -388 and 150 or 185, down right here in the very central core of things, as I think it's maybe about a foot, thereabouts is probably the largest temperature gradient on the observatory, where it from about room temperature, a little bit cooler than that, and drops like 200 degrees.

It's pretty fast. And we use carbon composite materials all throughout the telescope itself so that for one thing, it keeps some lightweight, but it also allows the structural engineers to tailor strength and platform stability. And we all in low coefficient of thermal expansion, so that as we go through these large temperature center that swings but changes the overall shape of the observatory doesn't change and the stresses are there. So it's very important because everything's built at room temperature, right? You're not assembling this telescope at 400 degrees below zero because nothing can do that. And then so you just make sure that everything goes together, ever stays happy when it goes through its [inaudible 00:18:48]. Now with that in mind, I've got a handful of pictures here of the various stages of assembly here.

This configuration here, so you've got the partially deployed observatory. This is as deployed as it got because we couldn't, and I'll get into this a little bit later, but we couldn't deploy all of the... You can see the mirrors, both the wings on the side of the primary mirror, as well as the secondary mirror tripod, and those are all folded up. And that was basically because you need to support those things properly in order to make everything work. And what's actually happening in this picture is if you can see it, there are very thin, well in this picture, but there are four sets of cables up at the top here that are actually holding the entire telescope part, which I think that weighs in the order of 3,000, 4,000 or 5,000 pounds, something like that.

And it's counterbalanced by a weight system that's off to the side, and down here in the middle, which is hidden by something else here is that telescope or sorry, that tube that deploys us away from there. So yeah, hanging there. And so from a ground support equipment and hardware safety feature that this was as deployed as they wanted to make it. And you can see over here, relative size, there's a nice human being that's on a lift, just to give you an idea of how big that is. And again, 6.5 Meters is about 21 feet. So it's very, very, very big. Here before the telescope was integrated with the rest of the sun shield and the spacecraft bus, it went through its own testing regime. And one of those stops was going down to Houston, to NASA Johnson, Johnson Space Center to go through a thermal vacuum test at extreme temperatures.

And NASA spent quite a bit of money repurposing this chamber for this test, because beforehand it was a normal thermal vacuum test or a thermal vacuum chamber that uses liquid nitrogen and gets you down to about 100 Calvin, which I always forget what that is in Fahrenheit. But cold, but not as cold as what we needed for JWST and the telescope. So they retrofitted this or not retrofitted, but they fitted this with a heat or the hydrogen, no helium, helium chamber so that the walls of the chain of the walls of the chamber to get down to 25 Kelvin, I think it was, [inaudible 00:21:37]. And so they were able to simulate the extreme cold that the telescope would go through. And it was a pretty extensive long term test. And if anyone was following at the time, this happened to be the test, it took about three, four months and well about halfway through a little thing called Hurricane Harvey came through and made life interesting for the people that were sitting the test.

And thankfully they didn't lose power, they didn't run out of coolant or anything like that. They had food, since it was coming, they had the resources they needed to stay safe and alive frankly. But yeah, that was an adventure for them, for sure. And again, in a little red box, I've got some people highlighted so you can get an idea of what it is. And oh, one thing that also pops out probably in the previous pictures too, is that we've all coded mirrors. All the mirrors are gold coded. And that was chosen back in the day due to its higher reflectivity in the infrared band than we are interested in. And so I think the fun fact out of how much gold we used, because it's very, very thin, but it's a large surface area.

So if you were to melt all the gold off and put it into a ball, I think it was supposed to weigh as much as a golf ball. So it's not as big as a golf ball, but at least weighs as much as a golf ball. So a few ounces. A couple of other pictures, just giving you an idea now on the stored configuration back here at Northrop Grumman, you have again lifts and people hanging out. This kind of lift is one of my favorite ones to point out to people, because other ones, you're on the edge of a crane. But then these ones are called diving boards, which you can see why it's called that because it's basically a giant forklift with a plank and you've got someone that's thankfully got a harness on and they can sit on it, they can lie on it, they can do whatever so they can reach in and get stuff.

Because that's what this one is mainly used for. These larger ones, you can't really get in to some tight areas and that's what these ones are used for to scoot yourself in really, really well and safely. Really quickly about deployments, when we talked about testing the various deployable features components, this is one of the examples of that. So the solar array was... This is five panel solar array and it's all nice and folded up according style during launch and then half an hour after launch we deploy it. And this is an example of how the testing was done.

You can see that there are, let's see, lines again, support cables. And then there's this essentially interesting track that's above here that keeps everything in line and doesn't put too much strain on the joints because when you do a deployment test like this, you always want to make it as zero G as possible. So no influence of the gravity that we have on earth. So that's why they do this sideways. And so the axle or the node hinge axis is parallel with with the gravity vector. And so by then offloading whatever part you're deploying in again, the vertical direction, you can allow the hinges in the motor or whatever's driving the deployment to do its job without having too much difficulty, extra resistance, I should say, extra non flight resistance to do the deployment.

Yeah, so they had this neat grid pattern along the bottom, they had plenty of cameras and to see how it worked out. Yeah. You can see in the end it was nice and flat and straight up. Next one in a similar vein, this is how they did that secondary mirror support structure deployment. They tilted the whole observatory and I guess the telescope on its side and then, let's see, can't really see it, but this big fixture there is where the attachment point is. It looks like a cable that's here too. So I think you may have a couple things, but yeah, you got three hinges, one down here, down there and then up here at the top. And there's a motor up here that's that does the actual driving, that's the driving part of it. Yeah. It's I think a 20-ish or so, 21 foot arm length, essentially between the secondary, primary and secondary mirror.

So it's a pretty big long tube that they have to do this with. So one of the fun things is, when you are done with the telescope, and when you're done with the satellite, you've got to ship it to your launch site. And so one night they loaded it up, they got it in the container and put it on a truck. So in here, this is a special humidity, temperature, air quality, cleanliness, controlled environment for the telescope. Because obviously with something like optics and mirrors, you want to keep things as clean as possible. And so we have much more stringent contamination control requirements than say your average satellite that say goes up for TV, direct TV or an XM radio, whatever, communication satellites. But yeah you put it on a truck and you drive it on out.

This is my picture, but I was here this night, watching it go and it was fun. It's the first time I'd actually seen a satellite roll out the door. I've seen plenty of pictures like this myself, but it was fun to see the process. What was really interesting and neat is that you've got your regular tractor trailer truck in the front here, but in the back there was a special wheel assembly. I don't know what you call it, but it essentially had its own steering system. So you could navigate tighter corners than just a regular trailer alone could. Yeah, so this is Redondo beach, and then this was, I think about... They finally got it out and gone down the road around 1:00 AM in the morning and then they drove it down to the Seal Beach, which is down to the south.

So I don't know, it's 20, 40 miles, something like that, but it took them, I think it was four to six hours. They go slow. They went in the freeway, they had a nice police escort of about, I don't know, six to eight cops going around. Yeah, then they put it on a boat. Before we get to this part, there was a boat that was down there in Seal Beach that was at the port. They put it down, put it on there and then they floated it down the coast of the Pacific and then brought it through the Panama Canal and then brought it around the northeast side of south America to French Guiana. And then they made it, came in there and here we are driving through the Guiana Space Center, which is the launch site.

So over here, this is the road that they came in on and then they're going to this. This area here is just office buildings. And then they're going towards the assembly buildings or the processing buildings that are down the road further. But I thought this was a pretty cooler shop because here again, you've got the cargo container that we saw in the other picture. And then over here is a full scale model full, scale build of a real rocket, the Ariane rocket that were going on. And they're not next to each other so you can't quite get the idea of how big it is, but it's a towering kind of a thing. So it's pretty neat to see. Yeah. So then next bit of stuff is now that we're in the processing facility, we were in this orientation, this sideways orientation in the transport container.

So how do you get yourself pointed up? And we have this rollover fixture that you can see working here. You attach to the bottom there and you just start rolling it over and it stands up straight. Yeah. So this is the again, 99.9% completed observatory. There was just a little bit of extra work that they wanted to finish here, but this is basically what we look like right now. It's pretty cool. Oh, yeah. And then my last slide that I've got here is, again, something you can find on NASA flicker pages. This is our rocket. And I thought this was pretty cool to show is that the Ariane 5 has no core stage and it's got boosters on the side so this is just the core stage itself.

And then up here and at the top, you got the top of the core stage and then you've got the second stage or the upper stage of the rocket. And then we'll attach right up here where this blue guide is, after everything gets attached where it is. So again, like I said, we're still on track for the 22nd for a launch. I've heard we've finished fueling and, yeah, so I think it's just getting ourselves attached to the rocket and getting in the payload faring, and then going through all the normal process we've got there because we really only got less than, or just over two weeks to go. So I think that basically finishes all of the stuff that I've got. So I can take questions, I think, right?

Heidi (31:38):

Thank you. We do have a mic in the room if anybody would like to pose any questions or if you prefer to write them in the chat, we'll be happy to repeat them for you or you can unmute I believe and ask them.

Speaker 3 (31:56):

So you talked a little bit on one of the first slides about some of the difficulties of having the main satellite bus be on the hot side of that sun shield. So that being said, why was the bus placed on the hot side as opposed to just having the sun shield basically block the entire spacecraft?

Josh Adamson (32:21):

I mean, I had never thought of that one before. I've been giving tours on JWST for, who knows how long, probably close to a decade. But that's probably the first time I've been asked why isn't essential on the bottom. I assume it has to do with, if you were to do that, you would basically freeze out the rest of the bus. Like I said, the normal...Let me go back to that slide and [inaudible 00:32:49]. It's your normal set of satellite stuff. And that always wants to just be around room temperature, thereabouts plus, minus a little bit, hot day, a cold day. So if you were to put the central down further below you, I think it simply becomes, you just freeze out the rest of the observatory and the electronics, so yeah. Yeah. It's that difference between wanting to keep something around room temperature and want wanting to keep something around absolute zero.

Speaker 3 (33:23):

Sure. Cool. Thank you.

Heidi (33:27):

Question that is chat, so I'll read that one really quick. Does the Webb use reaction wheels and if yes, how long do they last, longer than the Hubble?

Josh Adamson (33:37):

Yes, it does. I don't know how many Hubble has. They only have four, we have six sets of wheels. We also have smaller thrusters for course attitude adjustment, but for in science or during science operations, where you do use wheels. And yeah, we have six sets of them. That's that's on the attitude control side. All I have to do as a thermal engineer is make sure that they're in the center, right temperature range, so that's where I end.

Speaker 4 (34:09):

I guess we have a question here by another student.

Speaker 5 (34:14):

You mentioned that there was noise radiation from the heat field. How did you manage that? Or did you just allow it and compensate for it?

Josh Adamson (34:25):

Yeah. That's a good question. We all call it stray light. So normally with stray light, you're talking about a light source coming and bouncing around and zipping around. And in this case that's true, because you can get real stray light say from the sun, if it accidentally glimpse off the sun shield or something like that. But in our case, it's the heat of things around it that are the stray light for the most part. Yeah, we've gotten the telescope cold enough that it's not the problem and, right, in the sun shield as well. But there are kind of [inaudible 00:35:11] if I remember it, two main components or two main pieces that contribute the most to the stray light budget itself and that is the primary mirror itself, and that really the lower segments that are nearest the hot bus, those are the warmest ones and so they'll dominate that term.

And then secondly, the sun shield itself is not quite as cold as the telescope. And so it's just a little bit warmer, but again, as in any optical design, you've got baffling to stop stray light as best as possible. And in our case, you probably can't see it very well, but the hole that's in this snout here, that's kind of tailored to the instruments. You've also got a perimeter around the telescope. That's another source of stray light where interestingly the stars behind us are a source of stray light. So if we didn't have that extra perimeter, this black perimeter, we'd get light from front and light from the back, that would be a problem.

So that's how that was mitigated. And then even deeper inside the there's two more mirrors, the tertiary mirror and then the fine steering mirror. And the fine steering mirror actually has another mask on it. So that it's just, again, if everything were perfectly aligned, it has the shape of the hexagonal mirror as well as it's inside of the stray light perimeter that I was mentioning earlier too. So yeah, several layers in a normal optical design concept, I guess.

Speaker 5 (37:13):

And then also, where did you radiate off the cryo pump heat?

Josh Adamson (37:19):

So one of the really fun things about JWST and also one of the challenging things is that we are, except for that one mid infrared instrument, letting space cool us and suck the heat out of us. And so we have large radiators on the backside that you can't really see in this picture here that are attached to all the instruments. But that cryo cooler, one that gets the thing down to 6 Kelvin, most of its components frankly, are down here in the bus where everything's room temperature and can operate at a normal set of temperatures.

That's one of the other not emergent but new technologies that are coming in with JWST is that it's got a, I think they call it a remote crowd cooler where oftentimes you have this cryo cooler assembly that's attached directly whatever you're trying to cool, say a focal plane array inside of an optic assembly. But here we've got to send it further along. So yeah. But all that heat that's generated from the compressor action and things that's down in the bus that has its own thermal control system.

Speaker 5 (38:44):

So did you connect it with thermal pipes?

Josh Adamson (38:48):

Actually for this, we use helium gas and a series of basically stainless steel tubes that go up into a heat exchanger near the instrument that is attached again to the instrument that would actually cool it all down. So yeah, there's helium gas lines. I'm trying to think if you can find much about that online or not, or if it's all behind the wall of designing on insight.

Speaker 5 (39:22):

All right. Thanks.

Heidi (39:22):

Another question online really quick before somebody goes there. Can you share details of the material used for the five layer sun shield?

Josh Adamson (39:30):

Yeah. So normal spacecraft thermal control blankets feature materials is you often use either Mylar or Kapton. And in this case it's a special blend of Kapton that I guess was needed for probably the strength properties. But yeah, it's just coated Kapton. It's either coated with vapor deposit aluminum or it's coated with Silicon into it. Oh, and so along the lines of that, one of my favorite things to say as a thermal and spacecraft thermal engineer, is that any color you see on a spaceship or a spacecraft has either been chosen or at least deemed acceptable by the thermal design engineer. Because colors will actually tell you how heat moves in and out of that particular surface. And so to first order, you see three kinds of colors here. You see pink, you see black and you see silver.

And so the pink stuff you can see is all on the bottom. That's the hot side. And that's the Silicon... I don't think it's... I'm trying to remember if it's a Silicon coating or if it's actually Silicon that's doped in the cap done material itself. In either case it's got a Silicon feature to it or Silicon coating to it. That has a favorable coating to keep cool in the sun. But it's not quite as good as keeping heat away from the layers or from the other layers of the sun shield. So the bottom of the first layer and of the second layer of the sun shield are covered in this Silicon coating and then the top of the second, or is top of the first and top of the second and the top and bottom of the third, fourth and fifth are covered in the paper deposit aluminum.

And that is a very, very good reflector of anything so infrared or visible. And so it shuns all the heat that's coming up from the bottom of the sun shield out the sides. And then also when it gets to the top, it can emit as well as efficiently to the telescope itself. Another fun fact is that on average you get about 200 kilowatts or two yeah, 200 kilowatts absorbed on the sun shield first layer. But by the time it gets to layer five, there's only about two watts that makes it to layer five to the telescope itself. So you got a huge order of magnitude or many orders of magnitude loss of heat out the sides and away from the thing that you're trying to protect. And so if you again, read things on JWST sometimes you'll find a statement that says the JWST sun shield has an SPF rating of 1 million when in fact it's more on the order of 100,000 but who's counting?

Speaker 6 (42:44):

So one of the advantages you said about this is that the orbit keeps it out of the shadow at all times. Can you talk more about why that's such a big advantage and how the orbit achieves that goal?

Josh Adamson (42:55):

Yes, let's see. So let me go back to the picture. You can find all sorts of pictures about this. So again, we're at Largrant 0.2, which is a, for those of you who know your orbital mechanics, one of the five positions that the two body gravitational system kind of cancel each other out. For those of you that follow solar observing satellites, those are L1. So that's between the earth and the sun. L2 is on the opposite side of L1. I think they're symmetric. So I think L1 is a million miles towards the sun and L2 is a million miles away from the sun. So it becomes a gravitational neutral point. And then we actually orbit that point in space.

It's a weird thing. We're orbiting something that doesn't really exist, or physically as a piece of mass. And our orbit is on the order of, I want to say it's a 100,000 kilometer radius, so it's a huge, huge orbit. And if I remember right, I think it, we go around that one time in say six months. So in one of our years, we do two orbits in our orbit. But going back to why it's good for us, again, what I mentioned here, where Hubble and most other satellites go around the earth and go in and out of shadow, when you do that, you disturb the thermal equilibrium of the system. And when you do that, especially if you do it for a prolonged amount of time, or for really, really deep temperature changes, you're going to change the shape of the telescope by just CTEs and just the change in temperature.

So one of the interesting things is that because of the shape of the sun shield, and we have to keep the telescope in the shadow of the sun shield, we have essentially a donut of available attitudes we can go in. I think we got a plus and minus 50, yeah, 50 degree pitch angle and about a plus and minus five... No, it's a total range of pitch of 50 degrees. I think we go plus five and like minus 45. And then on roll, we have about plus and minus five on either side of that. And then if we go any outside of that and we start getting sunlight [inaudible 00:45:51] or starting to creep on the volume.

So even with that kind of small range of attitudes, just by changing that attitude, we are disturbing the stability of the telescope and the mirrors and the instruments on the order of milli Calvin, tens of milli Calvin. And that's enough to distort this already really tuned, low CTE, low distortion structure enough to, I guess, require a little re-phasing and adjusting of the mirrors. So that's why as we get on orbit, we'll see how well our models correlate to that behavior and how often we actually do need to re-phase it.

Speaker 6 (46:45):

Great, thanks. Quick second question. Why was this designed to detect infrared radiation specifically, as opposed to the visible light that Hubble is?

Josh Adamson (46:54):

Right. So that goes back to this picture here, and I don't have a good graphic on it, but I've seen a different graphic somewhere else. It's all about if you're aware of red shifting of distant universe, distant galaxies, different things. So the reason that Hubble can only look back per this graphic, 13.4 billion light years is because... Let me go back, this one, the further back or the further away, the more light years you have, the more red your color gets of your object. So if you were right next to it and it was green as you get further away, it gets more and more red. It goes from yellow, red. And so basically whatever wavelength that Hubble ends at, limits it just by physics. And so by having this extra band of infrared, we're able to see those things that Hubble just can't see. But that's definitely an astrophysics question for sermon.

Speaker 6 (48:08):

Great. Thanks.

Heidi (48:10):

We have another online question. Given the temperature difference from the bottom to the top of the web, would it make sense to use thermoelectric generators to create energy versus solar cells?

Josh Adamson (48:24):

The short answer to that is the TECs are inefficient, and they actually generate their own heat by that as well. I guess it depends on which direction you're using them. But yeah, it comes down to not being able to generate as much heat as you can just from straight up solar panels.

Speaker 7 (48:44):

How long do you expect it to take before the James Webb Space also reaches the second Lagrange point and deploys and we're able to use information that it gathers.

Josh Adamson (48:55):

That's a good one. Let me go back to that picture again. So you can find some really fun videos online, but basically it takes us about 30 days to get us out to L2 and then we'll do a final midcourse correction burn to get us in that final, very, very large orbit. However, we won't even be cold enough to start using the instruments until about another month after it, mean 40, 50 days, 40, 50, 60 days afterwards. Because again, we're using space to slowly cool us down, and yeah. So about two months in, they'll be able to turn on the instruments and then start aligning the mirrors, getting them collected and acting as one giant mirror.

And then over the course of the next four months after that, they'll go throughout the entire calibration checkout phase of the mission so that by L plus six months, the plan is that we are fully aligned, fully calibrated so that the real science will happen at that point. However, that said, I'm sure during that first six months as they do some of this stuff, they'll be, I don't know, useful. They'll be taking observations to do that obviously, but whether how useful those are that I don't know and if they'll release those to public or at least some burden of things or not. But yeah, six months down the road they'll be ready for the real observing campaign.

Speaker 7 (50:32):

Thank you.

Speaker 8 (50:33):

All right. So I was wondering if there is a severe enough temperature gradient between the bottom and the top of the primary mirror to require that the bottom element is a different shape than the top.

Josh Adamson (50:48):

Yes, there totally is. And interestingly enough... Let me go back to one of these pictures. There are three kinds of mirror prescriptions here. There's an A ring, a B ring and a C ring. So you already start out with three different prescriptions to get the mirror as is. One thing we just kind of don't have time to go into, but I think you can find some information online. So each one of the 18 mirror, or the primary mirror segments, as well as the secondary mirror have mechanisms on the backside that allow us to do that phasing, that fine tuning. So yes, each individual mirror should have its own prescription in the end. So yeah.

Speaker 8 (51:43):

Appreciate it. Thank you.

Heidi (51:45):

Hey, we've got one online. How did things change from the original design?

Josh Adamson (51:51):

I've been on the program a long time, but not that long. Well, no, actually I do. Let's see. So if you were able to find... I don't even know if they were to publish them. The solar array that's in the back here, there used to be two coming out the sides. The sun shield itself, the initial concepts of that looking back now were comically simple. Especially given the complexities of basically playing origami with tennis court size pieces of paper or plastic. And let's see this little flat back here, there's probably not that much detail in here, but it's essentially a deployable radiator for two of the science instruments. And that didn't exist long ago.

The thermal radiators for those two instruments used to be actually on the side of the science instrument area, because there's three on the top or there's radiators on the top and then there would be one on this side and one on that side. But in the end, the thermal design couldn't handle that. There's too much heating from the sun shield that was impinging on it. And so we went through that and changed that. But outside of that, the general architecture has stayed the same. They always knew they were going to do five layers, said it was never a four to five or a four to six discussion because that decision was made eons ago, way, way, way back. I think maybe in the early, early, early days of the program, the mirror was bigger. I want to say it maybe have been eight meters instead of six and a half, but then they got real and they figured, oh, we can't really do that.

Heidi (53:43):

Okay. I believe our time is up. Can we please thank Josh for his time today and for speaking to us?