NASA HEADQUARTERS ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY REBECCA WRIGHT
WASHINGTON, DC – SEPTEMBER 24, 2014

WRIGHT: Today is September 24th, 2014. This oral history interview is being conducted with NASA Administrator Charlie Bolden in Washington, DC, for the NASA Headquarters Oral History Project. The interviewer is Rebecca Wright, assisted by Sandra Johnson. Mr. Bolden has served as the NASA Administrator since July 2009. This interview is the second oral history session with Mr. Bolden focusing on NASA's Commercial Crew Program. The first session was on March 31st, 2014, and discussed the aspects that set the foundation of the program. Just last week on September 16th NASA took the next step in the Commercial Crew Program by selecting two companies to serve as future transportation providers to the International Space Station for American astronauts. We'd like to begin today with you giving us your thoughts about where you are with this decision and your expectations for the future.

BOLDEN: Where am I? I'm ecstatic, when you talk about attitude. It was a long road to get here. I feel that we're at the starting line now of the real Commercial Crew Development Program because we're into the phase that is now called the certification contract. So, it's the first time that we actually are formally engaged with a written contract with our two providers, Boeing and SpaceX.

I think you all may have talked to Kathy [Kathryn L.] Lueders [Program Manager, NASA Commercial Crew Program]. As she probably explained, this contract is a certification contract that allows them to now work on the full-scale development of two spacecraft, one from each.

Actually, two systems, because while each company is doing the capsule, then each company was responsible for identifying their own launch provider. In the case of SpaceX, they decided they were going to do everything in-house.

It represents a different way of doing business, totally different from the traditional way. When you look at the satisfaction of knowing that you have two providers who do things in two diametrically opposed ways, it means that the chances of being successful are pretty good, because SpaceX is doing something no one's ever done before and that's to build everything from the ground up—engine, launch vehicle, and capsule—and then do all the integration. Boeing, on the other hand, as a classic aerospace company, went out and contracted with ULA, United Launch Alliance, to use the Atlas V, and then they're building the capsule itself and doing the integration.

That's one of the reasons I feel really good, because we not only have two providers, which we have always said was essential to maintain competition and try to keep the price down, but it also gives us two providers who do business a different way. My guess is they will meet with different levels of success at different times. One will seem to be surging ahead in getting to the time that they're ready to fly a test flight and then finally fly their contract, and then another one will surge ahead. My guess is they'll go like this, because they use two different systems. I'm excited about it. I feel very good about where we sit right now.

WRIGHT: As you mentioned, they're end-to-end transportation systems. Not only is this seen as a cost-effective alternative for NASA, but what are other impacts from the fact that they're going to be handling so much of what NASA used to handle on their own, how does that impact the agency overall?

BOLDEN: You just said something that was interesting, and we have begun to have deep discussions about this, and that's cost-effective. The promise of commercial anything is that it will be competitive, which will hold the costs down, and so it will be cost-effective. That's the theory. That remains to be proven. No one's ever done this before. It could be that we were all sold a bill of goods, and it turns out to be just as expensive as [Space] Shuttle operations. I don't think so, but time will tell.

But one thing we knew was that if we went down to one provider, in time we were going to end up with the same cost as Shuttle or more, and it would be like depending on the Russians. So, we're in a good place, having two providers. I'm satisfied that we got what we wanted at least for now, and we'll see how it plays out. In terms of how we do it, how do we get there, as I mentioned before, we now begin to work with them diligently. Hopefully Congress will become more supportive than they have been.

It should not go without being said and Congress gets upset when I say it, but we could have been in a much better position with Commercial Crew had we had congressional support from the very beginning, but we got zero. None. They will probably be angry because I say this. But they gave the President [Barack Obama] no support for Commercial Crew, which meant Bill [William H.] Gerstenmaier and his team had to be very innovative, very imaginative, and very creative in finance to figure out how he could squeeze money out of a lot of different places to help the companies keep moving down the line. He has done that in an incredibly good way.

But now that we have signed the contracts, we've got two years that are really what we call development years, and anyone who knows anything about building anything says you can't fake it. You've got to pay money. Since these are fixed cost contracts, it means they get paid

every time they meet a milestone. Depending on how aggressive they are—when I talked about the two companies are going to jockey back and forth in who looks like they're doing the most the best—every time they meet a milestone, we've got to write a check. That means Congress is going to have to put the money in NASA's budget so that we can be able to do that to get to the next happy point, which is we've now got two companies that have demonstrated their vehicles, have flown a test flight, and we're now flying up to six flights under this contract carrying our crews to the International Space Station.

We hope that'll occur by 2017. Right now, we have no reason to believe that that won't happen, but it requires Congress to come through and grant the president's request. Because we are essentially behind in the amount of money we were able to put into the program doesn't mean that the cost of the program is reduced by all that. You don't get forgiven for the money that we should have been putting into it in the past three years. That money is going to come due, which means our ask is going to be bigger than most people expect for 2016 and 2017.

The term we use around here is "sticker shock" sometimes. Sticker shock is not a big amount. It's just when it's more than what people have been accustomed to paying, they just go, "Geez, what happened?" We have two years where we've really got to put substantial amounts of money into the program in order for them to be able to deliver by 2017. That will be a challenge for us to deal with the Congress and the administration. Not just the Congress, but the president has got to sign off on his budget. That's what we're trying to do right now, get our final numbers in for the 2016 budget. It will probably be more than we normally would have asked for Commercial Crew had we gotten support from the Congress earlier. Now you know more than you ever wanted to know.

WRIGHT: Fixed price for this type is something new as well.

BOLDEN: Fixed price contract. NASA doesn't do very many fixed price contracts for big programs like this, for a number of reasons. The primary reason no one likes to do fixed price contracts for a developmental program is because something will go wrong as a general rule, and when it does, it means somebody's got to pay to fix what went wrong. The company will have thought they heard or read in our request that we wanted this. We wanted a blue widget. They will build a blue widget for us, and we'll say, "Why the heck did you build a blue widget? We wanted it green."

They'll say, "No, that's not what you said. Right here in writing it said you wanted a blue widget; we gave you a blue widget."

We say, "That's unacceptable; we want a green widget."

They'll say, "We can make it green; that will cost you."

In a fixed price contract, you don't have that money. You've got to go back and ask to get more money to add on. It's a matter of who accepts the risk. Generally, it's the company that has to accept the risk in a fixed price contract, because what they're saying is we think NASA knew what they were asking for, and so they're not going to ask for very many changes, and if they do, they'll be minor, and we can absorb the cost for it. If they make a mistake, then they definitely have to absorb the cost.

So, it scares people to deal in a development program with a fixed cost contract, when you know something is going to go wrong. You just hope that if something goes wrong, it's not really expensive, because then you've got to decide who's going to do it, who's not. The pathway to programs is strewn with lawsuits. The Navy is probably the most famous for an

airplane program that just came off the wheels. It was decades in legal stuff before it was finally determined that the Navy had to pay General Dynamics [Incorporated] for an airplane that we did not build, but that was going to be a fixed price contract.

WRIGHT: Everything centered around discussions with Commercial Crew has always had the element of what level of safety requirements were going to be used. When Kathy Lueders was explaining the levels of certification, she was pretty specific about each one. Can you share with us some of the discussions on how those levels were built? I know that it's been compared to as stringent as when we did Shuttle. But it's different because we're using a different vehicle and you're using different players.

BOLDEN: Simply put—which nobody understands—we come up with the safety standard, which is a probability of loss of crew, or probability of loss of mission. When people talk about it will be as safe as Shuttle—I should know this and I don't, the LOC/LOM, the loss of crew/loss of mission number for Shuttle. I'm just going to give you a number, it's not right, so I will be on record as giving you a number that's not right, but I'll say it. One in 250 chance of loss of crew. Let's say that was our number for Shuttle. That means that in every 250 Shuttle flights, we know that there is a very good chance, very high likelihood, that we will lose one vehicle every time we fly 250 flights. If that was the standard for Shuttle, that is the minimum standard for Commercial Crew. That's what Kathy is talking about. I can go back and get it for you. We'll get it. I should have had it. I should have it memorized. ***see reference, pages 26-27***

The reason that Kathy always emphasizes safety is because in our request for proposal, in going out to industry, we did something else that the safety community was very uncomfortable

with. We said, "This contract selection is going to be based on a number of parameters." One of those parameters is always mission success. Mission success includes safety, the probability of loss of crew. That says that you've got this big category called mission success and safety is one component of it. Cost is another criterion. We said, "Cost will be as important as mission success." We were saying 50 percent. We have the right. We didn't say we would. We have the right to assess 50 percent of the quantitative number on your proposal. We have the right to put 50 percent based on your cost and 50 percent based on your ability to provide mission assurance. That's not good for strict safety people because they're saying, "You're automatically saying that cost is more important than safety."

We kept saying, "No, safety is paramount; safety is the most important thing with this vehicle." However, we have to be practical. Cost is a huge factor. It doesn't mean we'll pick the cheapest bidder, but it means that if a bidder wants to be competitive, they need to really get a sharp pencil and give us an offer that they think they can really do the job for but won't be something exorbitant. All the companies did that. Every company that bid gave us a bid that was within what we considered to be reasonable limits.

When people ask the question, "Boeing, their contract is for more, does that mean they're going to do more or something else? Are they going to be safer?" The answer is no. Boeing knew what we were asking for. They knew that safety was important, and they had to be able to guarantee that, and they said, "Based on the way we do business we can do it for this amount of money." SpaceX said, "The way we do business, which is really different, we can do it for this amount of money." There was no debate back and forth among us. We said, "Okay, shoot, you both say you're going to give us a good vehicle and you have a different price. We'd love to be able to do it at that price. But that's okay." I wasn't in on the deliberations, but in my debrief,

we agreed to the prices that they both submitted, and so that's why you saw a difference in the cost of the contracts.

WRIGHT: Through some of the messaging, I think the terms were there was a "team of specialists" that helped in the selection. Will the same team of specialists work all the way through the certification? Do your teams change out for different levels of certification?

BOLDEN: I'm not sure what they were talking about when they referred to the team of specialists. My guess is they're talking about the PIT [Partner Integration] Teams. Did somebody use the term PIT?

WRIGHT: No. I think the specialists had brought them this far; the NASA people working with those teams.

BOLDEN: I'm going to guess they're talking about the PIT teams. What those were was for each contractor—anybody who even considered that they might want to bid, we said early on, "If you want any assistance from NASA, we're going to offer the same thing to everybody. You tell us what you want. Whether you want an engineer, whether you want a crewman, or a flight controller, or what, we will try to make that available to you." Those were called Partner Integration Teams, PIT teams. SpaceX asked for a PIT team, Boeing asked for a PIT team, Sierra Nevada asked for a PIT team. Some of the companies that didn't bid, like Blue Origin and others, they may have even asked for a PIT team.

What we did was we took teams of specialists based on what the company asked for so that they could get a feel for whether this is the way we want to design this vehicle, is this going to meet what you're looking for. Not tell me what it should be but are we on the right track here. That's probably the team of specialists that they were talking about. If it is, they will continue to march. We're not going to swap people out on them or anything. The Astronaut Office has had a consistent team of folk who have been with each vendor.

They decided they didn't want to have a team of people that move from vendor to vendor to vendor. They wanted somebody who would become intimately familiar with each vehicle. I'm not sure. I think the flight controllers, the engineers, everybody did the same thing. That's probably the team of specialists that Kathy and others are talking about.

WRIGHT: I believe the two transportation systems, if all goes well, will offer seven seats. I think it was the day after [the selection announcement that] one of the selected teams announced that they're going to be looking for other folks to ride. How does that impact what the space agency needs? I know that none of those agreements have been made, because you haven't gotten that far yet, but are there so many seats that will always be saved for NASA?

BOLDEN: We have been discussing this from day one. We made a decision way back that NASA was focused on facilitating the success of a commercial space industry, and our primary focus was in getting vehicles that would be safe to take NASA crew members and partner crews to the International Space Station; however, we recognize the fact that because the administration, the president, wanted vehicles that would be available to carry anybody to space that wanted to go. We made some decisions early on that said that's what we're going to do.

We're going to do some things that we would not do this way if it were just for us. In order to facilitate the success of these guys, we're going to give them a lot more leeway. We're going to be a lot less demanding than we would normally be for a NASA system. We are not going to design this system. We're going to let them go, so that once it's built and once it's certified for us, they can go out and they can provide this vehicle to anybody they want to. The method that we've chosen, at least the way I've been briefed, is we're going to use the rental car system.

There are two things you could do. You could either get a taxi. People always use the term space taxi. We're not getting a taxi. In other words, we are not hiring SpaceX and Boeing to carry our crews to the International Space Station. We are hiring them to provide us with a launch system to include a crew vehicle that we can rent or lease and fly it to the International Space Station, keep it there for six months or however long the crew is there, and then bring it back. When we return to Earth, that vehicle will go back to the provider.

If they decide that everything they do is going to be reusable, they'll be able to get it back from us, and the next time it flies, it could be a SpaceX crew or a Boeing crew with somebody from the DoD [Department of Defense], from the Air Force, or somebody from NOAA [National Oceanic and Atmospheric Administration], or it could be a bunch of gazillionaires who just want to go fly in space for a week. That's what people say.

It's built to carry a crew of seven. Our intent would be, we'll carry somewhere between four and seven, always four, because we want one extra person on the International Space Station to enhance and allow us to increase the amount of science that we do on each increment. My guess is it'll be seldom that we fly a full crew of seven. Every time you add a person you can carry that much less cargo. Not having been intimately involved in all this, I think what you're going to find is that our balance is we fly four crew members—that gives us an extra

person to operate Station—we fly a lot more payload, a lot more cargo, experiments, replacement equipment.

When you talk about seven, number of crew, it's how many seats are in there. It doesn't matter how many seats are in there, you can only carry up so much mass. What we contracted for was an upmass and a capability to use all that upmass on crew, which meant we can carry up to seven people. I don't have any idea how much upmass that leaves you for cargo. If we want to carry a lot of cargo and the minimum amount of crew we need, we feel the minimum crew for Station is going to be about four.

WRIGHT: Once you're up and running and things are going well, are there thoughts about using the Russians as a contingency?

BOLDEN: Our intent is that Soyuz always remains an available backup vehicle. In my estimation we'd be foolish to say the partnership with Roscosmos [Russian Federal Space Agency] is done in terms of ever relying on Soyuz as a backup vehicle. We have seen from Shuttle, at least after [Space Shuttle] *Columbia* [STS-107 accident], we would never have been able to keep Station operating and we would not have been able to complete the construction of the Space Station as when we did had it not been for the fact that we had a Russian backup. Nobody else has a launch vehicle that can take crew. Even with two providers, I can't envision the day that we will say, "Okay, we're never going to fly on a Soyuz again."

Ideally, our hope would be that our commercial vehicles become the primary crew transport vehicles. If that happens, then you might find that we're carrying Russians and everybody, and maybe the Russians use Soyuz as—because they're in the market of selling

tourists—a space tourism vehicle. It would free them up. If they didn't have to carry crew, then it means they could fly two, three, four Soyuz a year and do nothing but carry tourists. But that's up to them. But I do not envision ever saying, "We're done; we are never going to utilize the Russians again." I don't see that.

WRIGHT: Once these routes are open for these transport vehicles, it certainly does impact the Station in its current form.

BOLDEN: It does. It increases the usage, and it increases the wear and tear. The one thing that we keep reminding the commercial industry of is, "We welcome you coming and visiting, but if you're going to stay longer than overnight, you're going to have to pay." This isn't free. You're not going to visit your old friend, looking for a place to stay until you can find a home. You're going to pay, because we got to provide food, air, everything else, and there's wear and tear on the system, even for the tourists. That is the reason that I have been almost since the beginning just pounding my fist on the table with the commercial space industry.

With organizations like the Commercial Spaceflight Federation and all of these organizations that say that they can do this better than we can, I said, "But you got to have another destination. You all have to get together and decide whether you're going to put another mini space station or a module or something." In order for commercial space to be viable, there has to be more than one destination. The International Space Station cannot possibly accommodate an industry. Bigelow Aerospace, I think they're great as a role model and trailblazer, but even Bigelow can't pull the whole load. There are going to need to be more places for the vehicles to go.

The other possibility, to be quite honest— the Russians claim they're going to build another station or a mini version of it, maybe put a module up or something, after 2020. The Chinese are saying they're going to have a station in 2020. To be quite honest, that would be great, because then while we may not be able to fly to them—and I don't know that that will be the case by then, things may have changed in terms of our relationship with China—but there's no limit; at least we hope that the Congress would not put a limit on American spacecraft flying to foreign destinations.

The more people who want to put things on orbit, the better for the industry, because ideally you want to be able to fly multiple times a year. You don't want to have two vehicles, two providers, and all they have is twice a year each going to the International Space Station carrying NASA astronauts.

That's just a fact of life. We don't talk about that. I talk about it all the time with the commercial providers, but most people when you read the pundits and all the people that are critical of everything that NASA does and are critical of the Space Launch System—because all we need to do is just turn that over, they can get us to Mars, don't worry about it—well, that's folly.

In order for a commercial industry to survive, they've got to have more customers than NASA. In all candor, I have not seen a concerted effort to have more receivers, more on-orbit vehicles of some kind that need the transportation for people. Cargo is no problem, cargo will survive, because they can take satellites and deploy them; they can take all kinds of stuff. People are different.

WRIGHT: Speaking of that, one of the capabilities of the transport system is that they need to be serviced as a safe haven. Explain that, and why that was an important component of these contracts—why they have to be able to be that lifeboat?

BOLDEN: Yes, because you may find that Station is in extremis or something and it can't survive for a period of time, and we just need a place where the crew can hold out until we can get something up there for them. It has to be able to survive for 210 days. It's six months plus some. That is just if we've lost all three of our launch capabilities: Soyuz is not available, Boeing has lost their vehicle for some reason, and SpaceX has lost their vehicle. We don't have a single way to get up there, and we do not want to shut down the International Space Station. We can get the crew back, but we can't replace them, because you'd like to be able to replace them so that you can keep operating Station. I think that's what we talk about. It becomes a lifeboat if necessary.

WRIGHT: Now that we're in the part of the Crew Program that has moved to the FAR [Federal Acquisition Regulation]-based contracts, if you would share with us what you believe the use of Space Act agreement has been, the impact it had on the progress of the whole program itself.

BOLDEN: I think Space Act agreements were the only thing that made it possible. I doubt that we would have ever been able to get to where we are in Commercial Crew; we wouldn't have a Commercial Cargo Program had it not been for Space Act agreements, because it enabled NASA to do multiple things in facilitating the success, the availability of nongovernmental vehicles to get to low-Earth orbit, without breaking the bank. If you remember, I want to say our total

investment in commercial cargo was I think about $1.5 billion. I don't know whether somebody gave you the figure. Total investment in bringing it to fruition. Then when we finally signed the contracts, that's $3.1 billion or something like that. So, for really dirt cheap, we went through the development program and got two vehicles. Now that we've gone through that, they are significantly cheaper even in the operational phase.

It's going to cost us some money to get through this certification phase, this development phase, but once that's done, I think you'll find just like cargo then the price comes down to whatever the status quo is going to be. Ideally when it comes down, then that cost per seat, when you average it out, will be less than what we pay for Soyuz right now. It may not be, depending on what the providers bid the next time we bid a contract for flights beyond the first six.

WRIGHT: During the announcement you not only shared information about the selection—not the process, but the selection—but you also shared a lot of information about the progress of relying on an SLS [Space Launch System], talking about how this is one large NASA Human Spaceflight Program. Why do you feel that was such an important time to tell the country what the rest of the story was?

BOLDEN: Because the country needs to understand that we did what we said we were going to do. I told people from the beginning, "I'm going to tell you what we're going to do, then we're going to do it, and I'm going to tell you what we did, and then we're going to go operate, and I'm going to tell you what we did that we said we were going to do. So, I'm going to tell you three times. I'm going to tell you, 'This is what we plan to do,' I'm going to tell you, 'This is what we're doing,' and then I'm going to say, 'Okay, that's what we did.'"

We promised that if we could get to the point where we could safely phase out of Shuttle, then NASA would turn to two things. We would turn to facilitating the introduction and the success of a commercial space industry that could take care of the pieces of the Space Shuttle. There'd be two different pieces—that's carrying stuff to orbit and carrying people to orbit. We'd have two different programs to replace one, but we were going to do that. But in doing so, it would allow us to have sufficient funds left over to go do what NASA is expected to do, which is explore and pioneer. So, it was a status report.

You've heard us talk a lot about Commercial Crew, you're hearing us celebrate it today, but don't forget we told you we were going to build a deep space exploration vehicle, a launch vehicle, and a crew module, and so right down the road, we're delivering.

We've got Orion. It's been finished, the first test vehicle, it's over being fueled, and come the 4th of December we're going to launch it, and it's going to come back and land in the Pacific Ocean, and then we're going to determine whether it's as good as we designed it to be. Or does it have some flaws that we did not expect that we need to go back and maybe do some redesign? We've got one more flight after this one, and then we're putting people in it. It's going to fly people on the third flight. We still have a lot of work to do. But that's the reason I thought it was important to fully inform the nation, the world actually, on what we're doing.

The other thing I think is just so that people know that we can walk and chew gum. It never ceases to amaze me that people think NASA can only do one thing at a time.

WRIGHT: That was a good parallel. Then of course you didn't talk about the rest. You just talked about that, so it was pretty good. One of the commercial providers' representatives made

the comment that the true winner of the Commercial Crew Program was the American taxpayer. Do you feel that that's a solid statement as well?

BOLDEN: If I base where we are with Commercial Cargo, I will say there is no question. Like I said, Shuttle was costing us I want to say $2 billion a year just to maintain. That was infrastructure and the systems in place whether we flew or not. If we didn't fly a single flight, Shuttle cost $2 billion a year. If we flew, then there was some little additive amount, $450 million a flight or I don't know what it was. When we signed the contracts for commercial cargo, $3.1 billion is the total value of two contracts for a five-year period of time in which we'll fly 20 flights. If you do the math, 20 times $450 million, which is the marginal differential cost between just maintaining Shuttle and actually operating it, $2 billion times five, $10 billion, just to maintain Shuttle, $3.1 billion is a lot less than $10 billion plus. That's why I say it's a win for the American taxpayer.

Now if Commercial Crew works out the same way, then there's no question, it's a win for the American taxpayer. But that remains to be seen. I don't want to overpromise. I tell people I think this is what we're going to be able to deliver, but time will tell.

WRIGHT: Kind of like the building years.

BOLDEN: The contractor has a role to play. It's like when you go to war. People say, "Why don't we just do this?" Military people say, "You've got to remember the enemy has a say in this. They don't line up and come at you the way you want them to do it." Boeing and SpaceX are businesses. They may have a strategy that we haven't anticipated, but I think they're very

patriotic. They understand where we are realistically, pragmatically, and they know that they've got to keep their costs down, and they will continue to keep their costs down.

WRIGHT: I think Kathy mentioned in her notes too, not only is NASA seen now as a technology innovator but a business innovator. So, it's helping get those businesses off the ground.

BOLDEN: Exactly. I think you will see that DoD, the intelligence community, other government organizations, they don't have a Space Act Agreement, they don't have that provision in their charter the way we do—the Space Act Agreements come from the [NASA] Space Act of 1958. But other agencies have other kinds of things they can do, CRADAs [Cooperative Research and Development Agreements], and there's all kinds of other transactional authorities [OTAs] that they can use. Just like us, they just don't use them very often, but I think we've provided the model that says those other transactional authorities can work if you do them right.

But it's a culture change. We demonstrated that even an organization like NASA that's steeped in culture can make a significant change.

WRIGHT: Actually, other than things that we'll talk about at another time, I think I pretty much have covered what we can about the crew program, unless there are some other things that you wanted to mention or talk about.

BOLDEN: Let me see what else is on my mind now that we're talking, because this is for posterity.

WRIGHT: I did have one question.

BOLDEN: Ask it and we'll figure it out.

WRIGHT: It has to do with ULA and Blue Origin, about the engines.

BOLDEN: Let's talk about that a little while. That was the significant news of the week. I'm very proud of our announcement on Commercial Crew; I think that was a game changer, to be quite honest. We were trumped in terms of importance for the nation by the announcement between ULA and Blue Origin that they are now going to team to build—it's not just an engine; it's a launch system that ULA wants to use to replace the Atlas V that uses a Russian rocket engine or two. If anybody remembers where we are, not where we were, where we are right now, when Congress left town, they were clamoring for the President, they demanded that the President order NASA and the Department of Defense to start immediately on building an American engine to replace the RD-180, the Russian rocket engine that ULA uses on the Atlas V.

NASA all along has cautioned everybody, "Let's not do that. I know what Congress says, I know what the President said, but let's counsel caution." Our recommendation was, let's go to industry and ask them what they think, what would they think would be the best way to provide it, because all my rocket guys, Robert [M.] Lightfoot and people from Marshall [Space Flight Center, Huntsville, Alabama] and everywhere else say, "We could build an engine. Two things. It'll take six years minimum, and it'll take $6 billion to $8 billion." If you got that kind of money and you got that kind of time, let's do that.

However, once we get to the end of the six years and we've spent the $6 billion to $8 billion, we have an engine. We don't have a vehicle to put it on, because engines don't plug and play. You can't take a Shuttle main engine and put it on an Atlas V. You can't take an RD-180 and put it on an SLS. The plumbing is not right; the propellant may not be the same. We said, "Let's go to industry."

The Air Force went out, you may remember, two weeks ago. That's what makes Blue Origin and ULA's announcement just a miracle. It's like manna from heaven. They went out two or three weeks ago and it was a request for information; it wasn't a request for proposal. They said, "We have to find a way to wean ourselves from dependence on Russian rocket engines." I don't even think they named the RD-180, but everybody knew what they were talking about. We need an American capability. They accepted our language. We need an American launch capability, which meant, "Industry, tell us how we can best get to an American launch capability," knowing that some of the companies were going to come back and say, "We'll build you a new engine."

That happened. There are some companies out there, that was their response. "Let's build this engine, because we've been working on this engine for years. It's on paper. We don't have any hardware, but we can build this for you really quick."

"How long?"

"Six years."

Blue Origin, that had been working—and we did not know this was coming. There may be somebody in NASA who did. I didn't. I never even dreamed it would happen particularly this quickly. I was hoping that something like this would happen. But we did know as a result of the CCDev, our Commercial Crew Development Program, Blue Origin was one of our early

partners in CCDev. They actually were awarded a small amount under a Space Act Agreement to look at the development of an alternative engine. I think what they chose was liquid oxygen and methane. I don't think we've ever flown one like that, not for a big engine. That's what they decided they wanted to do.

They had the [New] Shepard as their module. I don't think we ever gave them any money toward the design and development of their module. But Jeff Bezos said, "I don't care. I don't want it anyway." When he and I met five years ago he said, "I want to partner with NASA, but I can't get on your time schedule, because the first people to fly the New Shepard is going to be my son and me, and it's not going to fly until I'm ready to fly, till I think it will be safe for my son and me."

I said, "I love you." I said, "I'm happy. You may end up with a vehicle long before any of our partners do, and if you do, we'll come back and talk to you." We were happy.

Then because Blue Origin has been very very private and very quiet, we knew they were doing things, but we didn't know exactly what. We did know that they were developing an engine, and they were serious about it, because several times over the last two years we've actually had a Blue Origin engine on the test stand down at Stennis [Space Center, Mississippi]. They have test-fired their engine.

Blue Origin, as it turns out, is three years into the development cycle of an American-made engine. That says with this partnership they're three years away from being able to replace our dependence on Russian rocket engines if they could find a vehicle to put it in. ULA came along and said, "We want to get off dependence on the Russian rocket engine, and it may be that we design a new launch vehicle, it may be that we just modify the Atlas V to accept the BE-4.

That announcement was a real game changer. It may not work. We need to be very honest and up-front. It seemed like the perfect solution to our dilemma of the President responding to Congress, DoD and NASA responding to the President, and the nation being on its way to having its own self-sufficient way to launch heavy payloads into space commercially. If it works, we'll be able to do that about the same time we'll be flying Commercial Crew. It could not have been better. It's a marriage made in heaven.

It may be that Boeing says—because they contracted with ULA for a launch vehicle. They just happened to pick the Atlas V because it's the safest. It's the most reliable vehicle in the US inventory right now. They could say, however, that they'll switch to the new ULA/Blue Origin launch vehicle/engine suite—who knows? It's up to them. We want a contingency to change to the Atlas VI, or whatever you call this thing that has the Blue Origin engine, and then that gives us not only two alternatives, two redundant ways to get our crews to orbit, but two redundant American systems to get our crews to orbit. Then we don't have to depend on anything Russian to have redundancy in our launch system. So that gives us two American systems, a Russian system, so we now have three distinctly different launch systems. Different engines, different launch vehicle, different module. It is very unlikely that all three are going to crater simultaneously, short of a world war or something.

I say it's a real game changer to where we were two weeks ago, or the day before they made this announcement. That affects Commercial Crew. We're still concerned because if it doesn't work then we're back to Boeing dependent on the Atlas V with the RD-180, and we don't know where Russia is going to go. We know where Roscosmos is, but Roscosmos is the Russian Space Agency subject to whatever Prime Minister [Vladimir] Putin decides he wants to do.

WRIGHT: I'm glad we got a chance to talk about that subject.

BOLDEN: Yes, that was great news.

WRIGHT: Yes, it was good. Like you said, it was a good week.

BOLDEN: It was a great week. But it does have—in the long run it has everything to do with Commercial Crew because it gives the United States total independence of Russia. Yes, for Commercial Crew it gives us total independence of any foreign country. Now in the case of SLS and Orion, we purposely made ourselves dependent on our international partners for Orion, because we contracted with the European Space Agency to provide the service module for Orion. That has done what we call putting them in the critical path. If they don't produce, we don't fly, we don't have a vehicle, because you can't fly Orion without a service module, because that's power and propulsion, that's all kinds of stuff.

WRIGHT: After a few rough spots it seems like things are maybe moving in the right spot.

BOLDEN: It's life. This is like raising kids. You learn as you go through their development.

WRIGHT: You don't ever get through raising kids, do you?

BOLDEN: You don't ever get through raising kids. That's why I say I love this job. But it has frustrations. One of the frustrations for me is the fact that you can't speak as frankly—as open and honestly—as you'd like. We wanted to talk about the selection process, but everybody's nervous that we'll say something that's untoward or legally inappropriate. Because I'm a political appointee—and people do need to remember that—I work for the President.

I have been given as much leeway as anybody could be given. I've never been told by the President to say anything or do anything other than help us with STEM education, help reinvigorate the interest of young people in space, keep America number one, get Shuttle safely phased out, and extend the International Space Station. Those were the things he told me to do. I think we're doing okay.

But it's been rough. It's not going to change, but nothing worth having comes easy. That's half the fun, going through the ups and downs. It's like having your kids just disappoint you, and then all of a sudden they come back, and they do this wonderful thing, and you just want to jump up and down and scream and hug them. It makes those moments when everything works out that much better. Just imagine having a perfect kid, like my daughter. My daughter was the perfect kid until she screwed up in high school once, and took her brother's car, and the wheel fell off. When I found out about it, I was crushed. I could not believe that my baby girl, the perfect child, could ever, ever do anything like that. But after that it was great because it meant she went back to being the perfect child again. It meant that she had come from the depths of despair.

JOHNSON: Redeemed herself.

BOLDEN: She redeemed herself incredibly well.

WRIGHT: Thank you. We'll save our remaining time and use it for another time. Thank you for doing that. Appreciate it.

BOLDEN: That'll be great. Thank you all very much. Thanks for doing this.

[End of interview]

http://www.airsafe.com/risk/shuttle.htm

Space Shuttle Fatal Event Risk

Summary

If the remaining fleet of three Space Shuttles continue to fly until the end of their operational lives, there is from a 40% to 99% chance that there will be at least one more fatal event involving a Space Shuttle mission.

Background

From the inception of the Space Shuttle program in 1981 to the loss of Columbia in 2003, there have been a total of 113 missions and two fatal events. Two ways to estimate future risks would be to use a formal engineering or scientific assessment of risk or to use an estimate based on observed data. While there have been many formal assessments of Shuttle accident risks, there has also been wide variations in estimated accident risks. Two representative examples are one from Dr. Richard Feynman, a member of the Rogers Commission that investigated the Challenger accident, who estimated the likelihood of failure as about 1% per flight [1]. A second example is from a 1996 report from the U.S. General Accounting Office that identified a NASA-sponsored study that had a median estimate of a catastrophic shuttle failure of one in 145 launches [2].

One could also take the experience of the first 113 flights to come up with an estimate. Because the last resulted in a fatal event, it may be overly biased to include that outcome. If one were to err on the optimistic side and exclude the 113th mission, one could estimate the likelihood of a fatal event as one in 112. If one were to err on the conservative side and include both events, the estimate would be one fatal event per 56 missions.

The formal assessments and the basic estimate using observed data are varied, with about a factor of three difference from the lowest to the highest. One could take the extreme estimates, one fatal event per 145 flights and one in 56 flights, and use a basic probability model to estimate the risk of a future fatal event.

Risk Model

Risk is defined as the combination of a specific hazard and the likelihood of that hazard. The specific hazard in this context is a Space Shuttle flight that results in at least one crew fatality. The likelihood of

this event was estimated to be between one fatal event per 56 flights and one fatal event per 145 flights. A simple probability model is the binomial model, where the likelihood of the hazard is constant.

Assumptions and Estimates

The likelihood of at least one more fatal event would simply be (100% - the likelihood of no more fatal events). The following table presents the likelihood of a least one fatal event for a combination of two estimates of the probability of a fatal event on each flight (1/56 and 1/145) and two estimates of the total operational life of the shuttles. There are three remaining Shuttles, and those shuttles have flown 76 times. If it is assumed that each orbiter will fly no more than 50 times, then there would be 74 flights in the remaining lifetime of the fleet. If the assumption is a 100 flights per shuttle operational lifetime, then 224 flights would remain.

Table 1: Likelihood of More Fatal Events as a Function of Remaining Fleet Life and Fatal Event Probability

	74 Flights	**224 Flights**
1 per 56 Flights	73.7%	98.8%
1 per 145 Flights	40%	79.8%

[1] Feynman, R.P., 1988, *What Do You Care What Other People Think?*, Appendix F.

[2] Science Applications International Corporation, 1995, Shuttle Probabilistic Risk Assessment, Washington, DC, Center for Aerospace Information

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