NASA Museum Alliance Conversation
Exploration Mission One Briefing
First Mission into the Proving Ground and a Step Closer to Mars
Mike Sarafin, Mission Manager for Exploration Mission One, Washington D.C.

Moderator: Anita Sohus
Jet Propulsion Laboratory
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Coordinator: Thank you all for standing by. I would like to inform all parties that this call is being recorded. If you have any objections, please disconnect at this time. Thank you, please begin.

Anita Sohus: Thank you very much. Welcome everybody to the Museum Alliance talk today on Exploration Mission One. I want to remind you to mute your phones if you're not talking and do not put us on hold as sometimes that plays music, which is not what we want to hear. Today we're really pleased to have (Mike Seraphin) talking to us from NASA headquarters. He's the mission manager for Exploration Mission One. And that means he assures all aspects of mission preparations, certification of flight, mission management, launch operations, flight operations, and recovery operations and makes sure those are all safe and efficiently done.

During the operations phase of EM-1 he'll be the mission management team chair, and prior to assuming his current post, he was a NASA Flight Director for 10 years. As a flight director, he was responsible for overall safety and success during mission operations while overseeing human spaceflight operations from Houston’s Mission Control. And during this time he led missions for the Space Shuttle, International Space Station, and the Exploration (Orion) Mission Operations, including the maiden test flights of the uncrewed Orion spacecraft. So (Mike), he would like to -- if you could -- save your burning questions ‘til the end, and if you've got it queued up, go ahead, take it away, (Mike). Thank you.

(Mike Seraphin): Thank you, Anita. Well, good day, good afternoon to everybody. Again, my name's (Mike Seraphin). If you could queue up your charts and then when I say next slide, just kind of hit the spacebar I think we'll all end up at the same place. There is a separate video file available for all of you. We can go through that in our spare time. Otherwise it's really going to be a summary of what I talk through and kind of shows the mission that we intend to fly here in 2018 called Exploration Mission One. And I'll describe in more detail here shortly.

But it also shows progress towards that as we produce America's new spacecraft, Orion, and as we produce the most powerful rocket in the world called the Space Launch System and set up for this flight test. So it shows meaningful progress as we are -- no kidding -- going from a design on paper through production and getting ready to fly this test. So again, you're welcome to watch that video at your own leisure. We can do that here at the end of the day.

So on the very first slide this is just a view of our rocket and our spacecraft mated together during the launch phase on the right hand side. And then you see Orion in its space flight configuration and then off in the distance, Mars. So I do want to talk about Mars. So on the next slide you see the Earth on the left and the ultimate end goal destination, Mars.

As we say within the agency we're on a journey to Mars. It's going to take us some time to accomplish that journey. And through scientific human exploration and technology development we're going to achieve that end goal of putting a human on Mars. It's not going to happen overnight. It is going to cost us some time and it's also going to cost us some money to do that. And I want to kind of talk you through the architecture of where we are right now and our plan to accomplish that.

So if you go to the next slide, please. You see that we're in what's called an “Earth Reliant Region.” So right now we have humans flying on board the International Space Station. We've got a crew of six astronauts and cosmonauts that are up there. In fact, we just launched a new crew on board a Russian Soyuz vehicle yesterday, up to the International Space Station after an American astronaut -- Scott Kelly -- just returned from a yearlong stay on board the International Space Station.

We've been flying astronauts on board the International Space Station for 15 years continuously. And we're going to continue to fly humans in space onboard the International Space Station until it comes time to retire that amazing scientific platform. We've got commercial cargo vehicles delivering supplies to the International Space Station to supply and sustain our astronauts, and soon we will have commercial cruise services launching astronauts from American soil. Until then we're relying on our Russian colleagues and partners to get to and from - to get our astronauts to and from the International Space Station.

Also in this Earth reliant region we have a number of robotic spacecraft to help us understand deep space, including farther term destinations like Mars, including the Hubble Space Telescope.

So if you look - if you'll go to the next slide, please, you can see that we're moving into what's called the proving grounds. From this Earth reliant region into the area around the Moon. And this area is not just hours from Earth but its days from Earth. The Moon takes about three days to get to. And we're going to fly our new rocket -- the Space Launch System -- and our new spacecraft out to the area of the Moon and we're going to do that on its very first joint flight test called Exploration Mission One.

After some period of time, we're going to have in-space propulsion, in-space habitation, and we're going to demonstrate the ability to retrieve an asteroid using Orion on an asteroid re-direct mission. And that'll serve as the proving ground. And eventually we'll have enough confidence in this region that is days from Earth, it's harder to get to and harder to sustain yourself in than low Earth orbit, that will give us the ability and the confidence to go on to Mars.

So if you go on to this last slide here, you can see this Earth independent region where we aren't just hours or even days away from Earth, we are months to years away from Earth. And that's what's required to go to Mars. Mars is nine months in one direction from Earth. So if we're travelling out there and we realize we don't have enough water or oxygen, that's a bad thing. We got to turn around and come home.

So we've got to develop what we're terming Earth independent capability. The ability to sustain ourselves for years at a time in deep space, away from the logistics train of Earth, away from cargo vehicles shipping up new supplies of food and water and clothing. We have to have the ability to maintain not only our own personal health and well-being of our astronauts up there, but also the ability to maintain our spaceship and our spacecraft when things finally wear out and break. Because that just naturally happens through man-made devices.

So we need to have the ability to get into that Earth independent mode. And there are technologies enabling that, things like 3D printing and additive manufacturing where you can take something as simple as a powdered material and manufacture a brand new part on the spot if you've got - if you have a 3D printer.

Before we get there, though, we've got robotic precursors that are out there. Things like the rovers on the surface of Mars that are helping us understand the resources available, what would be available when we do send humans there. Is there water there? Can we harvest it from the soil? Are there other opportunities or areas of scientific interest at this far destination called Mars?

So that is our long-term destination and our long-term goal is to develop these technologies. And we can also get a return on investment through developing these technologies for life here on Earth. Not only will they help us understand ourselves and our own environment, in our own Solar System better, but we can adopt and adapt those technologies for use on Earth.

So that's the journey to Mars. If you go to the next slide this is the Orion spacecraft that's going to enable our astronauts to get safely to orbit and to return them back to Earth. It's comprised of a couple of pieces; in that center silver capsule in the middle there is the crew module. That's where our astronauts ride the rocket to orbit but also come home in. There's a heat shield on the base of the crew module. I'll talk a little bit more about the next - the other parts of it on a future slide, so if we could keep moving here to the next slide, it shows the Space Launch System.

So this is our amazing and powerful rocket that's being led by our team at the Marshall Space Flight Center in Huntsville, Alabama. It has a liquid core stage and some solid rocket boosters and is going to be capable of carrying in excess of 70 metric tons of cargo to orbit. And in this case, that cargo is our crew vehicle and our astronauts on board it, as well as their supplies.

So on this next slide you can see that that leads to the proving grounds. So Orion and the Space Launch System together will allow us to enter the proving ground and to move towards our destination of Mars. Mars is our stretch goal and today we have the technology and the means to send humans to Mars, but we need to do it within our means and within our budget that's provided.

And that's going to take some time, so we're going to do that in phases and we're going to leverage our knowledge and our experience gained on board the International Space Station, and demonstrate these new capabilities -- our new rocket, our new spacecraft -- as well as some other capabilities that are ahead of us -- in the proving ground and build that confidence days away from Earth before we go months to years away from Earth on a journey to Mars.

So that is our broader goal. And now I'm going to talk about how we're going to start taking the first step there on Exploration Mission One. So if you go to the next slide, you can see this is the launch vehicle -- the rocket and the spacecraft -- that we're going to fly on Exploration Mission One. This is the mission that I'm helping to lead here for our agency. And the rocket is going to be massive when it's ready. With Orion stacked on top it's going to be over 32 stories tall. It's going to weigh just under 6 million pounds. And it's going to produce just under 9 million pounds of thrust at liftoff. And if you work your way from the very tip of the rocket down to the business end where the engines are, you can see the uncrewed version of this that we're going to flight test here in 2018.

At the very top is the launch abort system. Normally it's just jettisoned after we get the spacecraft into space and we don't need it, but in the event of an emergency while our astronauts are on board and they need to get away from the rocket because something bad were to happen, they can use that launch abort system to safely pull the entire capsule with themselves in it away from the rocket. And that's a safety device, a very important one.

The crew module, again, is where they ride and here you see it underneath the aerodynamic shroud that the launch abort system provides and is jettisoned later during the launch phase. And then below it is our in-space power and propulsion unit called the service module. It produces power via solar rays and it provides propulsion via chemical propulsion or rocket engines.

Below it is a stage adapter, which just serves as a structural interface between the spacecraft and the propulsion stage. The propulsion stage provides that additional thrust required to leave Earth's orbit and will push us on our way to the Moon. Below that is the launch vehicle stage adapter, which again is another structural adapter that sits between the spacecraft and the liquid fuel tank that's provided by the core stage. And the stage adapter just provides not only a structural load path but an aerodynamic bearing to help us during the launch phase.

So the liquid core stage stores cryogenic oxygen and hydrogen and fuels the four liquid main engines mounted at the base of the core stage. Those liquid main engines produce just under half a million pounds of thrust each, so about 2 million pounds of thrust total for the four core stage engines and are derived from the Space Shuttle. The solid rocket boosters produce the majority of the thrust. They produce just under 7 million pounds of thrust between the two boosters and provide the vast majority of the propulsion to get to orbit.

So if you go to the next slide, you can see how all this comes together at America's space port, the Kennedy Space Center in Cape Canaveral, Florida. So the rocket comes together in pieces and the spacecraft comes together in pieces and they ultimately meet together at the launch pad. The rocket segments for the solid boosters come in on a railroad car from Utah where they're manufactured.

And go into the rotation processing surge facility where they're rotated from the horizontal as they were to ride on a rail car into the vertical as they need to be for launch. And then they're rolled over to the vehicle assembly building where they're stacked together. There's five segments per solid rocket booster and those propellant segments are stacked and become the structural backbone for the rocket as it's assembled. And we build a left booster and a right booster.

And then you can see on the right hand side here the turn basin. There's a barge that comes in called the Pegasus Barge and that's where our liquid fuel tank -- the core stage comes in as well as our upper stage. They come into the turn basin, they're brought into the vehicle assembly building, and then they're stacked with the boosters on top of the mobile launcher as well, inside the vehicle assembly building.

And then our spacecraft Orion comes together in pieces and it's fueled on the bottom center of this diagram. The spacecraft structure right now is currently being outfitted at the operations and checkout facility and once it's outfitted with flight computers and wiring and a cooling system and power system, it will be sent over to the multi payload processing facility where it gets fueled with hypergolic fuels and then is rolled over to the launch abort system facility where that safety device -- the launch abort power that I talked to you earlier about -- meets it and then is mated to the top of the spacecraft.

The crew module, service module, and launch abort tower are then rolled together over to the vehicle assembly building, stacked on top of the rocket, and then the whole thing rolls out on a giant crawler transporter out over the launch pad. There's a flame trench in the center of it. It rolls out over the center of the flame trench and then is mated to ground systems that allow us to fuel the rocket with the cryogenic oxygen and hydrogen on launch day and then when all the spacecraft, the launch vehicle systems are powered up, we commit to launch.

So if you go to the next slide you can see the flight test trajectory. We are going to launch on an eastward trajectory out of the Kennedy Space Center in Florida. So if you look at Earth in the upper left of this diagram here you can see the green arrow pointing up and around. That is our launch trajectory. And launch day we're going to launch our spacecraft Orion on the SLS Rocket out of the Kennedy Space Center. It'll rise to orbit and on the first orbit it will separate the solid rocket boosters; the liquid core stage will have done its job, it will separate. And the interim cryo-propulsion stage -- the upper stage -- will push Orion out of Earth's orbit and put it on a lunar trajectory. And that last little push is important, because that spacecraft weighs over 80,000 pounds. So Orion is now on its way to the Moon.

And on the outbound leg Orion will do a low lunar powered fly-by of the surface of the moon, only 62 miles above it; it will do a rocket powered assist to grab a little bit of the lunar gravity and then enter into what's called a distant retrograde orbit. And it's called a retrograde orbit because we rotate in the direction opposite the moon as it orbits the Earth. So the - if you're looking at the moon wanting to orbit the Earth here, it wants to go in a counterclockwise direction. But we rotate in a clockwise direction around the moon.

So we stay in that distant retrograde orbit for a little over a week and we test the spacecraft and when we're ready to come home, we're going to do again another powered fly-by of the moon and it will provide that little bit of gravity assist. We'll fire up the rocket engines one last time and send ourselves back on an Earth trajectory, which are the blue arrows heading back towards Earth. And then on that orbit -- it's called a direct reentry -- we're going to jettison the service module because it will have done its job. We'll reorient the Orion spacecraft heat shield forward and then it'll go from 400,000 feet of altitude to the ground in 10 minutes. Incredibly fast.

And Orion will - once it's through peak heating -- where it'll see temperatures nearing 4,000 degrees Fahrenheit just outside the heat shield due to drag coming in the atmosphere -- it will jettison the forward bake cover, which is a protective cover that goes over the parachute system on Orion and the parachutes will deploy and Orion will gently glide to the surface of the ocean, where it'll be recovered by a joint team of NASA and U.S. Navy personnel and we'll recover our spacecraft and bring home a treasure trove of data that will allow us to have confidence that we can fly Orion with astronauts on it on the very next mission and launch it on board the Space Launch System. So that's our trajectory.

The Moon is 250,000 miles away from Earth. Right now we're flying the International Space Station 250 miles from Earth. So we're going to fly 1,000 times farther than the International Space Station. And then beyond that another 30,000 miles. This mission will take a crewed spacecraft farther than we've very gone before, including the Apollo Era when we flew missions in the Apollo capsules out there - out to the moon and back. So we're going to fly farther than we've ever flown before on this very first mission called Exploration Mission One.

On the next slide -- this is animated -- so you can see us launching out of the Kennedy Space Center on that first orbit. The Space Launch System will push us to orbit and then on the very first orbit, send us on a lunar trajectory. We'll do that low lunar powered fly by -- gravity assist -- stay out there for about a week, another lunar powered fly-by, and then return on the return leg, jettison the service module and splash down off the coast of San Diego in California, where we'll be recovered via the recovery ship. So that animation shows that same trajectory that I just showed, but it shows it relative to the Earth and the moon. Again, 250,000 miles between the Earth and the moon.

So if we go to the next slide -- I want to talk about the importance of testing. We've got a lot of new technology here in place. We're using state of the art manufacturing techniques, things like friction stir welding, where we are literally welding two panels of aluminum together without heat. We're using pressure - well, we are using heat, but it's not heat by, like a welding torch.

It’s heat through pressure and it's a new manufacturing technique that reduces the likelihood of having a defect at a weld.

So these advanced manufacturing techniques, new engine controllers -- if you see the engine test firing located in the upper right -- I just came back from an engine test firing out at the Stennis Space Center in Mississippi two weeks ago, and watched one of these Space Shuttle heritage engines operating at a pressure that's higher than we've ever operated before in order to provide additional performance. So we're doing a lot of testing on our liquid main engines.

We're testing our solid rocket boosters. So if you see the diagram on the lower left there you can see one of the static tests where we literally took an entire booster and put it up against a concrete barrier at the base of a mountain out in Utah and fired this thing for the entire two minute duration as if it were climbing into orbit. Just like we did in the upper right where we fired a liquid engine for the entire duration it would take to fly the Space Launch System rocket to orbit, which is some eight minutes.

So we're doing testing here on the ground. In the lower right you see a structural test article, which is up in Ohio right now at the Plum Brook station just outside of Cleveland. We're pushing and pulling and vibrating and making sure that these things are going to be able to survive the launch environment, survive the reentry environment. We did a flight test of the Orion spacecraft in 2014 onboard a commercial vehicle that got us pretty high -- some 15 times higher than the International Space Station flies at 3,600 miles above the Earth -- but not nearly as high, not nearly as fast, and not nearly as hot as we're going to see when we return astronauts from the vicinity of the Moon on Exploration Mission Two. Not nearly as fast as we're going to see here on Exploration Mission One.

So when we fly Orion out of Earth's orbit, we're going to fly beyond the services that we take for granted every day here on Earth. We're going to fly farther than the communication satellites exist out in geosynchronous orbit at 2,200 nautical miles. We're going to fly beyond the GPS navigation constellation at 10,800 nautical miles to Earth. And again, we're going to go out to 250,000 miles.

We're going to fly through the Van Allen Radiation Belt, beyond the Earth's magnetic field, and we're going to come back at the highest speed reentry that we've demonstrated to date and we're going to put pressure and temperature on that heat shield of Orion during reentry that's hotter than we saw on its maiden flight test. So it's really important to test these new manufacturing techniques. It's really important to test these engines and structures, because they're going to see things that they've never seen before or using processes and materials that we haven't seen before. So that's the importance of testing.

And on the next chart -- if you go ahead -- this shows our schedule between now and 2018 when we launch Exploration Mission One. We've got a lot of activities ahead of us. We've already delivered the crew module -- the structure associated with Orion -- to the Kennedy Space Center. It's currently being outfitted in the operations and checkout building. We've got a lot of tests coming up. We've got a booster test that I just told you about and another one coming up. We've got engine testing, we've got powered on testing of the spacecraft, and we've got software testing. We're going to finish up our ground systems at the Kennedy Space Center. Again, a lot of activities leading to launch day in the fall of 2018, when we're going to launch this rocket and this spacecraft from America's spaceport of Kennedy Space Center.

And so that was the overview of what I wanted to talk about for Exploration Mission One. You can see here on the next chart we are on a path, we've got a schedule, and we're planning the launch in 2018. If you want to follow us along, you can go to the next chart and follow us at nasa.gov. We've got a number of Web sites out there. If you're a fan of the Orion spacecraft or if you're a fan of the rocket, you can follow the Facebook or Twitter site. Otherwise you can just follow the mission in general on nasa.gov. So that was all I had for you and I'll open the floor for any questions.

Man: (Unintelligible) System Ambassador. Just curious about the vehicle. How does it compare to the Saturn V we went to the moon in?

(Mike Seraphin): So the Space Launch System in comparison to the Saturn V, we've got a vehicle - the rocket itself is going to be built in three blocks. This first block is capable of carrying 70 metric tons to low Earth orbit. That is just below what the Saturn V was capable of at the end of the Apollo program. So that is what we're going to use on Exploration Mission One.

We do have an upgrade plan with a larger upper stage called Block 1B and that'll carry 105 metric tons to low Earth orbit, and that will surpass Saturn V or any vehicle built in the history of mankind. And right now we're on a path to do that no earlier than 2021 on Exploration Mission Two. And then we got an additional set of upgrade plans with advanced boosters called Block 2 that will provide 130 metric tons beyond that, and that'll nearly double the performance capability that we'll see here on this very first mission.

So for Exploration Mission One -- to more directly answer your question -- we are just shy of what Saturn V was capable of during the Apollo program, but by the time we're done with the Block upgrades for the Space Launch System we will have nearly doubled what Saturn could do.

(Dave Dueling): Hi, this is (Dave Dueling) at the New Mexico Museum of Space History in Alamogordo. I was in Huntsville and covered early shuttle development. How much commonality is there between the core stage and the external tank? I see that Boeing has the contract rather than Lockhart. Are you using the same tools? How much has been changed?

(Mike Seraphin): There are some similarities, but there are quite a few differences. We are using the Michaud Assembly Facility -- or MAF -- just outside of New Orleans. We've got a lot of the same skilled workforce from Lockheed-Martin. We have some of the same tooling, but largely the tooling has had a major overhaul and a major upgrade. The materials, we've gone back to aluminum, as opposed to at the end of the shuttle program we used aluminum-lithium for a super-lightweight tank. We're using just plain old aluminum here on the core stage.

So the materials are different, the manufacturing processes - we're using friction stir welding to assemble just machine panels together. We're using robotic application of the thermal protection system foam. So a lot of the foam on the external tank was hand-applied during the shuttle program -- or the majority of it -- we are doing automated application of foam, for the most part. There are very few exceptions on SLS where we're doing hand application. I'm trying to think what are some of the other differences.

Certainly the core stage is much taller. This tank is much taller. And the thrust structure on the shuttle was through the boosters and through the attach point for the space shuttle, right? So the shuttle was side mounted to the external tank. And the engines were at the base of the shuttle, so you had that cantilever effect on the shuttle providing and you have to offset that with the thrust vector and the thrust vector control. Space Launch System doesn't have that. It has the rocket engines mounted to the very base of the core stage and the core stage itself is providing its own thrust as opposed to the orbiter side mounted to it.

The avionics and flight computers are brand new. They're being upgraded and quite honestly we couldn't get some of the electronic parts that we flew on shuttle anymore -- because of obsolescence -- so we had to upgrade to the state of the art controllers. So there's quite a few differences. There are some similarities. Some of the manufacturers are the same, but those manufacturers and sub-contractors have also upgraded their tooling since that time, so I hope I answered your question.

(Dave Dueling): Yes. Very well. Thank you.

(Adrian): Hi, this is (Adrian) from (unintelligible), I'm a solar system ambassador. I had the privilege of being at EFT One, which was really great and exciting, so I'm glad things are moving ahead. I have two questions. One is I'm wondering what you learned about the heat shield on the reentry from that that's going into what you're working on now. And then in another direction I wanted to get a sense of where you are funding wise as far as getting a launch in 2018. Thanks.

(Mike Seraphin): Both good questions. So the heat shield on Exploration Flight Test One clearly did its job; it did well. What we ran into on that mission was we used what was called a monolithic heat shield, which is one giant heat shield that had a honeycomb and it was really cumbersome to manufacture. We had to have technicians hand apply the ablative material into each of the cells on the honeycomb, and there were thousands of cells.

And what happened was we realized there were small defects in the amount and the speed that the ablative material was applied into the honeycomb, and what that did was it appeared as little voids or gaps or cracks into the heat shell.

So we did an inspection after it was manufactured. We found these things, and then we literally had to go in and drill out the defects, and then reapply new material into it.

And it was a cumbersome process. So both in terms of speed of manufacturing, but also in reliability in manufacturing the heat shell, we decided to go to a different heat shell design called the block architecture. It's very similar to the tile design that the Shuttle had on its belly.

And it's a different material. It's called "Avcoat," and the block Avcoat design is literally going to put together blocks of this material, with a little bit of filler between the blocks. And that is going to be the heat shell that we fly in Exploration Mission-1.

So a different material, a different manufacturing process - we learned a lot. We're confident that we can get there on Exploration Mission-1 and fly it safely, but we really need to do that in an uncrewed configuration before we can confidently fly our astronauts on it on the very next Mission.

Woman: So has that Avcoat been tested otherwise, or will it be tested in any other ways?

(Mike Seraphin): We are testing Avcoat to our ability on the ground, but the ability to test ablative materials in a hypersonic configuration doesn't exist on earth. There's no test facility that we can do that at here. So the only way to really truly get a test is to fly it. And that's why we're doing this on Exploration Mission-1, is an uncrewed vehicle.

To get to your question on funding, we've got great support from Congress and from the Administration. With respect to exploration, we've actually gotten more money than we've asked for in the last two years, in terms of exploration and flying Orion in the Space Launch System.

And what that's doing is allowing us to hold our schedule. Any time you do something this large and this complex, you inevitably run into challenges along the way. The Team has done a great job working through all those challenges, and our funding is certainly supporting flying in 2018.

Woman: Great. Thank you.

(Mike Seraphin): Other questions?

(Silda): This is a non-nerdy question. It has nothing to do with technology. It has to do with the involvement of the younger generation. My name is (Silda). I'm from the Evergreen Aviation and Space Museum in McMinnville, Oregon. And I was wondering if you're going to do the same thing you've done for other missions, which is to involve the younger generation in some way or another to be a part of the Mission?

(Mike Seraphin): Yes. Of course. You know, one of NASA's Core Objectives is to inspire our youth to seek careers in the fields of Science, Technology, Engineering and Mathematics, and leading by example.

And inviting folks to follow us along through social media through our press conferences and through site visits of engine tests out at Stennis Space Center, Mississippi or through visits at the Kennedy Space Center, or the Visitors Center, or the Johnson Space Center in Mission Control in Houston, or any number off the NASA facilities and having open houses, or any number of ways that we do that.

We're going to continue to do those things. We're going to continue to have tweet-ups. We're going to continue to have just all the outlets that we can. We do have limited resources to do that with, because we've got to do things like build rockets and space ships. So I know some people would like us to do more. Our budget is finite, and we think about where we deploy those resources.

I'm personally working with our com team – our communications team here at NASA Headquarters - to help tell the story of Exploration Mission-1 in spending time talking to folks like you, because I think it's important.

Because you know, I'm not going to be doing this forever, and I want other folks to continue to support this journey to Mars and to continue human exploration, because it's something that I believe in. It's peaceful, and it inspires others, and others want to aspire to do what we're doing. And so yes, we're going to keep doing what we're doing.

Other questions?

Man: Hi, this is (Jeff Nee) from JPL. I just wanted to ask what is the overall cost for a SLS launch right now?

(Mike Seraphin): The overall cost for the SLS launch – I do not have a number for you. I can tell you what its annual budget is.

Man: Sure.

(Mike Seraphin): It's around 2 billion a year. We got just around 2 billion this year. We had slightly less in previous years, but it really depends on flight rate. We hope to get to an annual flight rate of one launch a year.

And we've got a path to do that in the mid-2020s. So we've got sustained cost that we need to maintain the manufacturing facilities and our skilled workforce to build these rockets and these engines. It's more than just the material cost. And that's largely within the Program's budget. So the Program, again, is about 2 billion a year.

Man: Good. Thanks. And then how many people does the Orion capsule house?

(Mike Seraphin): Yes. So Orion is capable in its initial design of carrying four astronauts out to the vicinity of the Moon and back for up to 21 days. We do have plans to fly up to six crew members in Orion. That's not part of the initial design. What that will require is some moving around of some of the flight equipment, and flight computers, and environmental support systems - which requires a little bit of miniaturization.

We've also got to work on the overall weight of the vehicle, and the more we fly it, the more we'll understand where we've got some margin to shave out of the vehicle structure or maybe the heat shield. But we don't want to be too cavalier upfront. We've got some margin designed into the system so that we understand where it can be taken out later.

Man: Thank you.

Anita Sohus: Hi, this is (Anita). During Apollo, the astronauts were very involved in the construction of the crew capsule. Has the generation of astronauts who will be flying Orion, they're already in the team, right? Are they working on this with you?

(Mike Seraphin): Yes. Yes, absolutely. We've got three astronauts assigned to work with us on exploration. Rick Mastraccio is our astronaut that's largely working with the Orion spacecraft team.

Butch Wilmore is our astronaut assigned to work with the SLS rocket team, and then one of our newest astronauts – Victor Glover – is working with our landing and recovery team – the team that's going to recover the astronauts after splashdown using a Navy ship. So we've got three astronauts working on this.

Anita Sohus: That's great. I also wanted to mention for folks who were wanting to see the video and couldn't open the WMV file, we've posted it now as a MOV file and also there's a YouTube link that we've posted.

Do we have any other questions for (Mike) or (Patricia) today?

(Amy Bouillet): (Amy Bouillet), Solar System Ambassador. What kind of configurations are planned for the service module and will EM-1 test be a special test configuration? Or is it one they'll be seeing on the standard mission?

(Mike Seraphin): So that's a good question. We've partnered with our allies at the European Space Agency - or ESA - to provide the service module. So the service module that we're going to fly on Exploration Mission-1 is derived from the European cargo vehicle that we flew five times up to the International Space Station, called the ATV - or Automated Transfer Vehicle.

"Jules Verne" was the very first of those ATVs to fly to the ISS, and we've got a service module that is provided under a partnership- or a barter agreement - with the European Space Agency, and it's currently in Torino, Italy.

The structure is being made in Torino, and it will - in April, next month - move to Bremen, Germany, where it will be outfitted with the power systems, and the thermal control systems and the propulsion systems necessary for it to do its power and propulsion job.

And then after it's outfitted in Bremen, Germany, it will be shipped here to the U.S. and arrive at the Kenney Space Center, where it will be mated with the crew module, and we'll do some systems tests on it.

So we've got a lot of work ahead of us, but it's a bartered vehicle, and we've traded some transportation and Science services on board the International Space Station for the European Astronauts on future missions to get a service module.

And the plan right now is to continue to fly the European service module moving forward, but if for some reason the Europeans or the U.S. were to change their mind, we could build our own here, because we've got a plan that

NASA owns the intellectual property of that service module if either partner were to decide to not continue that barter agreement.

(Mike Seraphin): Other questions? All good questions.

(Amy Bouillet): Are there any specific configurations planned, like one for Lunar orbit, and one for Mars orbit - or would it all be one with just different features?

(Mike Seraphin): We're planning on flying an Orion spacecraft that is based off of what I just talked to you about. We're going to continue to advance its capabilities, but it will be off of that same air frame, and off of the same heat shield and off of the same base design. It's going to be more capable on future missions. It's going to be able to carry more crew members for longer durations. And it may be capable of flying deeper and farther and faster into space.

Those are all things that are, you know, going to transpire over the next five, ten, twenty years. But we're going to continue to fly Orion as well as space launches. The rocket is going to get more powerful. It's going to go from carrying 70 metric tons to 105 to 130 metric tons of capability to Low-Earth orbit and then sending that beyond Earth orbit on a trajectory like we see here on Exploration Mission-1.

So we're going to continue to advance and grow those capabilities. We're also going to look for opportunities to reduce costs, because these are large systems. They are expensive to manufacture.

And we're also going to look for opportunities to reduce risk, because there are risks associated with flying humans and hardware like this in this harsh deep-space environment. So where there are opportunities to implement additional safety features, we'll look at those as well.

(Amy Bouillet): Okay, thank you.

Man: Speaking of safety features, do you have a system for radiation protection on the Orion spacecraft?

(Mike Seraphin): So we, right now, have flight computers that are designed to withstand high-radiation environments. So the computers themselves are radiation-hardened. The capsule has some capability in it to resist radiation from solar flares and galactic cosmic radiation to protect the astronauts onboard.

We haven't cracked the code, exactly, on how to prevent all radiation. So when our astronauts fly, they are going to be exposed to levels that are higher than they would be here on earth, because they don't have the luxury of an atmosphere that's 62 miles high above them, or have the luxury of a magnetic field surrounding them, provided by the Earth.

So there is going to be some residual risk associated with flying onboard Orion. We do have protocols in place to monitor radiation. We do have radiation area monitors to understand how high a dosage astronauts get.

And we also have procedures in place. In the event of a solar flare or some event, we will not do things like a spacewalk, where we've got even less protection from radiation, because all you have on is a suit. You're not inside a spacecraft anymore. You're outside the spacecraft, and you're in this really thin suit.

So we can forecast and see solar flares, and we've got capabilities in place to mitigate those risks. And then, quite honestly, one of the best means of protecting against radiation is just water.

And even on board the International Space Station today, we have what's called the water wall, where we have water stored for use for consumption later on. And we just put it up on walls.

So if we do have a solar event, we just tell the astronauts to go into that module, and what that water does is it absorbs to that (degree) of radiation from that solar flare, and we would use very similar protocols on future space missions beyond the Earth's orbit.

Man: Great. Thanks.

Woman: (Mike), talking about water providing protection from radiation aboard the spacecraft, what about on Mars itself, when they're there for long periods of time? How will they protect themselves then in their habitat, in just, you know, getting out and doing walks, and doing experiments and such?

(Mike Seraphin): Yes, so those are things that a little further out. There are a number of concepts that allow us to manage radiation and the risk that comes with having even less atmosphere on Mars.

There is an atmosphere, but it's very thin. It's very small. So there's a number of things that we can do. It can be built into the habitation design, or the habitation itself could be underground. It could be under the surface of the Martian soil.

Or if it were on the Moon, it could be under the surface of the Lunar soil. Folks are looking at putting things in craters by design. So there's a number of methods to deal with that.

Also, if you were to just have an in-situ resource utilization technique where you could harvest water. You would need to store it somewhere, so you could use a very similar technique to the water wall on board the International Space Station and put that in a storage area, so that if you knew that there was going to be a solar storm, you could have the astronauts go to a safe zone and protect them that way.

And not outside that day. Just like we do with snowstorms here on Earth, right?

Woman: Thank you.

(Mike Seraphin): All right.

Man: What is in the crew module for the unmanned mission? Is there anything in place of the astronauts?

(Mike Seraphin): Yes, we're flying a number of instruments and devices in there. We're flying radiation area monitors. We're flying some devices that will help us understand the vibration and g-load environment that the astronauts will go under.

We think we've characterized that pretty well, but it's different when you're actually strapped into the seat, so we're going to have this stuff mounted to the seat brackets as if there were an astronaut sitting there.

And of course we're going to have a number of cameras showing what it's like looking out the windows. For those of you that followed Exploration Flight Test 1, Orion's maiden test voyage in December of 2014, we showed some amazing views of Earth from 3600 miles up out the window.

And we're going to continue to do those things. Only this time, it will be looking back at the surface of the Moon with the Earth way, way off in the distance. So we've got a number of things planned.

Good questions. Any other questions?

Man: I'm looking at your slide #5, I guess, and at the proving ground section. Does it include a Lunar base on the surface, or just that deep space habitat that you have on there?

(Mike Seraphin): So, it does not include a Lunar landing element. That is a policy decision and a policy change that came with the current administration. Under the Constellation Program Lunar landings and Lunar bases were part of the architecture.

But with the current administration, we've modified that approach, and we've provided the ability for partners - if they're interested in going to the Moon -

to off-ramp there, but that is not our primary destination. Our primary destination is Mars, and we're going to go there through the proving grounds, not via the surface of the Moon.

Man: So the plan right now is to have a Mars surface base before a Lunar surface base?

(Mike Seraphin): That is the current plan. Yes.

Man: Okay. Interesting. Thank you.

Man: Yes, I have a question about the core stage engine. It looks like from the diagram, the EM-1 Mission has four of the RS-25s, which I think you said were the upgraded current rocket engines. Are there any more advanced engines planned for the higher 105 and 130 metric-ton payload capability?

(Mike Seraphin): So, right now we've got four missions of what were formerly Shuttle engines sitting on the ground. And that will get us through EM-4. And the RS-25s that we intend to fly on EM-1 through EM-4 are previously built for the Shuttle program engines. But we are going to fly them at speeds and pressures and temperatures that they have never been flown before, which is why we're testing them.

Separate from all that, we are looking to restart manufacturing – or we are currently assessing a restart of the manufacturing of the RS-25 engines, and as part of that, using advanced manufacturing techniques. - things like additive manufacturing or 3-D printing using metallic materials - to reduce the amount of time required to build a new engine.

Under the Shuttle program, the time required to build an engine was on the order of seven years. So we're looking at new manufacturing processes to speed up the production of those engines as well as lower the overall cost, and as part of that, Shuttle was a re-usable vehicle.

These engines are not reusable. We dispose of the core stage in the engines after each use. And we do not have the reuse requirement on those new engines that we're planning on manufacturing. So we're looking to upgrade the engines not only in terms of technology, but also in terms of materials and processes to get there.

I hope I answered your question.

Man: Well, let's see, there's just one final quick question. You know, I remember back to the Saturn days. The F-1, if I recall, each engine was 1.5 million. What are these, at the max, that you expect to get them rated to, individually - the RS-25?

(Mike Seraphin): Yes, the RS-25s are right around 450,000 pounds, so not what the individual F-1 engines were. But when you put those four together, you get around just shy of 2 million pounds of thrust, and then when you pair them with the solid rocket boosters, you get 8.8. So that's close to – but not equivalent to – a Saturn V in this initial vehicle config.

When we go to a larger upper stage - on Chart 5 again, if you're looking at that - you see the ICPS, the Interim Cryo Propulsion Stage – we're looking to go to a larger one with four engines. So have twice the fuel, four times the thrust, and they'll fly RL-10 engines on them. And that gets us from 70 metric tons of launch performance to 105 metric tons of launch performance. And we've got plans in place to do that right now.

Man: Can you just say what the propellants are for the first and second stages?

(Mike Seraphin): Liquid hydrogen and liquid oxygen.

Man: Thanks for everything.

(Mike Seraphin): All right.

Man: Thank you.

Anita Sohus: (Mike), we're at the top of the hour, and I want to be –

Woman: Is there anything about having any sort of launch capability in outer space at this point? Rather than launching from Earth?

(Mike Seraphin): So, at a certain point, we still have to get our astronauts safety to orbit and return them safely, right, to Earth? To do things like visit their family and have a cheeseburger. So we're still going to require the crew module and the launch vehicle to do that.

But if you want to go back to Chart 5, we are looking at in-space propulsion or in-space transportation. So I think this kind of gets to the question that you've got.

Woman: Right.

(Mike Seraphin): If you look at the proving ground in the center, there - the bottom center - there's something called solar electric propulsion. And just to the right of it, you see a Mars transit habitat. So what solar electric propulsion does, and what Mars transit habitat does is it allows you to have a living space that can push from one destination in space to another without having to go up and out of an atmosphere.

So it is not an atmospheric vehicle. It is an in-space vehicle that can transport either a cargo or crew from one location to another. Now if you want to land somewhere - call it Mars – that transit habitat or the solar electric propulsion vehicle is not going to be capable of doing it safely.

So you're going to need a dedicated lander to transport either your crew on from the orbit of Mars to the surface of Mars and then back from the surface up to the orbit. That make sense?

Woman: Yes. So kind of like in the movie, The Martian.

(Mike Seraphin): Yes. Only we're not going to use a sheet over the windows.

Woman: That means the budget's really bad. Thank you.

(Mike Seraphin): All right.

Anita Sohus: Hey, (Mike), we want to be respectful of any other time commitments you have.

(Mike Seraphin): Okay.

Anita Sohus: So if you have time for any other questions, or if you need to go.

(Mike Seraphin): Let me look at my schedule here real quick. I could probably do one more question, but after that, I think we'll call it a day. Anybody else? One more question?

(Jim Paradise): This is (Jim Paradise), Solar System Ambassador. Is are there any, like, actions to try and pull the schedule in? Like would they ever consider going crew on EM-1?

(Mike Seraphin): Boy, that would be a hard thing to do. Part of that is you get close enough that it doesn't matter how much money you throw at things – you still have a finite amount of work and your ability to get there with additional people actually starts to work against you.

So we're getting pretty close. I wouldn't say we're there right now with EM-1, but we're getting pretty close to the point of where once it's out of production, you have a certain amount of tests and other things that you got to do just to make it to the launch pad on launch day.

And if you add new things to that, like, I want to fly a life support system, and food, and cargo and all this other stuff that we're not planning on, it makes it harder to get to the launch pad on time.

So right now, we're not planning on flying the advanced life support systems that we're going to fly with astronauts on the very next mission, EM-2. We're not planning on flying food and clothing and all that other stuff. And we've got to manage all of that from a manifesting and cargo standpoint.

So we're not planning on doing that right now for this first flight test. We're just going to test the spacecraft, its ability to fly up and out of the atmosphere - the rocket - and return safely. And if we were to get more money, I would see that we would bring in capabilities that we've got planning, that we've got in plan, or EM-2 or later missions sooner, rather than change the content of EM-1.

If we were to fly a crew, that would be – that would be a high-risk endeavor, and we really need to prove this new rocket before we're going to put people onboard it. I believe that it's going to work - it's going to work well. But until you really demonstrate it, in the flight environment, it's really hard to have that level of confidence, so it's a fair question. I just don't know that -

(Jim Paradise): Yes. I know that, initially, the Shuttle was going to go unmanned in the first launch, and then there was kind of a late decision, and they put a crew on it. But, just curious. Thank you.

(Mike Seraphin): Yes. They did. They did. The environment in 1981 was a little different than the environment here in 2016, so, I appreciate the question, and I think it's a good one.

(Jim Paradise): Okay. Well, I greatly appreciate what you do, folks, and I'm a huge fan of the – of Science, Technology, Engineering and Math and our museum system. I live right here in Washington, DC. I love the Smithsonian's. I've been to the Museum of Flight out in Seattle, the Dayton Air Force Museum, any number of other museums around the country. I love them. Keep doing what you're doing, and thank you for your time.

Anita Sohus: Thank you.

(Patricia Moore), did you want to?

(Patricia Moore): Yes. So thanks everybody for joining. For those of you who don't know me, I'm the Museum Liaison for the Orion and SLS and Ground Systems teams. And many of you get blasts from me from time to time, and emails with resources, and video presentations and outreach materials.

So if you're not on my list and you would like to receive resources from me maybe once or twice a month, my email address is Patricia.L.Moore, and my last name is Moore, so it's P-A-T-R-I-C-I-A-DOT-L-DOT-M-O-O-R-E@nasa-DOT-gov. [patricia.l.moore@nasa.gov]

So we appreciate your joining in, and if you have any questions about Orion or SLS, or you're looking to integrate some more into your museum activities and programs, please give me a call, or shoot me an email. I'm happy to help you. Thanks, (Anita).

Anita Sohus: Terrific. Thank you. And just to remind everyone, we have a conversation on Thursday with (Scott Bolton), who is the Principle Investigator on the Juno Mission, which will be arriving at Jupiter on July 4th. So thank you all very much. Thank you, (Mike). Thank you, (Patricia). And thanks, all of you, for what you do.

Man: May I ask a quick question?

Anita Sohus: Sure.

Man: The email address that (Patricia) gave - some of you were talking over the top of it, and I didn't get it.

(Patricia Moore): Sure. It's Patricia – P-A-T-R-I-C-I-A-DOT-L-DOT-M-O-O-R-E. My last name is Moore@nasa.gov. [patricia.l.moore@nasa.gov]

Man: Thank you.

(Patricia Moore): No problem.

Anita Sohus: Thank you. Goodbye, everybody.

(Mike Seraphin): Goodbye.

(Patricia Moore): Bye.

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