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INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is March 1st, 2013. This oral history session is being conducted with Dr. Scott Horowitz in Houston, Texas for the NASA Johnson Space Center Oral History Project. Interviewer is Rebecca Wright, with Rebecca Hackler. Thanks again for finding time in your busy schedule to talk to us. Today's subject is the agency's Commercial Orbital Transportation Services [COTS] program. We'd like to start when you were in the role of NASA's Associate Administrator for the Exploration Systems Mission Directorate.

A few months before you arrived, NASA Administrator Mike [Michael D.] Griffin had taken the lead role for the agency, and when he arrived he had listed a number of priorities that were consistent with President George W. Bush's Vision for Space Exploration, which included a statement "to encourage the pursuit of appropriate partnerships with the emerging commercial space sector." Tell us what your understanding of this objective was and what was your involvement in it.

HOROWITZ: The key word is "appropriate." An appropriate relationship with the commercial sector is to encourage commercial space. Commercial is defined—when you're talking about the government, a good example everyone uses is airlines. Whenever you travel in the government, you buy a commercial airline ticket. Not always, but most of the time. That's a commercial relationship. They're a commercial business, they do business for profit. They make money,

and they have a service that we can simply purchase commercially. That's what was meant, first of all, by the word commercial.

The goal was to try to develop the same type of a relationship for space services. The first obvious place to start was in transporting cargo into low-Earth orbit. That's where COTS basically originated, if you want to go back to the original intention.

WRIGHT: A lot was going on when you arrived, because this was just a small part of the Vision for Space Exploration. The rest was a much bigger plan. How did your staff and the team that you were putting together view this objective, and how did it start to take a piece of your daily operations of work?

HOROWITZ: The entire Vision for Space Exploration, in my opinion, was a long overdue direction for the agency. Post-Apollo timeframe, the agency pretty much went from project to project to project. Space Shuttle was a project looking for something to do. Great capability, and it eventually became the way we did [International] Space Station [ISS], but there was no overarching goal. The Vision for Space Exploration—the basic premise was NASA needed to get out of low-Earth orbit.

One of the reasons NASA wanted to work with the commercial folks to provide COTS services was NASA would move one step ahead, beyond low-Earth orbit, and then the commercial folks would have an opportunity to fill in the low-Earth orbit services, the first step. Then NASA would do the next step. The long term goal would be as NASA kept doing the harder and further out things, then the commercial world would—if it was commercially viable—be able to provide the services, because all that technology had been developed, and

other companies could take it over. Basically NASA would do the hard stuff, and the commercial programs would do the routine stuff.

Most of the effort of course was on doing the really hard stuff, which is developing a replacement for the Space Shuttle, because it was scheduled to retire in 2010. The number one objective of the Space Shuttle's replacement was to provide a way to get a crew to and from low-Earth orbit and to provide a spacecraft which could travel beyond low-Earth orbit—to the Moon, to Mars, asteroids, wherever you wanted to go—and to do it on an order of magnitude safer than the Space Shuttle.

The Space Shuttle's track record, as you know—it depends on whose number you want to use, but it was somewhat less than one in 100. The Astronaut Office had issued a memo post-*Columbia* [STS-107 accident] that called for the next manned space vehicle to be able to have a predicted loss of crew better than one in 1,000. Everyone in the space business said wow, that's really hard. If you were a commercial paying passenger on an airliner and they said you had a one-in-1,000 chance of making it from here to Los Angeles today, you wouldn't get on the airplane. It puts it in perspective.

But it was hard. Our group was focused on building that capability. Plus then, in order to go beyond low-Earth orbit, you need to put sufficient cargo in low-Earth orbit to go somewhere and support exploration-type activities. Numbers were passed around in different architecture studies, but anything less than the capability of a Saturn V [rocket], which is 100-plus, 200 metric tons into low-Earth orbit, just doesn't provide you enough stuff to go anywhere.

The architecture which was studied and traded—hundreds of different architecture combinations, thousands of different rocket designs were traded. It was the summertime of 2005 when the final study was done, just before I was asked to come to NASA Headquarters

[Washington, D.C.]. My staff's main purpose was to execute the vision. In particular, do everything required to build the architecture to support space exploration.

Of course we had all the work we were doing to figure out the interface with us and all the international partners. There was a huge amount of work done on what the international partners would contribute to exploration, because we felt, and it was actually stated, that it would be an international pursuit. In fact my deputy at the time, Doug [Douglas R.] Cooke, that pretty much ate up most of his days. We had 13 nations participating.

My philosophy was instead of dictating what they do, why don't we bring them together and ask them what they'd like to do, and then figure out does that fit in the overall architecture. We were doing the basic transportation elements, some of which were going to be U.S.-only for strategic reasons. There were certain elements that if other people want to provide some of the same elements, that's fine, but there are certain things the U.S. would do.

COTS was this pretty minor piece at the beginning. It built up a little more as we were figuring out a way to, for example, supply the Space Station while we were building the new transportation system to move the crew to low-Earth orbit and beyond. To build the larger vehicles to go on, and design landers and habitats and ground transportation elements and power systems and the whole array of all the capabilities you would need in order to do exploration.

WRIGHT: Did you see the COTS piece as being a viable and important piece of the future? Or was it more of a contingency or the backup if some other program didn't come online?

HOROWITZ: For transporting goods to the Space Station, for example, that would become the primary method of transporting goods, again to free some of our resources up to go do the harder

things. We actually looked at the capability, and if you look at the requirements for Orion, it was a backup capability to COTS. COTS wasn't a backup capability to Orion. One of the reasons it was set up that way was because Ares and Orion were supposed to fly in the 2013 timeframe, with the ability to transport crew with a probability of loss of crew better than one in 1,000, which is not trivial.

But if you could move a crew to space in order to take the first step to go on a mission to the Moon or Mars or wherever, you can obviously take them to the Space Station. It's not a big deal. The requirements were that the government system would be designed primarily to go do exploration, but as a backup would be able to go resupply the Space Station, because the COTS was going to supply the Space Station.

COTS was very focused. Commercial companies had not done this before. There was a high risk in them being able to develop the capability, which was supposed to come online when the Shuttle retired in 2010. As much risk as there was on the technical side, there was even more risk on the financial side. To be quite honest, the business cases were not that robust. There's always the promise, and it's been this way since the beginning of thinking about doing commercial space.

For years and years and years, the promise of—chicken-egg thing—if we build it, they will come. "We can reduce the price, we'll get tens of thousands of satellite launches, and it'll be $1 a pound. We'll just throw things to orbit, and it'll be just like the airlines. We'll be launching rockets so fast, we'll need a traffic control tower to control the traffic. It'll be so dense, there'll be all these customers."

The problem of course in any system—it doesn't matter if you're going to build a car, build a house, build a rocket—if you build one a year, it's really expensive. If you build 10,000

a year, the price comes down. Because, there's a fixed cost of just having a building with people in it, and if you have to amortize that cost across one unit—if General Motors had to build one car a year, it'd be a multibillion-dollar car. The fact that they build millions of them means you can buy them for thousands of dollars. Same in the rocket industry, the biggest thing driving the cost is the rate.

To get the kinds of promises of efficiencies, the commercial space business had to have commercial customers. Just like in the airlines, NASA doesn't buy all the seats on a commercial airliner. You buy a very small percentage of them, but we get the advantage of there's a big market. When I announced the winners in '06 [COTS Final Selection Statement], I said as hard as the technical part is, I see the business case as being even more difficult.

That's how it all fit together. The plan was we do exploration, we go build the government program, we use COTS to fill in the routine resupply of Station. That whole program was set up to give people a chance to prove that they could actually do this and create a commercial space environment. If you go back to the Vision, that's what everybody wanted to do. Can we build a really vibrant commercial space industry? Especially for orbital services. There's already a pretty good space industry for satellites and imagery and things like that, but actual commercial space transportation was one of the goals.

WRIGHT: As you were getting on board and setting up your teams and working, at the same time the COTS program was coming online, they were getting ready to make their Announcement. As it moved through its timeline, how much input did you have prior to the selection? Or was your involvement, did it start with the actual Round 1 selection process?

HOROWITZ: I was the Round 1 selecting official. I was very involved. I read every single proposal cover to cover, and worked with—we had a small office here at Johnson Space Center as you know, run by Alan [J.] Lindenmoyer and Valin [B.] Thorn. Those two were running the office down here, providing the technical overview of the proposals.

We had quite a few proposals early on, and we had a down-select process. I think we finally got to six finalists, six that were viable proposals. Like in any proposal situation, lots of people propose, but some of them don't meet the basic criteria so you eliminate those proposals. Then you get down to the ones that meet the criteria. I was very involved in the review of those, and held reviews where all the proposals were brought to me and graded and reviewed.

I actually put together a team that included people from the business sector, because like I said, as hard as the technical part is—and I'm pretty good at the technical part—the business part I thought was going to be even more difficult because each proposal was going to be scored based on its technical merit as well as its financial merits, for its capability to meet the basic goal of producing a commercially viable space transportation system.

WRIGHT: How comfortable were you in evaluating through this new procedure, because these were going to be pulled in with Space Act Agreements and not your normal government procedures that you had been doing forever.

HOROWITZ: The use of Space Act agreements was really unusual. We spent a lot of time with contracting and with legal, and a huge amount of effort went into what was the right procurement strategy for this. This was a little different than anything we had done, because in a normal FAR [Federal Acquisition Regulations] procurement, there's a whole list of things you have to

accomplish, for good reason, and these monies were to be provided as basically an incentive, a subsidy directed pretty much by the Office of Management and Budget [OMB], who quite honestly didn't like the Space Shuttle. Paul Shawcross at OMB, Office of Management and Budget, in particular. His goal was to get rid of the thing, he hated it.

If you go back in history the Space Shuttle mostly looks the way it does because of the Office of Management and Budget, because they had this vision that we'd build this airplane thing that flew to space, and you'd just put gas in it and go fly it, and it would be really cheap. The same rocket scientists at OMB envisioned COTS would be that you give them a couple hundred million bucks, and we'll be buying cargo for less than $1,000 a pound.

Now as wrong as that concept was, we still believed in the goal to promote the commercially viable space industry, so we went through the NASA directives, the FAR rules. As it turns out, you can use legally a Space Act Agreement—which is really called an "other transactional authority," that's what it's called in the actual language—for very very limited use. And this was a real expansion of that use, because usually it's used for $1 million grants to a research university to go do some research. There's lots and lots of Space Act Agreements. It's called a Space Act Agreement because it's part of the original charter for NASA, the 1958 Space Act, so it's called Space Act Agreement.

Other agencies have this other transactional authority. The review of how you would do this—it was felt that the Space Act Agreement was probably the most appropriate for this particular [program]. It's not an acquisition, because by law you can't acquire anything with a Space Act Agreement. So we couldn't buy services, you can't buy hardware. You can basically subsidize research and development.

Really the $500 million under the Space Act Agreement was to subsidize research and development to come up with a commercially viable system. OMB had put in NASA's budget $500 million to do that. The people down here [at JSC] in Lindenmoyer's group and others had done a lot of research on things like prizes and other space things, and had come to the conclusion that companies would spend twice as much money as what you authorized. If you gave them a buck, they'd spend a buck, so they'd spend $2 to win $1 because of the prestige and the business case for future business.

When you looked at it, they were all promising they could do it for say $500 million, develop a rocket and a capsule, or whatever the concept was. If NASA gave them about half of that, they would kick in commercially the other half. Then they would have a service. Fifty percent of the development would have been subsidized by the government, to which they could go start making a profit. Because there's this commercial group out there selling rockets for 1,000 bucks a pound for payload, NASA could buy it like they buy tickets on an airline. That was the whole thing, that's one of the reasons the Space Act was used.

It was pretty much what we felt was the legal limit of the use of a Space Act. You really couldn't take it any further. Once all the companies had demonstrated their milestones in the Space Act Agreement—the other advantage of which is since it's not a FAR, and it's not a contract, it was a milestone-based payment system—if you read a Space Act, it actually says government can cancel it at any time.

The thought was it also reduced the agency's exposure and risk, because if I said I'm going to give you $100 to do something and you don't do it, I was only obligated to pay you the last payment that I paid you out of that. If you don't meet future milestones I don't owe you any

more money. I can cancel a Space Act Agreement if you don't perform. It's almost like a firm, fixed-price contract, but it wasn't a contract. It protected the agency as well as the companies.

The actual contract for services would come later, and that would be a FAR acquisition. Put out a request for proposal, you get proposals, analyze the proposals, you pick a winner, and now you're in a contract situation. But that was to be the beginning and the end of the use of Space Acts for commercial space. That was it.

WRIGHT: Were you surprised that you had 20 or so proposals?

HOROWITZ: I wasn't surprised. Like I said, there were only about half a dozen that were really viable. But everybody who was excited about space—we had some proposals that somebody was going to build a rocket engine in their garage, we had some proposals to, "Give us $200 million and we'll go do a study," and we had everything in between. Like I said, the first round was pretty much to get it down to about a half a dozen viable, serious proposals that were in line with what we wanted.

We give you some money, you put in some money. In this timeframe you build a rocket and a spacecraft that can go deliver some cargo to the Space Station. There's a lot of people that have been running around for years in conferences, yelling and screaming, "Get out of our way, just give us a chance. We can do it for one tenth the price, and much more reliability, and a whole lot faster and better than NASA." They've been screaming that for years. This was like "show me." I wasn't surprised we had a lot. Having half a dozen competitive ones, that were serious, was actually a pretty pleasant surprise.

WRIGHT: Part of the elimination process, if I can use that term, if it had been a FAR process there would have been a Source Evaluation Board, but this was done differently [with a Participant Evaluation Panel]. As you mentioned, you had to bring some business folks in. Could you share with us some of the details of how you got from 20-something proposals down to these last six, and maybe what were some of the features of those six that put them in that classification?

HOROWITZ: The first elimination was easy. Somebody sent us a picture of a bunch of copper tubes soldered together in their garage and said they were building a rocket engine that was 10 times more powerful than an SSME [Space Shuttle Main Engine] for one fifth the price. It was pretty easy to eliminate the ones that just were, "Thank you very much, we'll buy your matter-antimatter engine when you demonstrate it." Some of them were pretty easy.

Some just weren't aligned with what we wanted to do. Serious companies came and said, "Well, we'll do this whole study."

We said, "We don't want a study, we want you to go fly a piece of hardware." The first elimination was actually pretty simple. They just weren't aligned at all, or completely non-viable. Probably well intentioned, but not serious technically, understanding what it takes to actually go build a rocket. That part was pretty simple. The next elimination of course took a lot more time and effort to do.

WRIGHT: Tell us about how you had the six and then you moved it to two [winners]. From what we understand, at some point in this process, NASA hired a venture capitalist to help understand the business part of it.

HOROWITZ: We brought in different people to look at the proposals. In fact a lot of the process we used would be just like in a regular proposal situation, where you basically have your criteria and you have the proposals, and you rank the proposals against your criteria. If you broke it down, the two major criteria were is this technically viable, and does this have a snowball's chance of making money.

In general the government, when they contract, they don't care about the second part. I don't care if the contractor makes money, I want my widget. I want the contractor to stay in business because he has to build my widget, but I want my widget. Here, we wanted our widget, our rocket and our spacecraft, but it didn't do me any good to get the spacecraft if I didn't have a company that it looked like would be viable and make money at doing this so I could be one of the purchasers.

Again, the endgame was to be a minor purchaser of the company's services, not the only purchaser of the company's services. We wanted a company that was commercially viable, not one that depended on government customer alone. That's why we had some people who had business experience reviewing the proposals, because one of the big things was right off the bat we knew that the money we were giving them wasn't enough to do the job. It was about half as much to do the job.

When somebody submits a proposal, they say, "Oh, we can build your Space Shuttle for $100 million." Of course that's ridiculous, and so the government does a "should cost." With every proposal, people propose a cost. You don't always pick the lowest cost, because in general the contractors are all trying to underbid each other to get the job, and once you sign up for it, then they go well, it really costs this. The government usually has insight into what they think it

really will cost, should cost. While we're doing the "should cost," the technical viability, we're also doing the, "is there even a potential that this could make money in the future?" That's why we had the venture capitalist type people reviewing the proposals with us.

The FAA [Federal Aviation Administration] was part, because they had a stake in this. They were going to be the regulatory. If you looked at the people who all sat in the review committee, we had technical people, business people, FAA people. It was about a half a dozen or so people who had an interest, who were what I call the stakeholders, and had an input into the selection of the COTS finalists.

WRIGHT: Which were SpaceX and Rocketplane Kistler. Since you were the selector, those two now were going to bring forth part of this vision. SpaceX of course has its own history trail at this point, but RocketplaneKistler didn't have the success that they had hoped. Could you share with us some of the proceedings and issues that caused you to terminate their association?

HOROWITZ: RocketplaneKistler had been down this road before. They had received a lot of money, and the one advantage they had is they obviously had a lot of hardware. A lot of it was sitting in Michoud [Assembly Facility, New Orleans, Louisiana]. They had built a lot of rocket parts. They had an interesting technical proposal, in some ways pretty classic—rocket engines, capsules—but they were going to have a reusable upper stage and a reusable first stage. One of the problems you run into, and to make money at this, is a lot of people are very keen on the idea that the only way to make money is to reuse the hardware. We don't throw away an airliner every time we fly coast to coast and get a new one.

On the surface, that seems like a really good idea. Again, come back to my comments on rate. [The] Boeing [Company] builds lots of airplanes, so there's a production line. In the space business, if you don't build lots of rockets, even if you reuse it, it may be just as expensive. You're only building one a year. But that was the concept. Kistler was going to have the first stage land back down with airbags. They were going to "poof," catch the first stage.

But the really interesting part was they were going to reuse the second stage. Shuttle reuses the first stage; the solid rocket boosters are reusable. They go land, big parachute in the water, boat tugs them in, they clean them out, and they reload them. I'd actually been through that trade study probably a dozen times, because I actually worked for ATK [Alliant Techsystems, Inc.] for a while. We kept asking the question, "Is this really saving us any money?" Depending on whose study you looked at, total cost and everything, we found out maybe. It depended on whose study you wanted to look at. You can say yes, maybe it saves 15 percent. There's a lot of people who claim it's going to save 100 percent, it's going to be just a fraction of the cost to reuse the hardware.

In the Shuttle Program, we reused the Shuttle, but we didn't reuse the tank, but we reused the engines. The Shuttle is a hybrid, and this was going to take it one step further. They were going to reuse the whole upper stage. It was going to fly back in and reenter, and they were going to be able to reuse the whole thing. That was a big technical challenge, but they had a lot of smart technical people, and it looked like it might work. That was part of the Kistler thing. Their technical thing was interesting, it was challenging. It had some percentage chance that it wouldn't work that way.

Their biggest challenge turned out to be meeting their funding milestones, the business part. Again, we had the technical half of the proposal and the financial part of the proposal. I

had a bunch that had maybe good technical but lousy financials, and I had ones that had good financials and lousy technical, and all combinations in between. The basic premise I had is, I don't care how good the financial proposal is, if it's technically not going to work, it doesn't matter. The risk was on the financial side, because it had to be at least technically viable. Doesn't do any good to have a really great business case for a thing that just isn't going to work. I used to say if it violates the laws of physics, I don't care. We're not changing those this week, that's a longer term job.

There was a whole series of milestones in all the proposals. The two we finally chose had to meet financial milestones, and that's where Kistler ran into trouble. They had these fundraising milestones, and they had this plan to raise money. The venture capitalist said, "Well, this could work but it's high risk. They'll have to do this, this, and this." Basically they didn't get very far down the road, which is the same problem they had had earlier, and they couldn't raise the money.

We gave them money to get started, and in general most of this works in the venture capitalist world, if I want to get $1 million from you, you have to show me that you can make money at this, and one of the ways you can show me you can make money and that you're financially viable is show me the money. They'd go out and they'd get some money. By them getting money, other people said well, they can get money. The government has selected them, so the government must feel they're going to give them money, therefore I'll give them money too.

The bottom line was they couldn't meet those milestones. I basically used a three-strike policy. You missed your milestone, we'll try again. You missed your milestone, we'll try again. You missed your milestone, you're out. Just done. Government is done throwing money at this.

Gave you three shots at this, we're done. To me it was pretty simple. That's the way it was set up, and they didn't meet their milestones. We tried, now we'll go on. Within about six months they'd pretty much not met their milestones. Within a year that Space Act Agreement was terminated.

WRIGHT: As you saw those signs heading in that direction, were you working on a contingency on how you were going to replace them?

HOROWITZ: We had basically said what we'd do is we'd dust off the old proposals, but to be fair we'd have to put out another request to let people know that the remaining money in that pot—I think it was about $175 million—would be allotted for someone to come take their place. That process had already started, "How would you do that, how would you put it?" That all occurred after I left. Rick [Richard J.] Gilbrech was in charge at the time and basically went through the same process again. They let everybody bring their proposals back in and do the same thing all over again.

WRIGHT: The other piece of that, your other selectee was up and running. How were you involved in keeping up with what that group was doing and how they were meeting their milestones?

HOROWITZ: The Space Act Agreement had milestones, and my job was to make sure they were meeting their milestones. The early milestones for SpaceX were actually pretty easy. Their fundraising ones, for them to come up with their matching funds was easy. Elon [Musk, [Musk,

SpaceX founder and Chief Executive Officer] wrote a check, put it in the bank, he was done. Very low risk for SpaceX to meet their matching fund requirement. It was a little more complicated than that, but that's basically what it was. Because of his financial backing, financial status, he literally could put money in an escrow account, or however they set it up. They could get to those milestones pretty easy.

Then the trick was going to be, could he actually deliver the hardware on time? When we looked at all the proposals, we also did like you do in program management. We had our groups that looked at, given a budget and given milestones, what is the probability that you can actually execute on time, on schedule, for the money you're given. We call it the confidence level. If I tell you to go build a Space Shuttle, and you tell me you can do it in five years for $5 billion, maybe that's the 75 percent confidence level. We look at all programs of similar complexities based on this huge database of all programs ever done in aerospace. You can pretty much predict, fairly accurately, what's the probability that a good program manager with those funds and that time can execute that job.

None of the proposals were higher than 20 percent. None. That was the best. For the money they were promising—and we gave huge discounts for the fact that they didn't have to have NASA breathing down their neck. In fact one of the keys of the Space Act is we're not buying a service, we're just subsidizing development, we're going to come in later. We're going to leave you alone. You don't get a boarding party, you don't have to go to engineering review boards, you don't have to have these huge things.

You still are going to have your own milestones which we're going to send technical people to go check the box that you did one, but by no means were they going to be held to the standards that we would hold our programs to, as far as what is a really viable systems

requirement review, what's a real preliminary design review, all our entry and exit criteria. We weren't going to send any of the experts down to make sure they were dotting Is, crossing Ts. They just had to have one really, because later we're going to evaluate the product for suitability technically.

Pretty much they wanted to be left alone. We said we'll leave you alone, here's this money, like a research thing. You don't go down and breathe down a researcher's neck every day when they're doing their research. The money is at risk, because you don't know what they're going to come up with. They start marching along, and since I was just there for the first couple years, the progress was pretty good.

When they signed the Space Act Agreement there was a little matrix, and it had six flights. One of the things we wanted to see was since we're not going to be in there specifying all the details of all the reviews and the design, you have to demonstrate capability. Before we would even consider discussing a contract, they would have to demonstrate the capability. "You don't review our stuff, and you don't bother us technically, we'll just demonstrate it." NASA doesn't go and review the Boeing design for the 747 [aircraft], we buy airline tickets. So we said okay, well demonstrate.

They had originally proposed six flights. Three of them were funded under the Space Act Agreement, and the money they received per flight was actually pretty low. Purposely, to help the company succeed, a lot of the money was front-loaded. A lot of the money was stuck to give them to help them get off the ground, and help them entice other monies from companies that would buy their services. The monies for the actual flights were really just milestone payments. They really weren't money—and of course by law they couldn't be—to buy it. They weren't a

service. When they flew a flight, we weren't buying the service. It was just they demonstrated another milestone.

There were six flights. Three of them were designated for COTS, and three of them were designated for themselves and others and development. I think their first flight was considered a flight for SpaceX alone. A couple I think they had DoD [Department of Defense] interest, and they had some agreement with others to fly a couple flights. I think they even had commercial payloads scheduled for those. Then three were specific to be COTS milestones.

I think the last flight was supposed to have flown in [September] 2009, if I remember the original schedule. These flights were all going to occur in different quarters of 2008, 2009. They were motivated to get it all demonstrated so then they could compete for a commercial contract, so when the Shuttle retired they could start sending cargo to the Space Station. That was the original schedule.

We looked at that and looked at the money they had, and what they wanted to do, and there was probably less than a 20 percent chance. But they said, "Hey, this is commercial, this is better. You guys have no idea, but we can do it a lot better than the government." We calculated they couldn't fly six flights by 2009, but of course we're the government. That was the whole arrangement, and the initial progress of the SpaceX and Kistler responses to the COTS funding.

WRIGHT: With a hands-off approach during the development phase, did you, as a very involved NASA administrator and former astronaut have issues with safety? How you felt they were going to involve the element of safety in their programs for what you would need to accept their spacecraft.

HOROWITZ: No, absolutely not. Because I forbid anyone to even discuss the fact that they were going to try to send people. The folks down here in the COTS office said we need to have COTS A, B, C and D; we have to have this manned capability. I said no, we are not going to do that, they don't meet the requirements for that. If you have to do that, that is an entirely different thing. We are going to see can they be viable commercially to send cargo.

Making a business case for cargo was iffy at best. Making a commercial case for crew has yet to be made by anybody. I have not seen a single document in a decade that even hints that anybody could make a nickel commercially sending crew to orbit. Now there's the Virgin Galactic [LLC] idea of sending people to space, which is not to orbit. That's for a couple-minute ride into zero-G [gravity], above the atmosphere and back down, which I think might make money. Might, if they're lucky.

But going to space and back means you have to accelerate the crew to about Mach 3.5. Can you make money at Mach 3.5? I don't know. The airlines are having a heck of a time making money at Mach 0.8. The supersonic transport, the [Aérospatiale-BAC] Concorde is no longer flying. They couldn't make money at Mach 2. Making money at Mach 3 I think is iffy. Making money at Mach 25 is right now ridiculous.

You could run the numbers any way you want. If I stick five people in a little spacecraft and I launch it to Mach 25, let's say I charge $5 million a seat. That's 25 million bucks. Anybody that tells me today they can go build a rocket and a spacecraft, I don't care who it is, for $25 million and make money at it is laughable. It's laughable.

My prediction was that eventually you could do this commercially for maybe half the price of what we were paying, if you were lucky. But there's two things that affect cost and profit in space. The two things are production rate, like we discussed, and size matters. It really

does. You want to send a lot of people to space cheap? Go take a Saturn V or an Ares V [rocket], stick 100 seats in it, sell them for 5 million bucks apiece, and that'll basically buy you a Shuttle flight.

If you can stick 100 people in the payload bay of a Shuttle, you might be able to make a nickel. I don't know 500 people that have got enough money to give you $5 million to go spend a couple days in space. The only report that even addressed this—there was a Tauri Group report in 2002, and it showed this commercial market, and all these great studies they have. I think several years ago we were supposed to have passed the point where we had 30 or 40 paying customers to do what Dennis [A.] Tito did going to [International Space] Station. I think we've had eight that gave Russia about $25 million. The prediction was 30 or 40, and it's this exponential growing thing, so by today 100 people would be going to space this year.

Not seeing it happen. They actually did some study in Japan and all around the world. Even in that report they predicted, because it's a supply-demand, cost-availability type thing, that if you could get the cost down to $1 million, $2 million a seat, there might be a market. There might be enough customers who could pay that kind of money that it might make money. It's like this Virgin Galactic thing. I think there may be enough people—it's probably not you and me—who would be willing to pay $200,000 to be an astronaut. Go up, go down for a few minutes, and get a little pin, or whatever they're going to give them. Maybe they'll give them a little champagne, I don't know. It's going to be a pretty expensive bottle of champagne, if they can actually do it.

Of course they were supposed to be flying in two years. It's been a decade. Somehow someone's going to have to subsidize, try to make the money back on however much money they're spending a year over those ten years. The business case is going to get harder and harder

and harder. Now if you just throw away the investment, don't care about recouping that investment, then that's a different story. You just want to recoup your day-to-day operating expenses.

Making money at this at low prices is very very very difficult. The crew thing, the safety thing—we were building the manned capability. And again, it was walk before you run. So, if the commercial people could prove they could reliably send cargo to space. Safety is reliability plus safety. Reliability is not safety, but you can't have safety without reliability. Reliability is necessary but not sufficient. If they could prove they had a reliable system to deliver cargo, then we could start having discussions of what do you have to do to that system to make it safe. Add abort systems, prove that the failure modes are benign enough that you can escape from them, have reliability.

One of the discussions—I talked to Elon [Musk] personally quite a few times. In fact there was a Futron [Corporation] paper that was written that he commissioned, and the conclusion was to make money and have high reliability, you need a very very simple rocket with very very few parts. It actually said the most reliable rocket will be a two-stage rocket with one engine per stage. He was going to build this really big engine for the first stage and a medium size engine for the second stage.

Of course that's not what the rocket looks like today. I remember asking him once, "Elon, you said the most reliable rocket is the simplest number of parts, only one separation event, only one engine per stage, least number of moving parts. Less parts, less cost, most cost-effective, most reliable. What happened?" Tongue in cheek, because I know what happened.

He looked at me and said, "Building a rocket engine is really expensive."

The interesting thing is there was another development going on that did exactly what Elon said you should do. It was called Ares I. It was designed based on that very principle. I know, because I designed it. It had two stages, one engine per stage, using very reliable components. Not only were they reliable, they were man-rated with all of the checks and balances. Even that system's predicted reliability with a robust escape system was not much more than one in 1,000. Numbers ran all over the place—they were like one in 1,250, one in 1,300—but even that was difficult. Thinking you were going to do it without that kind of attention to detail and robustness and testing is just nonsense.

The original question, was I worried about it? No. Because in my mind nobody was stupid enough to think we were going to turn over manned spaceflight to a completely untried commercial entity that wasn't even commercially viable to do cargo. That was going to be two, three steps down the road. As we moved on and we got beyond low-Earth orbit, a few years of demonstrating reliable, repeatable, cost-effective transportation, if all that happened, then we'd go back and discuss okay, can you build the airline? Are there enough people, are there enough destinations, is there enough market?

No one has yet to even show me how you can make money sending people to space. Haven't seen it, I'm waiting. I'd love it to be true but it's just not. The whole premise is false.

WRIGHT: Let me ask a question that's related, and a dull question, but it's one that we'd like to understand. You were the selection authority, but you had a program office at the Johnson Space Center, a small office. Can you share why that office was here, and the way that office was formed, and how it worked with you in the process of moving this forward?

HOROWITZ: First, from a high level philosophy, my predecessor felt that like the exploration program, everything should be centered out of Headquarters. My basic view is Headquarters doesn't do work. Work is done at the Centers, push work down to the lowest level. I'm a real fan of work goes at the Centers.

Which is the Center for manned spaceflight? The Johnson Space Center. That's the Center for manned spaceflight. If you're going to look at supporting the International Space Station, part of the manned space program, where do you want to put that work? The International Space Station is the customer. The people who have experience with supplying things to the International Space Station were at the Johnson Space Center.

You probably could have put it at Marshall Space Flight Center [Huntsville, Alabama] too, if you were just as interested in just the rocket part of it, because they're the rocket engine guys. They're really good at building rockets. We [JSC] operate the Space Station. Since the real goal was commercial, you can't have a commercial thing without a customer. You have to be customer-centric, and the customer was at Johnson Space Center, and of course just like Marshall does, we have rocket scientists.

It made sense to put it here, because of course they're very closely coupled with the International Space Station, who is the customer, if you will. Space Act Agreements have no requirements, but the follow-on would be to have requirements. Requirements would come from the customer. It made sense to have the oversight and the management—again, not a lot of management. They weren't a big office. And one of the reasons that weren't a big office, if they were managing the development of the system, they would have been a big office. Jokingly, there'd probably have been two of them for every one of the contractor, looking over their shoulders. But it was commercial, so it had to be small.

Their job was just to monitor the fact that they made milestones. That really was all their job was. Were they meeting milestones, and were we getting things ready for the eventual ability to go to a contract to buy services for the Space Station? Again, they were supposed to do COTS, they were supposed to demonstrate a capability. 2009 was the promise. Then we would talk contract, because if they flew in 2009 we'd have time to do a contract. The Shuttle would retire in '10, and then we could buy services.

Pretty straightforward plan. That's why [the office] was small, and that's why it was at Johnson Space Center. I think at one point there were supposed to be 160 billets at Headquarters, and by the time I left I'd gotten it down to about 100, because, again, work goes on at the Centers. Stop amassing people up at Headquarters, all we do is get in everybody's way. Our job is to provide top cover. I'm the one who goes to Congress and gets yelled at and screamed at, fights with the Office of Management and Budget.

By the way, a little side note—in the budgeting process, the Congress wasn't my problem. Congress really supported exploration. Office of Management and Budget was my archenemy in the administration for which I worked. My hardest battles were fought with OMB, not the Congress. The reason we didn't get the monies we needed was because of the Office of Management and Budget, not Congress. If OMB had authorized the money in the budget request, we would have gotten the money we needed to go do exploration. But we had people at OMB who wanted to kill the manned space program. That was their goal.

WRIGHT: Do you believe part of that was to move this whole commercial effort forward? Or was it two separate issues?

HOROWITZ: At that time all they cared about was getting the money away from manned spaceflight, NASA. They were big fans of "we'll just make it all commercial. We don't need NASA doing this, we'll just buy it." That was their claim, you can just buy this stuff. "Why the heck do we have to pay me money to go develop rockets? You guys cost too much."

Which is interesting—if you look at the end of the Space Shuttle Program, I think it was about $2.7 billion a year for the entire fully burdened Space Shuttle budget line. The average for the 30-year history of flying Shuttles from '81 till the retirement of the Shuttle [in 2011] was an average of about 4.5 flights per year. If you do the math, that equals about $600 million per flight. Fully burdened—government cost, contractor cost, gas, astronaut, tank—everything that we buy.

Let's say we assumed a ridiculously cheap price of $25 million to $30 million a seat, for seven seats. That's worth about $200 million approximately. Subtract that from $600 million, you get $400 million. We could bring up about 30,000 to 40,000 pounds to low-Earth orbit, so it's about 10,000 bucks a pound. Space Shuttle is about $10,000 per pound, or something like that. Even if you inflate a little bit, 10,000 to 20,000 bucks a pound, less than 10,000 bucks a kilo.

The promise was everyone could do it an order of magnitude cheaper. That's where you get the 1,000 bucks a pound. The promise was commercial could do 1,000 bucks a pound and OMB was like, "Wow, if I could do it for 1,000 bucks a pound, look at all the money I'm going to save."

Isn't SpaceX supposed to be launched today [CRS-2 mission to ISS]?

WRIGHT: In about 40 minutes.

HOROWITZ: Hopefully that goes well. We have a CRS [Commercial Resupply Services] contract for $1.6 billion for 12 flights. That's $133 million per flight. I think I saw they're bringing up about 1,200 pounds, so that's a little more than $100,000 a pound. I think they inverted the ten. It's not one tenth the price, it's ten times the price of flying the Shuttle. That's just what it is.

My basic contention is we did the experiment and we have the results, it didn't work. It's that simple. Whether the rocket works or not is inconsequential. That was the easy part. The part was can we buy services for the promise of 1,000 bucks a pound. I don't see a demonstration of that.

WRIGHT: I know Rebecca [Hackler] has some questions, so I'm going to switch over to her.

HACKLER: If you don't mind going back to the beginning—there were some programs in the early 2000s run out of different NASA Centers that could be seen as antecedents to the COTS program, particularly Alternate Access to Station and ISS Commercial Cargo Services. I was wondering how much you were aware of those when the COTS program was being put together, and how much the ideas from those programs informed how COTS was executed.

HOROWITZ: When those were going on, I was here at JSC. I was aware they were happening, but I wasn't involved with them. For example the RLS, which was the Reusable Launch System, was one of the big ones. I actually did get very involved in that, not by my own desire. I got called in the office one day—JSC had been hands off of X-33 [spaceplane] and RLS. That was

one of the examples of this was going to be this Shuttle replacement, commercial. I think they called it VentureStar or some pretty cool name. It was being developed by the Skunk Works in Lockheed [Martin's Advanced Development Program].

My understanding at the time was we were hands off. Our management at the time did not see that this was very viable. I think they got a call from Headquarters saying, "You will look at this and you will figure out, as the manned spaceflight Center, how to man rate this system." As one of the senior astronauts working advanced programs, just going to meetings for the Astronaut Office, you got volunteered. [James E.] Van Laak I think was the guy running this little group we put together. "You guys write the human rating requirements for these new spacecraft."

This was my first introduction. Let's go pull up the requirements for Gemini and Apollo and Mercury, the manned rating requirements for space stations, and we'll start there, because there were the human rating requirements. In fact there was a JSC document that came out of that after some very interesting meetings and discussions. That document I think is pretty much forgotten and lost, you probably couldn't even search and find it, but it eventually became the human rating requirements that are now the Headquarters NASA directive, after about four or five reiterations.

The interesting thing was when I said let's just pull off all the old ones and read through them, there must be a lot of great lessons learned on how to man-rate a system. It didn't exist. It wasn't written down. That was my first shock. Then we go out and we visit VentureStar, and there were these other programs going on. Start asking them simple questions, technical questions. Like, "You say it weighs this much and it's going to go this fast and use these engines with this fuel." Rocket science is rocket science. The basic equations aren't really hard.

I say, "I don't get it. You're going to build something the size of the Space Shuttle." The volume of this vehicle was the size of the solid rocket boosters, the external tank, and the Space Shuttle all rolled together. Yet its structural weight was the weight of the Space Shuttle. My first question was, "What unobtainium are you building this thing out of." If you did the math—because this was a single stage. Remember when I said I came to the conclusion it had to be two-stage, Elon said it had to be two-stage. Anybody who's been in this business, you have to be two-stage, because the Earth just has too much damn gravity. We're not changing that, and rocket fuels are only so good.

When you did the math, their payload fraction was like zero. In fact it was a negative number. What miracle is going to occur that this thing is even going to work? That was the first problem. Then crew safety came in. We said, "Okay, so what are your provisions for crew safety?"

They said, "What do you mean? It's safe."

"How safe?"

"Seven nines." Which means 0.9999999 reliable. "It's an elevator to space."

I said, "Really. Based on what?"

"It just is."

Wow, that's a pretty good claim. Like the Shuttle claim, "It's an airliner, it has all this reliability." I say, "Well, most rockets I know don't quite get to that many nines." In fact to demonstrate that you'd have to fly probably one billion times without a problem. Then my next question is so what are provisions for crew safety, and what's the crew interface.

"Why do you need a crew interface?"

"To look at the systems, turn it on, turn it off, fly it."

"Push the button and it goes." No joke. This was the entire mentality at that time. Most of this was pretty laughable, to be quite honest. Technically it was completely non-viable. There were some technically viable ideas out there. There were some that were like capsules and heat shields. I have on my shelf lots of different things. Some of them were technically fine, they just were like variations on a theme.

I tell people, "Look at the airport now." If you were to walk out in an airport in 1967, you'd see the very first, brand-spanking-new shiny Boeing 737s. Except that the picture is in black-and-white and made with film, if you took a digital picture of the same spot at the same airport today, you'd see a nice shiny 737. It's about the same length, it's about the same size wings. The engines are fatter because they're high bypass turbofans. But why do they look that way? Because physics dictates that answer.

Why do spacecraft look like teardrop capsules? Because physics dictates that answer if you want a robust, reliable reentry vehicle. We tried it with the Shuttle and we found out we weren't very robust. We could do it, but it's very very very difficult and very expensive.

Yes, I was aware of all these different programs. I'd seen lots of different ones. I didn't know all of them. I wasn't involved obviously in the contracting or at that level. We did pull a lot of that stuff off the shelf. A lot of those kinds of things were proposed by the same people that proposed the earlier ones. A lot of that history was brought up.

In fact Rocketplane had been one of the ones who had gone through this. The plus side was they had developed all this hardware. By weight they had 70 percent of the hardware, and that gave them a huge advantage from a material standpoint. Again, the technical stuff, you can do the math. The business case was actually the more difficult part.

HACKLER: The final selection between either RpK or one of the other six finalists was more or less a decision between their stronger technical case or the other company's stronger business case. What was the final tipping point for you in making that selection?

HOROWITZ: In order to be selected they had to be technically viable. That was the tipping point. They were technically viable, others were not technically viable. In other words they said, "We're going to go fly this widget and carry seven people." If I did the math and said, "There's no chance that you could possibly do that, because the math doesn't work out," then they were eliminated, because it didn't matter how good the business case was, if it wasn't going to work, it wasn't going to work.

HACKLER: If you have time for me to ask one more question—you said the FAA was a stakeholder in the selection process. Can you talk a little bit more about their role?

HOROWITZ: Because this is commercial—I've actually built an experimental airplane—it's regulated by the FAA. Everyone said well, this is commercial, so it'll be regulated by the FAA. The interesting thing is if you go look at the laws—it was just extended [2012 FAA reauthorization bill]—the FAA is in a really bad position. NASA is not a regulating authority. The FAA grants the licenses, just like when I build an experimental airplane, the FAA grants me a certificate. If I meet certain criteria I can get an airworthiness certificate for an airplane.

They were going to do the certificate to allow you to go fly in space. They actually approved the launches. When [ScaledComposites] SpaceShipOne [2004 Ansari X Prize winner] launched, they had to have the FAA state that Mojave could be a spaceport and they could come

back in out of the atmosphere and land back on the Earth. There's legislation that states FAA, you're the regulating authority, but you have absolutely no authority to enforce any standards on these providers until they kill somebody. It actually says that. It has been lobbied to get that legislation to allow these people to run whatever they want. Just like they didn't want NASA, they don't want the government to regulate them. They want to be self-regulated.

Some groups self-regulate. You have groups that get together and have conferences and share things and come up with their own internal codes of standards, technical groups. That can work in a mature industry. This is not a mature industry. They actually said, "We're the Wild West. We want to go do this commercially, and we can't possibly make any money if you overregulate us." It's the classic do you regulate a private industry, should you regulate the airlines, should you have FAA standards to dictate design standards and safety standards on commercial airplanes, should you have that for rockets and spacecraft?

Right now the answer is the FAA is responsible, but by law they're not allowed to do anything. In fact that was supposed to have expired in 2012. I think they got a several-year extension [to 2015]. Because by 2012 there'd be hundreds of these things flying, and thousands of people going to space. I'm still waiting. I don't envy the FAA's position, they're in a really bad spot.

HACKLER: Thank you.

WRIGHT: Any other thoughts?

HOROWITZ: The biggest thought I'll share with you—people have lost sight of what the original plan was. NASA was given a vision to go explore. It's something that NASA can do and nobody else can. We had tens of thousands of people with a lot of talent to go do that. It was going to be a pretty exciting time. I felt in order for commercial to be viable, actually NASA had to be viable, doing the next big thing, and then the commercial could keep filling in.

For example, to really make money—and I believe Dr. Griffin has written a paper on the subject, if you ever look it up—the real place to make money is the Moon. Commercial people sending commercial supplies to the Moon, it's like the Antarctic model. It was government-only to do the Antarctic bases, but now a lot of services are provided by commercial providers, and they make money at it. It's a pretty remote place and hard to get to, but commercially viable boats and planes can go do that.

As these people learned in low-Earth orbit—to send a pound to the Space Station is worth so many dollars, to send a pound to the Moon is worth a lot more. There's probably a better business case actually to go to the Moon, but that would mean you'd have to have a customer. International Space Station is a customer, but it's a pretty limited customer if you think about it. There's only three to six people up there at a time. They only use a few tons of supplies a year, that's it. The value of that is measured in hundreds of millions. If you were to actually be supporting an international group on the Moon or Mars, that's worth a hell of a lot more money commercially.

The other thing that's interesting, that I find, actually to be quite honest, annoying, is the definition of commercial. Commercial is I buy a commercial service and I pay you for that service. Somehow that's turned into I'll give you government money to develop the widget, and then you get to sell it to me at whatever price you want to. That's not commercial. But that's

what this has devolved into. The fact that it's devolved into that, and that now we have put the manned spaceflight program completely dependent on a completely unproven commercial industry is to me just foolhardy. The fact that the word safety is hardly ever even mentioned, I find actually quite sad.

WRIGHT: If I can share this with you very quickly; it is part of a press release that came from NASA Headquarters that said, "NASA initiatives like COTS are helping to develop a robust U.S. commercial space transportation industry with the goal of achieving safe, reliable and cost-effective transportation to and from the ISS and low-Earth orbit."

HOROWITZ: Bullshit. It's just bullshit. I'll tell you what it is, and it was told to me face-to-face by the person who's doing this. It's politics. In 2008 Lori [B.] Garver looked at me at a symposium, out at Stanford [University, Stanford, California], shortly after I left NASA—I'd never been at this thing before—and said, "When Hillary Clinton is elected President I'm going to cancel Constellation."

I said, "Why would you do that? One, you seem not to know very much about it. Two, what if you find it's actually meeting its goals, and has issues, but it's doing well?"

She looked at me and says, "You don't understand, it's politics."

This is all about taking money away from red states [Republican party strongholds] and sending it to people who support their political desires. It's that simple. Anybody who thinks it's anything else is full of themselves. I lived in [Washington] DC for about two and a half years. I couldn't wait to get out. Eight-mile-by-eight-mile square, referred to as a 64-square-mile logic-free zone.

WRIGHT: I remember you saying that before, and I thought that was pretty interesting.

HOROWITZ: It's absolutely true. If you try to think like myself and others who are rocket people, and people who understand operations and rockets and design and engineering and usually think in a fairly logical manner, you will not get it, because it doesn't work that way.

That statement is complete and utter horse pucky. There's no safety standards put on these people. It's not cost—100,000 bucks a pound? I'm sorry, I'm failing to see that. Part of the reason is the rockets are just too damn small to be cost-effective. You want to make money, build bigger rockets, build more of them, that ain't happening. Faster? We were supposed to do six flights in 2009. This is the second or third one in 2013. The $250 million of initial investment has now turned into $1 billion and growing. Just go add up all the milestones and additional milestones and all the other payments. It's complete nonsense.

Interesting point—when we flew Ares I-X, which flew right after I left, JSC went back and did a total cost analysis—full-cost accounting, government, all of our waste and all of our overhead. The number I saw was about $400 million to fly that flight. The cost to get to the first Falcon 9 flight was about $400 million. They flew two stages, we flew one stage and a simulated second stage. But we also flew something that was three to five times bigger, that was able to toss about 50,000 pounds to low-Earth orbit, not 10,000.

There's probably a reason they're only bringing up 1,200 pounds versus the 6,000 pounds that they say they can fly. If you look at the notes saying they can lift up like 60-some hundred pounds, then why are they only sending up 1,200 pounds? It's the math, and the physics don't lie.

WRIGHT: Thank you. I know we've kept you a few more minutes than what we should have, so thank you.

[End of interview]