NASA Johnson Space Center Oral History Project
Commercial Crew & Cargo Program Office
Oral History Transcript

Kurt D. Eberly and Michael R. Pinkston
Interviewed by Rebecca Wright
Dulles, Virginia – June 3, 2013

WRIGHT: Today is June 3rd, 2013. This oral history interview is being conducted with Mike Pinkston and Kurt Eberly at the Headquarters of the Orbital Sciences Corporation in Dulles, Virginia, for the Commercial Crew & Cargo Program Office history project. Interviewer is Rebecca Wright, with Rebecca Hackler.

Thank you very much for both of you being here. We know that you're key members of the Antares team, and we would like for you to help us understand more about the work that you've done. Kurt, if you would start, just give us a brief background on your time with Orbital and your involvement with the program.

EBERLY: I joined Orbital on September 16th, 1991. The day will live in history.

PINKSTON: It will now.

EBERLY: It was straight out of college. Antonio [L.] Elias, one of our Vice Presidents, was recruiting at MIT [Massachusetts Institute of Technology, Cambridge]. That's where I graduated from. I thought it sounded like a neat place to work, since they just showed a video of the Pegasus rocket having launched to orbit on its first try. I think that was the first commercially-developed rocket at the time.

I thought Orbital Sciences must be a pretty neat place to work, so I came on board in September of 1991 and worked Pegasus for probably eight or nine years, and ended up moving to Vandenberg Air Force Base [California] where we do a lot of our integration and launches for Pegasus. That's where we build up the rocket, and we actually take it around the world and launch it from different regions. Then I worked Minotaur, which is another one of our rockets, and then I got involved in the missile defense project, Ground-Based Midcourse Defense [GMD]. Actually, Mike and I worked on that for a number of years in the early 2000s.

Then I had a cushy job as a Systems Engineering Director, hiring and training and so on, supplying systems engineers to the various programs at Orbital. In 2007 I was tapped to help lead what was called the Taurus II rocket at the time. That was an idea that Orbital had, and we can talk more about that later certainly. April 2007 is when we started what was called the Taurus II project that became the Antares project, and we just had our first launch in April of 2013.

WRIGHT: That was a good day, wasn't it?

EBERLY: Sure was.

PINKSTON: That was a great day.

WRIGHT: Mike, could you share with us your background?

PINKSTON: Sure. I graduated from Oklahoma State [University, Stillwater] in the summer of 1987, and I started with a company called Space Data Corporation in Tempe, Arizona. That was a small company. I was attracted to Arizona to begin with, so that was prime reason number one, I wanted a job in Arizona. Then I toured on my interview and they were working on a couple of what I thought were cool Space Shuttle-type payloads so I thought, "I've got to jump into that."

I did some small pointing systems for the Space Shuttle, a lot of small rockets, and then around the [1988] timeframe Space Data was acquired by Orbital. So I consider myself an Orbital employee for my entire career, although I did start at a small predecessor company. I've been essentially in the same place my whole career, since 1987. The cool Shuttle payload that I saw when I did my interview, I actually ended up working on that one. Then another one after that, and then a couple of small rocket programs.

I ended up also for about a nine-month stint at Vandenberg Air Force Base working on Pegasus. That's where I first met Kurt, back in the early-to-mid-'90s. I worked Pegasus for a couple of years, then as chief engineer on the Minotaur I program, through the development of that product line. Then I got vectored over in 2000 to work the proposal effort for what became our GMD interceptor program, which again, I worked with Kurt for a long time on that. I worked the GMD program for a decade, actually more than a decade if you count the proposal. In 2004 I became the program manager, and then ran that program through the end of 2010.

I spent a couple of years working a targets program for Missile Defense Agency [in the Department of Defense], and then was tapped on the shoulder in the summer of last year and asked if I would be at all interested in taking over for the Antares Program Manager Brent [R.] Collins, who was retiring. In fact, they had coerced him into staying longer than he wanted to stay, and eventually Brent passed the baton in October of last year. I've been here ever since. That's it in a nutshell.

WRIGHT: That's a good nutshell. Let's go back to when you first learned about the COTS [Commercial Orbital Transportation Systems] development, and the partnership between Orbital and NASA for this venture. Can you tell us your thoughts, when you heard about how this was going to be possibly different from what you'd worked on before?

EBERLY: Yes. A little bit of background—Orbital had found somewhat of a niche market in developing national security spacecraft, because we build spacecraft as well as rockets. We had started launching several developing satellites quickly and launching them fairly cheaply on a Delta II rocket, which is a medium-class liquid rocket that's still in service, although it's being phased out. As it was being phased out, the writing was on the wall. The Air Force ended its support of Delta II because its mainstay was launching GPS [global positioning system] satellites, and they decided they were going to launch GPS satellites on EELVs [evolved expendable launch vehicles], larger rockets. It was pretty clear that Delta II was not going to stay in production.

The Orbital management was excited about this recent business, which was developing these low-cost national security spacecraft, and then launching them on this medium-class rocket. If that medium-class rocket went away, that market would no longer be there. The first idea for Taurus II was as a replacement for Delta II, so that we could continue this market. So it actually predated the COTS effort. We had done some studies internally within Orbital for years, around the 2005 timeframe.

Then, in January 2006, the COTS RFP [Request for Proposal] was issued. We were excited. This was a corollary market that would also help us to bring the resources to bear to develop this new launch vehicle. We submitted a whole proposal, and the spacecraft we were bidding at the time I believe used Russian proximity operations avionics. We thought that was a low-risk approach because it was up and running and the Russians already had automated rendezvous in place. And we were not selected. SpaceX [Space Exploration Technologies Corp.] and [Rocketplane] Kistler were selected by NASA later in 2006, so we just kept the Taurus II in study phase at that point. I think our CEO [chief executive officer, David W. Thompson] and our Board of Directors needed more assurance that there was going to be a strong market.

Then Kistler was terminated in October 2007, a year and a half later, and the funds that were remaining on the COTS program from Kistler were re-competed. It was a new RFP that was issued, so we were very excited to have an opportunity to have a second go at it. We think that part of the reason we weren't selected was we had the Russian docking hardware, although that was never really explicitly stated in the RFP documentation.

So we were careful this time to have a different approach for our spacecraft, and we elected to go with the Japanese proximity operations avionics which were built by Mitsubishi Electric Corporation, the same rendezvous approach system that the [Japan Aerospace Exploration Agency] HTV [H-II Transfer vehicle] uses right now. We tried to present a very reasonable approach to building the rocket and building the spacecraft, drawing on heritage from our other launch vehicles.

Also, because it's a much bigger rocket than we have typically flown on Pegasus or Minotaur or Taurus, we decided to go with a liquid first stage, which is typical for rockets of this class. We decided to hire a Ukrainian company, Yuzhnoye [Design Bureau], and their sister company, Yuzhmash [A.M. Makarov Yuzhny Machine-Building Plant], to build the first stage core, the tanks, and the pressurization system. We think that that brought a lot of heritage from the Zenit rocket program.

The upper stack—we decided to go with a solid rocket motor, which is very similar to how we launched a lot of our other rockets. We buy solid rocket motors from ATK [Alliant Techsystems, Inc.] and we put Orbital avionics on them. We analyze it, we do all the software, we do all the structures, and we do all the integration work. From the first stage up it was very similar to past rockets that we had done. That's the rocket.

On the spacecraft we planned to use a bipropellant propulsion system that was very similar to a lot of the large geosynchronous spacecraft that we build and market commercially. We hired Thales Alenia Space in Italy, who are the makers of the MPLM [Multi-Purpose Logistics Module] which used to fly inside the Shuttle as a logistics carrier. We hired them to do that same basic job for Cygnus. We think that pulling on that heritage from these suppliers that had done this kind of work before presented an attractive proposal, in terms of low risk to NASA, and that we'd be able to execute the development.

We were selected in February of 2008, so that really gave our CEO and the Board the impetus to move ahead with this project. We [Taurus II group] were funded starting in April of 2007, so roughly a year prior we had started the first phase of development under internal research and development funds. That's Orbital funds. The COTS award, which at the time was just one single launch of the rocket and the spacecraft that were going to demonstrate that capability to go to the [International] Space Station [ISS]—winning that assistance in the development and that purchase of a single demonstration mission gave the assurance that we needed to our CEO and our Board to free up additional funds to fund through to the first launch. That was a really big step.

I think that's the crux of the COTS and the CRS [Commercial Resupply Services] development paradigm. The government says, "We're going to promise that if you develop it, here's a little bit of money to help you," but certainly it's not going to cover everything or even half. "If you then put in the rest of the money and get all the way through development, we will buy X number of launches from you." In the case of the first COTS award, it was just one single launch of an Antares rocket and a Cygnus spacecraft.

The government caps their risk by saying, "We'll pay you by milestones. When you get to PDR [Preliminary Design Review], we might pay you some money. If you do a certain development test that retires risk, you test-fire the first stage, we'll pay you a little bit more money," and so on. And the same with the spacecraft. They limit their risk and their exposure to the commercial development, because what if we ran into problems or we had cost overruns? That's all on the contractor to cover those kinds of cost overruns, and the government is able to limit their risk, their exposure, for the development.

That's really what's new about the COTS Space Act Agreement method of developing new hardware. I think given the amount of money that's been invested in COTS—I think it's about $800 million between SpaceX and Orbital, and the amount that was wasted on Kistler—for $800 million you get two new launch vehicles available to NASA, two new maneuvering spacecraft capable of rendezvous with the Space Station, and two new launch pads that are available for launches to the Space Station, on two different launch ranges. I think that that's an amazing success story for the government, in terms of developing two new systems that are pretty complicated and have some stringent requirements.

WRIGHT: And different. In contrast to what SpaceX chose for their route, your route was one that you thought was low-risk, wrapping in the international collaboration with their proven heritage components.

EBERLY: Yes, that's right. We definitely have a different approach. We tend to subcontract out more of our systems, and I think SpaceX tends to try to do everything in-house that they possibly can. There are certain things we do in-house, avionics and harnessing and software and guidance, but we typically will go out of house for a lot of our big subsystems.

WRIGHT: NASA provided some of the funding. What other aspects do you feel that NASA contributed to the development of the Antares?

EBERLY: They made available expertise in certain technological areas that are very hard to get. We had a problem with the AJ-26 engines that we selected for the first stage. They're the original Soviet moon rocket engines that were built for the Soviet moon rocket, the N-1, and they were placed in storage when that program was cancelled. They were built in the '70s, so they've been in storage for a long time and they have materials on them that are susceptible to stress corrosion cracking. It was not known to us that this was the case, nor to the vendor, Aerojet.

Aerojet purchased these from a Russian supplier in the '90s, and they had about 40 of them in Sacramento [California] that they sold to us as the AJ-26 configuration for Antares. This fundamental flaw in the materials—they were never designed to be in storage that long—was found in an early development test where we fired the engine at [NASA] Stennis [Space Center, Mississippi].

The expertise that NASA brought to bear on those engines, they really helped us through the process to where we can now identify the defects in this material. We can screen it out, we can do weld repair, and then have a flightworthy engine after that process. NASA brought their Marshall Space Flight Center [Huntsville, Alabama] materials expertise and lab to bear. I think it was essential to bring all that history that they have working with cracked metals on other vehicles. They certainly have a lot of experience and a lot of lab equipment that's very costly and expensive. They're able to really step in and quickly analyze the materials and buttress the claims of Orbital and Aerojet, and help us through the process of developing the weld repair process and the inspection process that assures us that the engines are going to be flightworthy when we fly them.

WRIGHT: Did you sense a partnership of working with NASA personnel?

EBERLY: Yes, absolutely. Our strategy was to be completely open with them and treat them as investment partners, which was how they wanted to be treated. The COTS office itself was very small, it was really just two or three people. When they wanted to provide this help, they had to reach out to the various Centers where the expertise resides. It's not like they had a whole program that was just managing us.

We kept them informed every step of the way, and we still do. Anything they want to see, we show it to them. I think there's only about one meeting that they've ever requested to attend that we've said that we'd rather have that internal. We've tried to keep them fully informed of our progress, every step of the way. In return, they've come forward and when they hear a problem they say, "Hey, we know of this expertise, it resides here. Can we apply it for you?" They will pay through some funds that they have available for risk reduction, risk management, and they funded the support to us in most cases where it's development work.

There's also another example where we had an issue about contamination, particles in the propellant storage tanks on the core, and whether that presented a risk to the rocket engines in terms of an unintentional ignition. We use liquid oxygen as the oxidizer, and so metal particles can strike another metal surface in the engine and create a spark, and cause an ignition. There's an expert at [NASA] White Sands [Test Facility, New Mexico], Joel [M.] Stoltzfus, who we asked to help us. He came in and they funded him.

He brought some test data that really only he is going to have. They've done these studies, firing metal particles at various angles against a metal plate in a LOX [liquid oxygen]-rich environment and seeing if an ignition occurs. That kind of work is painstaking, it's hazardous, and it's difficult and expensive. He was able to bring that experience which had been developed for many other programs, including Shuttle, this database of knowledge. That was really helpful to us to get past that issue and get through the first launch. That's a couple of examples of the things that they've helped us out with.

In terms of Stennis, we needed a place to do the acceptance testing of these engines and practice. The great thing about a liquid rocket is you can fire them as an acceptance test before you launch your rocket, and then turn them off and clean them up and fly them. You have a very good assurance that they're working properly, as opposed to a solid rocket motor, where you just ignite them once and there's no way to shut them off. We were looking for a test stand for our engine. So there we were a commercial user on a NASA Center. If there was a commercial liquid rocket engine test stand somewhere we could have gone there, but it turns out that these are some of the specialized facilities that are very hard to find in the commercial world. You can't really go down to Joe's Rocket Test Stand Services and hire them.

That's where we came in as a commercial user. We had a Space Act Agreement directly with them, a separate reimbursable Space Act Agreement, where we paid them. Instead of the COTS one where NASA was paying us, this was a different one where we were paying Stennis, and still do. We go down there with an engine and we pay their time and materials. We've gotten a lot of support from Stennis. We pay the direct costs that we incur, but they bring this history of testing rocket engines and configuring the test stand, and getting the propellants to flow correctly to the engine so you don't have any issues. They reconfigured the test stand from a horizontal to a vertical configuration, and they put the instrumentation in them. That's the kind of stuff that we're able to tap into those decades of experience.

PINKSTON: Comparing the cost of duplicating that capability ourselves, it's just an enormous advantage.

WRIGHT: And the delay of finding someplace that's readily available.

EBERLY: Right.

PINKSTON: The other area where NASA's really helped out is in the development of the fueling facility. That was another area where, as I was coming onto the program last year, we ran into some significant challenges with getting that facility operational. Both in terms of people, and material that NASA had in inventory as residual that they were able to provide to us. There were a number of examples we can provide where people and hardware and expertise were all brought to the table and helped us over that obviously critical hurdle in terms of getting the facility up so that we could get into the integrated testing late last year.

WRIGHT: And this was at MARS [Mid-Atlantic Regional Spaceport, Wallops, Virginia], is that what you're referring to?

PINKSTON: Yes, that's exactly right.

WRIGHT: Would y'all talk about that part of the partnership? Because it's not just a partnership with NASA, but now you've got another very vital part of Orbital's future there.

EBERLY: Sure. MARS is the Mid-Atlantic Regional Spaceport. It's primarily [the state of] Virginia that's the major funder, but they do coordinate with Maryland. Wallops Flight Facility is part of [NASA] Goddard Space Flight Center, which is in [Greenbelt] Maryland, and the good Senator from Maryland, Barbara [A.] Mikulski, is a big supporter of NASA. She's on the appropriation committee that deals with the NASA budget. Goddard is in her district, so she's taken a really keen interest in the project—COTS in general—and she's a big supporter of commercial space, in particular Wallops and Goddard. She helped to make sure that the project was supported properly politically, and that's been a big benefit.

The spaceport has been supported by Virginia, and it had been a part of Virginia since I think the mid-'90s. We've done some commercial Pegasus launches out of there before. They provided the launch pad for the Minotaur [rocket], and we launched four or five Minotaurs prior to this year off of Pad 0-B. But it only had about four or five employees, and they'd never done anything this big. Really, this was a big step up for them to grow their capability to have a launch pad. The idea was that they had bonding authority, so they could issue bonds on the behalf of this project and raise the funds to help offset the total cost, and we would contribute funds as well.

The idea was to build something akin to an airport, where they would build the airport and operate it, and then you'd have root users like airlines come in and say, "I want to do a launch and I'll pay you a user fee, an occupancy fee." That's the idea, and the benefit to Virginia is that economic benefit of bringing programs and users to the Commonwealth of Virginia. The [Virginia] Economic Development [Partnership], under the Governor's control, also helped to sway the decision to come to Wallops Island and to MARS.

We had a decision that we had set up between Cape Canaveral in Florida—Space Florida was a state organization that was trying to entice us to come there, and MARS was the equivalent for Virginia. Ultimately Virginia won out for a number of reasons, including they just had a better plan with the bonding authority to raise funds to get the project done, and we're located in Virginia and we thought the proximity was a little better. Plus, Cape Canaveral, the Eastern Range tends to get a little crowded sometimes with the EELV launches going out of there. The thought was that we'd have a clearer launch schedule going out of Wallops, and be able to launch when we really wanted to and when NASA wanted us to. For those reasons we chose to go to MARS.

Having said that, they razed the old Pad 0-A, where the first and only Conestoga rocket had been launched. They took it down and then we built it up, brand-new. The project has been quite extensive. Certainly was a bigger and more complex and more difficult project than any of us had entertained. There's just a lot of complexity with what's called a liquid fuel farm, which is the storage tanks full of equipment, full of liquid and gas, that you have to load into the vehicle to get it to fly right. Getting that all supplied to the vehicle at the right cleanliness levels and temperatures and pressures and flow rates is very, very challenging. That's something we certainly underestimated as a company.

We're through it now, with a lot of help from Virginia, from NASA, from Wallops. [NASA] Kennedy [Space Flight Center, Florida] sent folks up, NASA Stennis—all through JSC, helping us out by giving us additional resources. They really came through for us. We're done, it works, it worked great for the last launch, and we have a lot more knowledge now of what it takes to get one of these medium-class liquid vehicles launched.

WRIGHT: Tell us about the magic day in April [first Antares test flight].

EBERLY: April 21st, 2013.

PINKSTON: The day that shall live in infamy.

EBERLY: It was our third attempt to launch the test flight. The first attempt, we had gotten very close but we had an umbilical prematurely disconnect. That shut us down for that day, but we solved that problem pretty quickly. That was on a Wednesday. We went again on Saturday, but the winds were very strong at altitude, and they were in a very unusual direction. The way we had planned for the rocket to fly resulted in the potential for debris in the event of a destruct action, which you always have to account for. It could have ended up on Assateague Island, which was populated with some people.

We had to call an abort for that Saturday, much to everyone's disappointment, although I was a little bit relieved that we weren't going to try to launch with such unusually strong winds. The first launch of a new rocket, you're relying so much on models of how it's going to behave once it lifts off. You think you know how it's going to behave, but you could be wrong about certain aspects of the guidance constants or the autopilot parameters. It might be a little bit less stable than you thought, and an extra wind gust or two could make a difference in terms of success or failure.

First launches of new rockets have a fairly poor success rate if you look historically across the fleet in the U.S., or even internationally. So it was very tense. The next day, on Sunday, it was predicted to be calm and it was. A really good wind situation, and we just ticked right down through the countdown. Got down to inside of three minutes, and that's when we start our auto sequencer. Everything looked great on the data. The pad had been supplying propellants very repeatably in the last two attempts to the vehicle, so we were all in the control room, had the screens up with the various shots.

I think we all had our favorite view that we wanted to see dialed in on the TV camera, and it was just great to finally—we had done a stage one development test prior, called the 7000 test, where we practice fired the first stage on the launch pad. We had gotten down to half a second before ignition and had an automated abort. We fixed that timing issue, and when we got counting down I was thinking, "Oh my gosh, I hope this thing doesn't abort." I saw the counter coming down, and I just turned my attention to the TV screen and I was so happy to see flames coming out of the flame trench.

There really weren't as many flames as I thought, and this is the first time we really had everything up and running to lift off. We had a lot of water—you may have seen the large water tank that's adjacent to the pad, and that was to supply cooling water to the pad. It really mitigated a lot of the flames. As it lifted off, we do a maneuver that Antonio [L.] Elias called the [Paul] Baumgartner Maneuver [named for the Lead Guidance, Navigation, and Control Engineer on Antares], where you've got this transporter erector launcher that's rocked back.

You don't want the flames to toast that thing because you want to save it for the next launch, so first you kick the attitude this way [demonstrates], and then the rocket goes that way, and the flames never really impact the transporter erector launcher. We thought, "The magnitude's like a degree or two, you're never going to see it on the video," but I think everyone saw it and it was very exciting to see that happen.

PINKSTON: It was not exciting, it was scary.

EBERLY: It was scary. The other thing I really noticed was that it was so slow in lifting off. Compared to a solid rocket motor powered vehicle, it's so slow coming off the pad. It just seems to take forever. Then I calmed down. As soon as it got away I thought, "This thing is flying straight and looks great." It was 235 seconds of the first stage burn, and that's a long, long time that these rocket engines—which we've had problems with. We had the cracks, we had the test failures. We'd done our homework, but you can never be sure that everything's going to work properly together. All the dynamics involved when you lift off, the vibrations and the aerodynamic model of flying through the air and so on.

But it was just perfect. Got through the first stage burn, burned out, separated the stages. By then I think we thought we were kind of home free. People were clapping in the control room when the first stage burned out and then MECO [main engine cut-off] was announced, and then that separation—everyone clapped spontaneously. You're supposed to hold your fire until the payload is separated successfully in orbit, but I think everyone's so relieved that that part of the mission was done that they couldn't resist. It was a happy day.

And all the data review after the flight has shown that it was really just flawless in terms of the execution. The models that we were so worried about—the slosh model on the first stage, the thrust frame bending model, the autopilot design—everything was so spot on. It really shows that we have taken the A-Team from within Orbital. We really had our best people up and down the line and in every position. This is a very important project for Orbital Sciences, so we were able to get those people applied to this project, and show that we really nailed the data that we've reviewed. We just had our final data review, two days of data review, last week to our customer.

WRIGHT: Yes, I had read that once you reviewed the data it really was as good as you thought it was.

PINKSTON: Yes. I'll just tack on a couple of things to what Kurt said. He mentioned the modeling aspect, and that's always a huge source of uncertainty in a first flight. I think a large reason why the first flight's success rate, if you look across the history of launch vehicles—depends on the bar you set based on what you expect in a recurring launch program—it's not very good. You multiply that for this one for us, it being our first large liquid rocket, and a real eye opener to me is just how much more complex and particular the guidance and control of the first stage is in a large, lumbering liquid rocket.

We were very conservative in the wind constraints we set, both to avoid banging the rocket into the launcher, as well as some of the upper level winds, both of which caused us to abort on Saturday. It also caused us to wave off even an attempt on the Friday before that. To go through that first flight and to go through the data and see everything really lined up in spades with what the models were predicting—it was really satisfying I think for the whole team.

A lot of folks worked a long time on this program, and I think frankly that's another area where having some independent expertise on the NASA side—I heard nothing but rave reviews of the independent verification that was done on our guidance and control system that NASA had provided. It really bolstered our confidence going in, and I think the results bore out just how critical that help was to us, in terms of getting it right the first time.

WRIGHT: Can you give us some examples about the things that you learned through the testing? You mentioned the firing test and the cold test, the different phases that you went through that you were able to learn what you needed to know.

PINKSTON: It started all the way back last spring, early summer timeframe, when we had just started doing some of the initial testing of the fueling facility itself. We learned a number of things in that process, a lot of lessons learned. There were a lot of headaches that had to be worked off. We actually found one of the key subsystems, the chilled helium subsystem, was not coming close to meeting our requirements. That is a very notable area where NASA was able to come through. They found a residual heat exchanger that they had laying in that bone yard somewhere that we were able to bring out between that 7000 test and the first test flight. We cut that in and fixed that problem for good. You learn how to get the facility to flow commodities.

When we first brought the test article up, which is essentially a full-up first stage with some elements of the flight avionics on it to make it do what it needs to do to load propellants and fire the engines, some of the initial tests there were disappointing in the results. When you start seeing the interaction of pressurization valves on the core and how they affect the fueling facility, we had a number of problems there that we had to work our way through.

We got to the point where we were confident that we could operate the system without blowing relief valves on the facility side, and then we got into what was called the 5000 series testing, which was a set of incremental tests where we started with loading liquid oxygen on. Then we advanced to a full load of liquid oxygen and some chilled helium, and the third test was when they'll actually put kerosene and the full load of chilled helium on it as well. You kind of work your way into it.

You've got three specific tests before the hot fire, and we had to run each of those tests twice. Each time we learned something. I don't think I remember a case—after the initial bringing out of the system, I don't think we ever had a problem with actually getting commodities on or off the vehicle. But we found all kinds of other things—timing interactions between the loading system and the flight system. They're both software-driven systems, and you find little timing idiosyncrasies that abort you out at the wrong time.

Each of those tests we learned something. We learned something important and we folded in a change, folded in the change and then got to the hot fire event. First attempt at that, as Kurt said, we aborted out at somewhere close to half a second before the engines fired. It's just devastating. You've been working to get that close, but we figured out what went wrong and we fixed it and tried again, and that test was great. We got a lot of really good data off of that hot fire test.

Another pretty amazing thing, to me anyway, is that we had almost to the day two months between the 7K [7000] hot fire test and the actual test flight launch. We did the hot fire on February 22nd, and we did the launch on April 21st. In that two months we completely refurbished the pad after the hot fire test. In the hot fire test itself we measured lots of environment instrumentation on the first stage and the first stage components, and we found some things exceeded our expectations.

We had to go back and re-qualify some components, got the test article off the pad, and another little quirk is that we're actually going to reuse all that hardware. There's some on-pad cleaning operations and servicing that we had to do that was significantly hampered by weather. We were able to get all that done, test article off, get the pad refurbished, re-qualify components that need to be re-qualified, reviewed all the data, went through all the requisite reviews in a two month time period. It's really quite amazing to me that we were able to sweep through it.

WRIGHT: Busy.

PINKSTON: It was extremely busy. I think the short answer to all of that is we just learned a ton. I mean, from the time a year ago when we first started testing the facility, through the 5K testing and the 7K testing, to the test flight—it was just a constant acquisition of knowledge that allowed us to really trim up the operation. Again, I think the results of the test flight showed how well that worked.

WRIGHT: Take us now from April 21st to the next upcoming demonstration flight.

PINKSTON: We've got a lot of hardware, so that's not a huge problem for us. I'll say that over the course of the first third of the year we were pretty squarely focused on 7K and the test mission. So we did get ourselves a little bit behind on processing the rocket for the COTS demonstration mission. We were trying to hit a June date, which would have been another close to two month turnaround. One of the things everybody was quite concerned with was how does the pad come through a launch operation? If you look at the condition of the launch pad after the test mission flight, it was really in outstanding condition compared to what it could have been, so the refurbishment of the pad is going to be fairly straightforward.

There are some changes we need to make, there's always a few lessons learned. Pieces that fly off of things that shouldn't, that need to be secured a little better. We burned up some cables that we wish we hadn't, so we're off repairing those and replacing a few. I think all in all we're going to have a pad that's ready by the mid-to-late-July timeframe. That's good. The rocket, we made a tough decision to actually replace an engine.

As Kurt mentioned previously, these are aged engines and the one that we had out there for the next flight, there's a minor defect. We worked with Aerojet and the original Russian manufacturer, and they've all given us a clean bill of health on it. We had some residual questions that just hadn't quite been answered, so we made the decision to go ahead and push that down the line a little bit and give ourselves more time, just to make sure we're absolutely certain we understood the conditions and not carry any extra risk that we weren't ready to carry.

I think very soon we'll get past that. We made the decision almost a month ago to go ahead and swap that engine out. That delayed us into probably a mid-to-late August readiness for the COTS demo, and there's a conflict at this point with the Space Station. I think there's an HTV mission that's currently slated in early August. That's still not completely shaken out, but that probably pushes us into a launch that's late August, early September by the time everything shakes out.

But I think we're making good progress. Short form, I think the pad came through in really good shape. We'll get it turned around and it'll be ready late July. We made the decision to swap the engine, and that put probably another four weeks of risk into our schedule. That pushed us out into late August, mid-to-late August. We were probably looking at a mid-to-late July readiness before that, and with the HTV mission right there it was likely we weren't going to have the window that early anyway.

WRIGHT: Who would have thought, got to take a ticket. Rebecca, do want to ask some questions?

HACKLER: Sure. You mentioned that last week you had the two-day review. Can you talk a little bit more about not only that milestone, but how you worked with NASA in general to verify that you had met all the requirements for milestones. Did those require any negotiation to ensure those were completed and you could get your payment?

EBERLY: I would say, as we've talked about, we've been very open with our counterparts—Bruce [A.] Manners, Kevin [M.] Meehan, and Alan [J.] Lindenmoyer—at the COTS office, and they've brought in additional expertise as needed. The Space Act Agreement was written in 2008, and here we are launching in 2013. Back in 2008, before the rocket or the spacecraft were even developed you had to write down, "Here's the milestones we're going to achieve and here's the payments that are going to go with it."

The criteria are listed in the Space Act Agreement, which is akin to a contract. We purposefully, on both sides, kept things a little vague in terms of what were going to be the criteria. As we got closer to each milestone we would sit down with Bruce and his team, and usually they would take the lead and say, "Based on all we know about your rocket, here's what we expect." A good example was stage one assembly completion.

It sounds pretty easy, the first stage should be done, but there are certain parts that don't get put on the first stage until you're ready to launch. Ordinances that are hooked up, and pivots are not removed, so there's some things that seem pretty obvious, but nonetheless you have to work your way through and get everyone to understand, the first stage is semi-complete. We've got the rocket engines, the thrust ring, the stage one core. We've put them together and we've tested them. These other parts that don't go on until later, we agree they're part of the first stage, and they aren't normally installed at the time, but we'll make sure that they're accounted for and that we have them in our possession.

We worked out a process where they came to Wallops and in essence did a physical configuration audit where they walked down to the vehicle, took pictures, and then we showed them all the build documentation. We have a pretty complete set of build paperwork, just as part of our normal process for each part. It's tested properly, it's got the right pedigree, it's the right part number and so on. Then we show all that and deliver that to NASA, give them a copy. It's not a contract deliverable per se, but it's the supporting documentation that helps them know that we've met the milestone.

I think they had some oversight from the GAO [Government Accountability Office] and from some of the members of Congress that were feeling like, "Oh, these Space Act Agreements are a little loosey goosey and they allow the contractors to get paid when the government can go at risk." I think they were feeling a little heat from their management, from [NASA] HQ [Headquarters, Washington, D.C.] and from GAO.

They had been audited, which I think is fine and we supported their audits. As we came to understand it, it was good for us to supply them with this kind of documentary evidence of completion of the milestones because it helped them have an audit trail. It helped the program stay supported, and to answer the critics that were trying to say that this was a boondoggle of some kind for the commercial space industry.

I think they were reasonable. Once we explained to them, "This is what we can show you for this particular milestone," we may have had a little back-and-forth, but we came to an agreement pretty quickly. There's never really been a dispute about whether we met a milestone or not. We never go to them and say we're done when we're not, and they know that because we keep them informed. A lot of the milestones are pretty objective, and so it's pretty clear when they're complete.

Speaking of milestones, we did add in the augmentation funds. When we started the project it was really just the one launch of the rocket, and as I said earlier, the first launches of a new rocket don't have a great track record. The thought was, "We don't have money for a dedicated test flight, so we're just going to have to put the first operational Cygnus on top of the first operational Antares and launch it, and hope that we succeed and get all the demonstration milestones completed that would allow us to proceed on with the cargo delivery flights next."

I think SpaceX started out with roughly $100 million more of the COTS money to begin with, and then there was some decrement from what Kistler spent. We started a little bit in the hole, so we couldn't fit in the multiple test flights that they had proposed. Everyone agreed, both on the NASA side and the Orbital side, that having a dedicated test flight of just the rocket before you put this high-value, first of its kind Cygnus spacecraft on board would make a lot of sense and retire a lot of risk from the program.

When funds were made available [in fiscal year 2011], I think we were in complete agreement between us and NASA. The first priority would be a test flight of the Antares, and then the construction and launch of a dummy Cygnus. It basically had the same mass properties and shape, but was heavily instrumented so they could measure the environments that the real Cygnus would see, very precisely, on the ascent, because the rocket launch is the most astringent environment that a spacecraft will see in its lifetime.

That was all very successful. We collected a lot of data from the Cygnus mass simulator that was flown on the [Antares] test flight, and I think we're very happy that we've retired a lot of risk from this dedicated test flight. I think that was a really key move for the program, to be able to fit that in.

HACKLER: As you progress through your development, because you are doing rocket science, which is called rocket science for a reason, there were some milestone slips and development fell behind the original projected schedules. How did you address those schedule delays?

EBERLY: We had a weekly telecon [telephone conference], we gave scheduled updates, we had a monthly scheduled working group at the JSC, and we presented our best estimate of the schedule going forward. When we added in the test flight we agreed to delay the first launch by some amount, I think from December [2012] to March of the following year. We were waiting for the pad to be complete, and we also had the trouble with the rocket engines that we had to resolve, so that really set us back.

We just tried to keep NASA informed every step of the way, and with our best estimate of where we thought the schedule was going to end up. We were wrong many times, in terms of how long we thought it was going to take for both of those things to be resolved. To their credit, they were patient. I think the additional Shuttle flight that they got approved [STS-135] that carried up the last MPLM that was chock-full of supplies—and I think they left it attached to the Space Station—that bought them more time, in terms of needing the logistics train to start coming down the pike. That was lucky for us, that they were in a position where they actually didn't need the cargo as early as had been projected back in 2008.

HACKLER: You also worked a lot with the ISS Program Office, coordinating their safety concerns and scheduling. Can you talk a little bit about your relationship with that group of folks?

EBERLY: Have you talked to the Cygnus folks already?

HACKLER: No, we haven't.

EBERLY: I think that's who you should talk to because the IRD [Interface Requirements Document] is really between Cygnus and the ISS. Cygnus takes those safety requirements and flows them down to Antares. We don't really have to interface with the ISS at all. We drop off Cygnus well below the Station, so there's no collision hazard, there's no risk of any kind of problem. Then Cygnus, once we separate, they maneuver up and do the rendezvous. So it's really on them to do all their really intricate fault isolation and safety requirements that you have to meet in order to be able to approach the ISS safely. That's really not in the rocket's job jar.

In terms of the scheduling, for the test flight we weren't going to the ISS so we didn't have to deal with that. As Mike mentioned, we have a slot in September and we have a slot in December, and so we are trying very hard to make sure we meet those. We understand how crowded the schedule is with all the visiting vehicles, having the right crews there with the right training.

PINKSTON: It's a whole lot of moving parts.

EBERLY: Yes. We're starting to really appreciate the difficulty of the scheduling process for all the ISS partners and users.

HACKLER: Do you work with the FAA [Federal Aviation Administration] Office of Commercial Space Transportation for the launch licensing?

EBERLY: That's right, exactly. That was in the Space Act, that we would be commercially licensed to launch, and the CRS contract says the same thing. We're responsible for all that regulatory work, so we have a licensing lead. We've done a number of commercial launches within our company, mainly on Pegasus, where we get the commercial license. We've actually done a commercially-licensed launch from Spain, we took the Pegasus over there. So we're familiar with how to do all that and stay on the right side of the ITAR [International Traffic in Arms Regulations] rules.

That's worked pretty well; the FAA has been pretty easy to work with. The only thing I'll say is there's sometimes a disconnect between the requirements that the FAA has and the requirements of the launch range, and it's just disappointing that they're not in sync because they really need to be. My understanding is that the ranges can change their regulations more quickly than the FAA can change their laws, and that's why there's that disconnect at times. But I think they've gone pretty smoothly. They mostly defer to the range safety folks for all the flight safety and ground safety stuff, and the FAA folks are really in monitor mode.

HACKLER: I was thinking as you were talking about your backgrounds and your years of experience on other projects at Orbital, that you had a [knowledge] base you were ready to apply to this new project. Are there any specific areas you can think of where that helped?

EBERLY: That's right, yes. I think within Orbital Sciences and the launch systems group that we've worked in for our careers, we have become adept at flying new configurations of rockets because we try to use all the same hard stuff. That is the navigator that senses your position and your attitude, the flight computer that interfaces with it and runs the autopilot and keeps the rocket flying in the right direction, and the guidance that then sequences all the separation events and the ordinance events. That set of avionics, and the software that links them all together is done already because we fly it on all of our other rockets. We really, really try to make a common implementation of the avionics and the software and the guidance, which can really take forever. If you didn't already have that and have the analytical tools to go and test it and verify that it's working right, that can take a long time.

So we were able to adapt that over from other vehicles that we built. A lot of the targets that we've talked about for missile defense, a lot of them are one-off configurations. They're trying to do a test of a radar, but they want a rocket that flies like this and it has this aspect angle and this speed and this velocity and this radar cross section. You end up taking strategic motors that they've got in storage somewhere from a discontinued ICBM [Intercontinental Ballistic Missile] program, and put together a new vehicle that has three stages.

We constantly have to analyze the environments that are going to be induced by a new configuration. What are the loads, what's the aerodynamics, and where does the autopilot need to be? I think that has served us very well. "This rocket flies slow, it's got a very regular aerodynamic shape, it's only got two stages"—that kind of expertise and experience, and the analytical tools we're able to bring along really paid off for us I think.

PINKSTON: Just an example from my history—I talked you through what I've done from the Pegasus program, the Minotaur I program, the GMD program, and the IRBM [Intermediate-Range Ballistic Missile] target program that I've worked have all used the same basic set of hardware. The same rocket motors, with little tweaks and twists here and there, same avionics. They evolve over time, with obsolescence and added capability, but basically the same set of avionics—the same navigator, the same cold gas attitude control system components. You build an experience base with that set of hardware that's just invaluable. I come over to this program and I look at it, and, "Hey, gee!"

It's a hell of a lot bigger around, and it's taller, so our structures are bigger, but all the stuff inside is the same. On that upper stack is a new rocket motor, it's a bigger structure, but everything else in there is stuff that we've done before. I don't think there's any substitute for building that kind of historical, heritage-based understanding of what you're applying. As Kurt said, all you've got to do at that point is figure out what environment it's going to see and make sure it doesn't exceed any of our qualification levels.

The real new thing on this was the first stage. I think our history has always been finding the best pieces of stuff that exist today, and I think we did that with the first stage. You've got the Zenit heritage on the core, you've got these AJ-26 engines. While they're old, we know they work. At least they did back then.

EBERLY: And they're already built.

PINKSTON: And they're already built. You don't have to develop it, you don't have all this qualification to do. It's simply adapting, and that's really how we've done business for years.

EBERLY: I guess you could say we tend to be in a systems integrator role. We're the integrator. We buy the parts, we know what the parts need to do. We do the interfaces, we do the analytical work, the simulations. Zenit and Yuzhnoye really came through in terms of analyzing the parts. We didn't know anything about liquid oxygen in a tank, how much boils off and how much pressure is created in the space that's not filled with liquid. That's what they have expertise at, how to keep that pressurized to keep the engines happy with enough propellant so there's no cavitation in the pumps.

They really came through for us, and that's an area that we've learned a lot from them. They brought their expertise that we really didn't have in-house to Orbital. We had never done this before. The upper stack—after that clapping after the first stage separated, that was our bread and butter for Orbital to fly the rest of the way. I think we were able to effectively bring in these outside suppliers with significant heritage.

PINKSTON: Still help us through the first stage.

EBERLY: They got us through the first stage, that's right.

HACKLER: Just a question out of curiosity—you mentioned it was originally called the Taurus II. Why was the name changed?

EBERLY: I think Taurus II was a study name that we had back in '06, and we just kept it. We had almost changed it a couple times, and it originally was going to look more like a Taurus, which is kind of a smaller solid rocket motor vehicle. Originally this was going to have a smaller core, a three meter core and some strap-on solids, so it was sort of like a Taurus. We did a trade study, and did away with the solid rocket motor strap-on boosters and went with the 3.9-meter core, which is bigger, and just have one configuration as our decision. So it really started to look less and less like a Taurus.

One of the purposes for calling it Taurus II was we thought the first launch of this rocket was going to come from Vandenberg Air Force Base. They knew Taurus, and we thought that we'd have a better time of it with the range safety folks if we called it Taurus II because they would know instantly, "Oh, it's Orbital Sciences and it's the same guys. We can approve their systems more readily." It turns out we haven't been to Vandenberg, and we may not ever go to Vandenberg to launch this thing. So all the reasons for keeping it fell away, and our then CEO really thought this needed its own name. Operationally we thought, "If I don't change the name now—." Once you do a launch, you can never change it. That's really when he decided to do it.

HACKLER: The last question I have before I turn it back over to Rebecca Wright—one of the goals of the COTS program is to encourage the space transportation industry, not just for NASA's purposes, but the broader commercial sector. What other future uses of this new vehicle that you've developed are you looking at?

EBERLY: We really want to launch spacecraft, provide a commercial launch service to the government, as we do with our vehicles. Mainly to the government, but also to commercial users. We want to launch spacecraft into low-Earth orbit, or geosynchronous, or to Earth escape. We have on-ramped this vehicle to the NASA Launch Services contract, which is a commercial procurement vehicle. It's for the government, but you do procurement, you get an FAA launch license, and so on. In that sense it's commercial. We've also done the same with the Air Force contract, the OSP-3, Orbital/Suborbital Program-3 contract.

Both of those are IDIQ, indefinite delivery, indefinite quantity-type ordering schemes for the government. Basically, you get onto an approved supplier list, and then when they have a mission that they want to launch they issue a Request for Proposal, and you come in with your best price. We've already gone through the process of writing a long proposal, detailing all the services that you'll provide, and you have a statement of work. Now it's just down to bidding. You can't win one of those contracts until your first launch. Now that COTS has given us our first demonstration launch, we can use that to bid on future spacecraft launches for the Air Force and for NASA. That's a direct benefit.

We also launched four secondaries on that test flight, and on these next launches we hope to line up more secondary payloads to go fly along and help us out a little bit. On the Orb-3 Mission, which will be our fifth launch, there's some extra capacity just for a contractual reason. We're flying an enhanced-capability rocket with a standard-capability Cygnus, just because NASA ISS wanted certain features on that Cygnus, dual-berth visiting vehicle features that allow two visiting vehicles to be berthed at the same time. For unrelated reasons we have some extra performance on that mission, so we're trying to use that up with a larger secondary payload.

HACKLER: Thank you.

WRIGHT: Was there anything else that y'all would like to add that we haven't covered? Anything about CRS?

EBERLY: We want to get past this development. We want to see Cygnus fly successfully and berth with the Station, and that'll be the last of the demonstrations. Then it's just on to supplying a regular cargo delivery service. It's going to be interesting to see that, and we just hope to be a regular supplier, like space FedEx [Corporation, shipping service]. Just show up every now and then with some cargo for the astronauts on schedule. That's going to be our goal, to really make sure that we can meet the dates going forward, now that we're done with development on the ground side and the rocket side.

That's the challenge that Mike and I have, to productionize this program and make sure our subs [subcontractors] are delivering hardware that's flightworthy on schedule, and we can get our operations efficient enough that we can meet all these dates so we're not having to ask for any more delays. That's painful for everyone, and certainly the customer. That's what the next phase is going to be for CRS, providing that regular service to the Space Station. We're excited to be part of that and part of keeping the astronauts working on the ISS.

PINKSTON: I think the whole idea of commercial resupply, it's an exciting direction that it's going, shipping some of this away from big government programs to commercial suppliers. Being on the front end of that, you figure that's a trend that's going to go for a long time. Just the way budgets are and will be going forward, being on the front end of that trend is exciting.

We're squarely focused on getting the COTS demonstration done. I think back to since I've been on the program, all the significant development milestones we've clicked off over the course of the last seven, eight months, it's pretty astounding. We've got one more giant step to take with the COTS demo, and then it really is on to making this a regular and repeatable service that we can provide when it's required. FedEx of the Space Station, and we're glad to do it.

EBERLY: I think to that point, NASA took some risk with this procurement. They didn't have the money to do a typical procurement where they would write down every requirement and a long spec [specification] on how you should design your rocket. Instead they gave us performance requirements. "Deliver this cargo in the end, and we'll open the door for you at the ISS." They still have to prescribe the safety requirements, and that's what Cygnus has to do, but in terms of Antares there were no requirements that weren't internally derived by us or by the range that we had to go to.

NASA really could oversee us with an office of three people, and they could bring in expertise as they needed. If you think about that and the money they spent and the way they capped their risk, it was a really successful way to develop a new aerospace system from the government's perspective. From our perspective, we'll see. We're still trying to dig out of the hole that we're in. We try to stay out of sight of our CEO still, but he'll get over it when we get a few more launches going.

I think that's the benefit. The aerospace industry is mature enough to the point where you can say, "Go do this, deliver something in orbit. I don't have to tell you how to do it because industry already knows how to do it." I think that's been proven to be the case for SpaceX and for Orbital.

WRIGHT: We thank you both for your time and for all your great information. We wish you great luck and we can't wait until the end of summer when we see the demonstration launch.

PINKSTON: Thank you.

EBERLY: Thank you.

[End of Interview]