# NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
# COMMERCIAL CREW & CARGO PROGRAM OFFICE
# ORAL HISTORY TRANSCRIPT

DAVID W. THOMPSON
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is June 3, 2013. This oral history interview is being conducted with David Thompson at the Headquarters of the Orbital Sciences Corporation in Dulles, Virginia for Commercial Crew & Cargo Program Office History Project. Interviewer is Rebecca Wright, assisted by Rebecca Hackler. Mr. Thompson is the founder, Chairman, CEO [Chief Executive Officer], and President of Orbital.

Thanks again for taking time out of your schedule. We appreciate you sitting down and talking with us about the COTS [Commercial Orbital Transportation Services] program. We'd like for you to start by providing us with just a brief background of how you started the Orbital Sciences Corporation, and how you got involved with the COTS program at NASA.

THOMPSON: Good morning, Rebecca. Orbital was founded in 1982 by two friends and me. The idea for the company went back four or five years earlier than that, to the late 1970s. I don't think there was a specific day that I could point to where the idea emerged fully formed, but I was thinking about at least some of the fragments of the idea back in 1977 or '78, when I was either in graduate school or working at the [NASA] Marshall Space Flight Center [Huntsville, Alabama] as a young engineer.

There were a couple of other developments taking place in the space industry about that time that informed some of my thinking. Probably the one that was most relevant was a German

company that was started about 1976. Their name translated into English as Orbital Transport and Rockets, Incorporated. The German abbreviation was OTRAG [Orbital Transport und Raketen AG].

I believe that was really the first time that there was a serious startup effort made to create a new company that was going to focus on space transportation. It was written up in *Aviation Week* [*& Space Technology* magazine], and I remember reading about it as a graduate student and thinking, "That's kind of interesting." Probably about 1978 the idea occurred to me that it would be fun to have a rocket company. Now in those days there weren't very many, in fact there were almost no precedents that one could look at. It's not like saying, "It would be nice to start a hardware store." You could see hardware stores existed. You may or may not be successful if you wanted to create a hardware store, but at least there was ample evidence that it was possible to do. This was not true for rocket companies.

In 1980 another kind of proof emerged when the Europeans formed Arianespace [SA] to market and operate the Ariane family of rockets. All these things eventually converged after I had left NASA, went to business school, and met a couple of other guys that had some similar interests. We ended up doing a study for NASA in late 1980 and early 1981 to try to identify nontraditional customers that might make use of the Space Shuttle, which was approaching its first flight about that time.

The emphasis in this was on materials, research, and manufacturing in the low gravity or microgravity environment, low-[Earth] orbit. Although we couldn't add a lot to the understanding of what it would take to get that kind of industrial application off the ground, we did decide that there were some niche opportunities, in particular in regard to transfer vehicles that could be used in conjunction with the Space Shuttle to boost satellites into higher energy

orbits than those that the Shuttle itself could reach. And that one day, we would like to perhaps start a company to design and build such things.

The three of us graduated from business school in 1981. We didn't immediately start a company, but after staying in touch and corresponding on the ideas over the course of about a year, we finally decided in the spring of 1982 to start Orbital. The initial project that we were going to undertake was to design, build, and market a Space Shuttle-based transfer vehicle for boosting commercial satellites into geostationary orbit. That's how the company came about.

WRIGHT: What were your hopes at that time? What were your expectations as you were entering that field?

THOMPSON: The original idea for the company was limited to launch systems, and other launch-related products. Our aspirations were limited, simply to starting a company that could raise enough capital to overcome the financial barriers to entry that existed in the industry, and to assemble a sufficiently knowledgeable and credible team that could actually implement the project so that customers would feel comfortable in buying a fairly expensive product from a small company, entrusting their satellites to the performance of that product. The early years were all focused around developing a single product and getting it through testing and into production, and building up a base of initial customers to use that product. That consumed pretty much all of our energy and our capital for the first three to four years of the company's development.

A little less than four years after the company was started we had substantially completed development of that first product. We were working on some designs for a second, related

product. We had had some success in winning orders from one of the commercial communication satellite builders on the one hand, and from NASA itself on the other hand for a limited initial production run of these vehicles.

In January of 1986 the Space Shuttle *Challenger* [STS 51-L] accident occurred, and that really changed the whole market environment for our product. For a few years things were very uncertain, and we had to—more quickly than we otherwise would've done so—broaden our product line. In a way that turned out to be a good thing. It forced us to really rethink the company's basic strategy such that by the late 1980s we had shifted our focus to probably a more informed, and maybe a little more sophisticated strategy, that we've pretty much pursued for the last 25 years.

We focus on developing and building small- and medium-class satellites and launch vehicles, which initially served somewhat limited niche markets, but those markets have grown, in general, faster than the industry as a whole. Then we try to compete in those areas on the basis of being able to develop and build systems on shorter schedules and for lower costs than most of our competitors are able to. That's how we evolved during our first six or eight years in business, back through the end of the 1980s.

WRIGHT: How did you first hear about NASA's intention to move toward these commercial partnerships, and what was your interest when you learned about that?

THOMPSON: Going back to the earliest days of our company, in the period 1982 through 1984, there was a major initiative that NASA undertook to enter into a variety of nontraditional partnerships with American companies. We benefited from that, and many other companies also

participated in a range of projects that covered everything from advancing the technology of commercial satellite communications and broadcasting systems, to in-orbit platforms for research and other applications. Some of those ultimately succeeded and others fell by the wayside, but there was a flurry of early cooperative ventures in the 1980s between NASA and private companies.

Fast forward to about 10 years ago, sometime around 2003 or 2004—the International Space Station had not been completed but it was pretty clear that it was on a path to completion. We had a permanent human presence in space beginning in 2000. It occurred to us, even before NASA announced the COTS program, that there might be a business opportunity in providing logistics services for cargo and other forms of delivery to and return from the Space Station. We started working, probably in 2003, on some early concepts to do that.

It was around 2005 that NASA announced that it was going to enter into one or more cooperative research and development programs under what became the COTS initiative. There was a large group of companies that were interested in that, and many submitted proposals in late 2005, for what ultimately turned out to be two major Space Act Agreements. Our proposal was not one of the ones selected at that time.

We ended up working with one of the companies that was selected, Rocketplane Kistler—I think it was mostly during 2007—to see if we could help them implement their proposed approach to Space Station cargo delivery. It eventually became clear to us that there was a mismatch between the ambitions they had and the capital that was likely to be available to them. Not long after we parted ways with them, they had pretty much exhausted their ability to keep going and NASA had to terminate that cooperative agreement and re-solicit interest in a second COTS partnership.

We made a proposal on that in late 2007, and were selected in early 2008 to implement this approach, which was different than the one that we had proposed a couple of years earlier. There were certain aspects of that original approach that we changed, given feedback from NASA as to what they liked and what they didn't like. The new launch vehicle that we were proposing to develop was a constant between the two, but the spacecraft approach to delivering the cargo changed between the first and second proposals. By February of 2008 we had signed a cooperative research and development agreement that took the form of a Space Act Agreement, and off we went.

WRIGHT: And you're still going.

THOMPSON: That's right. We hope to complete the remaining work under the COTS agreement at the end of the summer, probably in either August or September.

WRIGHT: In your approach, you chose to develop only Capabilities A and B, for [unpressurized and pressurized] cargo [delivery and disposal]. Can you share with us why your company chose not to pursue the option to do return cargo, as well as the possible crew option?

THOMPSON: Yes. Our view was based on balancing the expected investment that we would have to make, over and above the funding that NASA was providing, with the anticipated near- and mid-term demand for logistics support to the Space Station. Basically we concluded that returning intact cargo was not likely to be a large part of the overall traffic model, and the

incremental cost of implementing that was high enough that we probably wouldn't see a good return on that incremental investment.

We also concluded that human transportation was an even more difficult undertaking, and would be something that we could pursue in the future but we didn't want to commit to doing in the beginning. In our proposed approach we focused on delivering both pressurized and unpressurized cargo, and disposing of unneeded things from the Space Station with the same system, but not actually returning intact cargo or sending up crew members.

WRIGHT: Another decision that your company made was to use more of an international collaboration for its spacecraft. Could you share the philosophy of pulling these proven systems together, and why you went that way instead of creating a whole new venture?

THOMPSON: The approach we took in regards to both the launch vehicle and the spacecraft portions of our COTS system reflected the general model that we've used for a long time in developing a range of other spacecraft and launch vehicle products. We have a supply base that, although it is primarily domestic, there are certain cases where we buy components or subsystems from non-U.S. suppliers when we think they provide the best products in their class.

In the case of our COTS spacecraft, which we call Cygnus, we found an example of that for the Pressurized Cargo Module in Thales Alenia [Space], which is based in Italy. That portion of Thales has, over the last 25 or 30 years, designed and built a pretty wide array of human-rated, pressurized modules that have been used in a variety of programs, starting with SpaceLab back in the late '70s, that was accommodated on a variety of Shuttle missions. Then with the commercial venture SpaceHab [Inc.] in the '80s and '90s, they built that hardware.

On the European side, they contributed pretty much all of the non-U.S., non-Russian pressurized modules on the International Space Station. Since human-rated spacecraft represent a new challenge for us, we thought in that area—which was the pressurized module that for perhaps weeks at a time would be an integral part of the Space Station—we wanted to work with a supplier that had a lot of prior experience. They've done a very good job for us.

Otherwise on the spacecraft—although we do have some international components, for instance we use parts of the same proximity communication systems that JAXA [Japan Aerospace Exploration Agency] has developed for the HTV [H-II Transfer Vehicle]—otherwise most of the components on the spacecraft follow our existing supply chain practices for a variety of other satellites.

On the launch vehicle side it was a little different story. We saw an opportunity for fairly low-cost development and production of the first stage of our new Antares rocket by working with Yuzhnoye [Design Bureau], which is based in Ukraine. They have designed, and together with their manufacturing affiliate, Yuzhmash [A.M. Makarov Yuzhny Machine-Building Plant], manufactured the launch vehicle tanks and structures that are used in a variety of non-U.S. rockets, most prominently the Zenit [rocket] system that has both a ground-launched as well as a sea-launched variant. The design of our system evolved to the point that it could be built using a lot of the same design approaches, and the tooling and test equipment that they already had in place for the Zenit program, which would save money. That worked out well too.

The other major international component of our launch vehicle is the first stage rocket engines. On the current version of Antares we use two AJ-26 engines that we buy directly from Aerojet in the U.S. But in turn Aerojet, in the past, purchased what are called NK-33 engines from a Russian engine builder called Kuznetsov [Design Bureau], sometimes referred to as

SNTK. They're one of the two main rocket engine builders in Russia, and have produced engines for the Soyuz rocket and others since the 1950s. That worked out a little less easily than we expected. One of the two big development challenges that we encountered centered around the main engines, which we really had to struggle with from mid-2010 through mid-2012, during that two-year period.

WRIGHT: Another partnership that you developed as part of this overall program is with the Mid-Atlantic Regional Spaceport [MARS]. Would you explain to us why Orbital felt that was a value to not only this project, but also to your future projects, to become part of that?

THOMPSON: The Wallops Island [Virginia] launch site is one that Orbital has used for 20 years or so for a variety of smaller rockets. Back in 2008, when we were embarking on the development of the Antares vehicle—which is a bigger, medium-class launch vehicle, bigger than things we had done before—we were seeking an anchor customer commitment to buy the first set of production units. It turned out that the COTS agreement and the follow-on CRS [Commercial Resupply Services] contract provided that initial demand.

It was clear that the first launch site that we needed to establish was one that would allow us to reach a mid-inclination orbit, because that's where the Space Station operates. That in turn quickly narrowed the options to either Wallops Island on the coast of Virginia, or Cape Canaveral at the [NASA] Kennedy Space Center in Florida.

We had a competition between the commercial operators at both sites, MARS in the case of Virginia, and Space Florida in the case of Cape Canaveral. They both made good proposals, but we ultimately selected Wallops because, at the time, the business proposal that they put

forward was viewed as somewhat better than the proposal that Space Florida made. There were some other factors that gave advantages to one or the other that tended to about balance out. We probably could've made either site work, but we ended up selecting Wallops Island on the basis of what was viewed as a lower investment cost to us to develop that site.

Now it turned out, in retrospect, that both Orbital and MARS seriously underestimated the difficulty of creating, sort of from a green field, a brand new, medium-class launch complex of a type that could handle a vehicle like Antares. In fact, the cost came in about three times higher than the original estimate that MARS made, and it took about two years longer than the original schedule that had been proposed.

As a result, we ended up having to advance a substantial amount of funding to the state of Virginia. Because it operates on a two-year budget, by 2010 it had exhausted the initial commitment that we all thought was going to be adequate to fund the infrastructure development. To keep the project on track from mid-2010 to mid-2012, Orbital advanced about $45 million in funding to MARS. Had we not done that, the work would've either stopped or slowed down, and we still would be waiting for the launch base to be ready.

NASA also contributed to developing some of the facilities that we use there, particularly the vehicle assembly building, which is on a modest scale functionally equivalent to the VAB [Vehicle Assembly Building] at the Cape. It's much smaller. NASA did a good job bringing their part of the infrastructure online, on time, in 2011. The real difficulty was in the launch pad and the associated liquid fueling and pressurization systems. That just ended up being much more difficult than we originally expected.

Fortunately, we stuck with it and supplemented the MARS team with a sizeable group of Orbital engineers who went down to Wallops Island in 2011 and helped MARS and its contractors push through the final work that was substantially completed in the fall of last year.

WRIGHT: I understand that part of the COTS program overall was to help companies that may need additional expertise to develop this new spacecraft. Can you share with us the relationship that Orbital had with NASA? Especially the Project Executive, Bruce [A.] Manners. Do you feel like Orbital has benefited from expertise coming from the NASA partnership?

THOMPSON: Yes, it's been a different kind of relationship than what we've typically had with NASA in more traditional contracts, where we design and build a science satellite or produce an existing commercial launch vehicle for a NASA mission. In this case, NASA was pretty responsive to the needs we had for specialized technical know-how that we generally didn't have, as it related to either human rating our system, or in the case of the launch vehicle and the launch complex, to equipment or expertise that was beyond things that we had experienced in the past.

For instance, we had a problem that came up about this time last year, in the summer of 2012. It was a piece of equipment in the launch complex itself, which is used to chill the liquid oxygen that is the oxidizer on our launch vehicle, and also liquid helium that we use in pressurization of certain launch vehicle systems to a super-cold level. Colder than just the normal boiling point of, say, oxygen. The cooler we had purchased just wasn't efficient enough, and NASA was able to find a used model, I think from [NASA] Stennis [Space Center,

Mississippi]. They got that up to us and sent a small team along with it to help us install it and check it out, and that worked out really well.

There were numerous other cases where, beyond the program office and its engineering support at JSC, that other parts of NASA helped. The Marshall Space Flight Center, the Stennis Center, and Kennedy Space Center all contributed. Of course, the launch complex itself at Wallops was implemented by the guys there [NASA Wallops Flight Facility]. We had roughly half of the field center network within the Agency at one time or another, providing know-how or surplus equipment to our work, which made a big difference.

WRIGHT: It seems like this has been more of a partnership.

THOMPSON: Yes, it was. The management team within the COTS program office in Houston was also very helpful in helping us work through various kinds of problems that came up. I think they set the tone. It's been a great relationship now for five years.

WRIGHT: Rebecca, do you want to ask a couple questions?

HACKLER: Sure. Following up on the progression of the COTS work, the COTS budget was augmented for fiscal year '11, and you were able to add some additional milestones for risk reduction. Can you talk a little bit about that process? Not only the milestones you added, but also how you found out about the funding and decided how to apply it.

THOMPSON: Yes, okay. I'm not sure I remember exactly how we found out about it. Within our agreement, the effect was to increase the funding available to NASA to apply to our Space Act Agreement from about $180 million—which is where it started back in 2008—to about $290 million. It was an increase of about $110 million. Those are not exact figures, but probably accurate to the nearest $5 million.

In our case, the primary use of those additional funds was to pay for a test flight of the new Antares rocket, which was not part of the original COTS program. Originally, because NASA's funding was limited to about $180 million we didn't think there was enough government or private money available to do a test flight of the rocket prior to the demonstration flight to the Space Station, so we were going to do all of that at once. The first flight of the rocket was also going to be the first flight of the Cygnus spacecraft, and the first time we went all the way to the Space Station.

When the additional funds became available in fiscal year 2011, the logical thing for us to do was to distribute the risk a little bit and take care of the launch vehicle first flight separately. Our view then, and now, was that the highest risk of our approach really was related to developing and demonstrating the design of a new medium-class rocket, so we applied virtually all of the funds to the test flight that we carried out back in April of this year.

Now that the COTS work has nearly been completed, the final tallies of investments are roughly as follows. NASA invested approximately $350 million in our COTS agreement and related activities. The $350 million is the sum of $290 million that we received under the COTS Space Act Agreement, and my estimate of about another $60 million in facilities and technical support across those various centers over a five year period. So we received, on average, $10 or

$12 million a year of in-kind support and facility construction, principally at Wallops. That isn't dedicated to just what we're doing, but we are the first user of those facilities.

So NASA put in, over a five-plus-year period, about $350 million. Orbital has invested about $580 million over that same period, and MARS, the Virginia state agency that runs the commercial spaceport at Wallops, has invested about $70 million. The sum of those, within $10 million either way, is just about an even billion dollars. That's been over about a six-year period.

HACKLER: Since we're talking about the finances—as you are very aware, rocket development is very risky and a very high-cost venture. You talked about Rocketplane Kistler and their Space Act Agreement being terminated because they didn't have enough financing. Going back to the beginning of your business, how did you manage to find investors and customers, and get the financing to get this startup venture going?

THOMPSON: That was probably the biggest single problem that we had to solve. It was, I think, the most important reason why the concept of a private rocket company back in the late '70s and early '80s was so novel. Then, as now, the amount of capital required to carry out research and development, and to construct facilities, and to buy production equipment to actually create a new launch vehicle—it takes a lot of capital. Given the industry structure that existed then—and it hasn't fundamentally changed today—where there aren't hundreds of customers, there are dozens of customers for such systems. The risk that a customer takes to its either business or government programs by launching a satellite on a relatively new rocket from a brand new supplier is pretty high. It's a tough problem.

Orbital used just about every form of financing that was available during the ’80s and ’90s. We quickly exhausted the capacity of seed capital and traditional venture capital sources, which in those days viewed $10 million as a pretty large venture investment. That would not be the case today, with both a bigger venture capital sector and with the inflation of 30 years. Ten million dollars of venture capital in the early ’80s was a lot of venture capital to go into a company.

We also relied on a financing structure known as a research and development [R&D] limited partnership. In fact, in 1983 and 1984 we used what was, up to that time, one of the largest R&D limited partnerships that had ever been done to fund most of the development work on our first product. But even that wasn’t enough, so we used some vendor financing, and a limited amount of debt financing. As a private company without much of a track record, bank debt was pretty much unavailable, but in the late ’80s as we built up a contract backlog and some assets that could secure the debt, we were able to tap the debt markets to a limited degree.

By 1990, as we had gone some distance towards the R&D funding of our second major product, the Pegasus rocket, we went public. We needed to broaden our access to capital, and private sources were pretty well tapped out. Following an IPO [Initial Public Offering] in 1990, we did several follow-on public offerings in ’91 and ’93. Then a variety of other financings later on in the second half of the 1990s, when high-yield debt was accessible to the company and widely available.

Over the course of our first 20 years in business, we raised about a billion and a quarter dollars in capital from these different sources. Fortunately, over the last 10 years we haven’t had to raise any new capital, which is a whole lot better position to be in. One of the big barriers to

entry for new space-related companies is—probably not a billion dollars, but to do anything meaningful is a couple hundred million dollars, as a threshold of entrance to this sector.

HACKLER: Thirty years later, you're still around. That's pretty impressive.

THOMPSON: We had a lot of smart and dedicated people, and we also had more good luck than bad. I don't want to underestimate the importance of good fortune.

HACKLER: In the course of the COTS competition, what sort of questions did NASA ask about your financing? What sort of discussions or negotiations took place?

THOMPSON: Rebecca, I don't remember much about that. I know you're going to talk a little later to Antonio [L.] Elias, who was more directly involved. To some extent, NASA was maybe a little more sensitive to that because of the problems that they'd had earlier with Rocketplane Kistler. When we were proposing in late 2007 and selected in early 2008, we had a couple hundred million dollars of cash on our balance sheet. We were generating an annual free cash flow of, depending on the year, say $60 to $80 million, and we had untapped bank credit lines of $150 million more.

So there's no question that we had the financial resources to do the project, even though the project turned out to cost a fair amount more than we originally thought. It hasn't suffered at all from lack of capital, we've funded all the things that needed to be done. It's had an adverse impact over the last couple of years on our free cash flow, but we expected that would be the case.

The company still has a couple hundred million dollars of cash. We would've had more had we not done this, but on the other hand, having done it, we've now got a new medium-class launch vehicle, together with a site to launch it from, and a new spacecraft in our product line that together should generate a good bit of growth for the company over the next few decades.

Launch vehicles in particular have a pretty long life cycle. One of the challenging things is that they're hard to develop and they're expensive to develop. One of the good things is that if you can develop them and get them into reliable service, the product cycle from that point on can easily be 25 years, maybe longer. We're in the late phase of the investment period, and hopefully in a year or two we'll be in the early years of the return period.

HACKLER: Part of that return is through the Commercial Resupply Services contract administered by the ISS [International Space Station] Program Office. One thing I'm curious about—the Round 2 COTS competition and the CRS contract award took place within a very close time period. Were you already planning on submitting a proposal for the CRS contract before the COTS Round 2 competition came up? How did you keep those two competitions separate?

THOMPSON: The proposal for the second round of COTS went in late 2007, and the selection was made in February of 2008. Then it was about eight or nine months later, in the fall of 2008, that the proposals went in on the CRS program. The selections there were made right at the end of the year, late December 2008. So they were fairly close in time, separated by less than a year.

We had the expectation that there would be an opportunity to take what we were developing under the COTS program and apply it to an operational program at the time we did

the COTS work. But I don't think CRS, at that point, had been completely defined in terms of its duration or the magnitude of cargo delivery. It was defined pretty soon thereafter, so in bidding COTS we anticipated—without complete definition of what CRS was going to be—that there would be an opportunity almost right away for the first operational use of the system.

HACKLER: The last question I have before I turn it back over to Rebecca Wright—you've had some sort of relationship with NASA from the very beginning of this venture. How has that relationship evolved and changed over the past few decades?

THOMPSON: Our NASA business in 2013—it probably won't be an all-time high, because if we go way back there were probably years where it was more than this—but it'll be at a peak, at least of the last 10 or 15 years, in terms of the percentage of our business that derives from work for NASA. Either directly, in contracts like CRS, or indirectly, in scientific satellites that we build for other institutions that NASA funds.

We do quite a bit of work in the science programs that NASA implements through principal investigators at universities and research labs—as well as NASA Centers, but more often than not at universities or affiliated research labs—where they're the prime contractors and we are a major subcontractor in building a scientific spacecraft. This year about 15 percent of our total revenue will come from work we do directly or indirectly in the NASA science programs across all of the major areas: astrophysics, heliophysics, Earth science, and planetary exploration. And about 25 percent will come from the human spaceflight activities of NASA, most of that revolving around COTS and CRS. The sum of the two, about 40 percent of our business, will come directly or indirectly from NASA.

That's a little higher percentage than what we've typically seen. Probably the average of the last 10 years is more like 30 to 35 [percent] of our business has been with NASA. This year 25 percent of our business will be with commercial satellite operators, and the other remaining 35 percent will be with defense and other national security customers.

NASA was one of our first two customers back in the mid-1980s, pre-*Challenger*, and there were years in the late '80s where NASA was probably 80 percent of our revenue. There were years in the '90s where it was probably 20 percent of our revenue, so now we're somewhere in the middle at about 40 percent. But on a more diverse set of programs, from Space Station logistics to small astrophysics satellites.

The relationship varies depending on the nature of the product we're selling and how direct the connection might be. If we're selling an astrophysics satellite to MIT [Massachusetts Institute of Technology, Cambridge], which in turn is implementing an exoplanet mission for NASA, we're one step removed. If, on the other hand, we're doing the CRS program for Johnson, we're in a direct relationship. In some cases, if we're selling a rocket—for instance later this month one of our Pegasus rockets will launch a solar physics satellite for NASA—that relationship is a direct contract between KSC and Orbital. Back three or four months ago, one of the satellites we built for [NASA] Goddard Space Flight Center [Greenbelt, Maryland], Landsat 8, was launched. That was another case of a direct relationship.

Those latter examples tend to be relatively mature products. The Pegasus launch vehicle made its first launch 23 years ago, and this will be its 45$^{th}$ launch coming up. It's a fairly mature product, and the nature of the relationship reflects that. It's a fairly standard product, and it's purchased on a fixed-price basis and sold more or less the same way we'd sell it to any other customer, whether it's a government agency or a private satellite operator. Some of the other

systems that we're building are the first of their kind, so the contracts reflect that, and the amount of technical interaction tends to be more frequent.

On CRS it's been a bit of a new experience on both sides. On the one hand, the CRS program is structured fundamentally as a service NASA is purchasing for cargo delivery, as opposed to a product they're buying. They're doing that on a fixed-price basis, which normally implies a lower level of interaction. But at the same time, the service is delivered through a system that has to be human-rated and will become part of the Space Station for extended periods, so it has to meet many of the human safety standards that NASA uses for any kind of activity involving astronauts. I think that's actually worked fairly smoothly because we had the predecessor work on COTS that paved the way to how that was all going to work.

We have 14 or 15 active programs with NASA today, maybe more than that. We run the scientific sounding rocket program for NASA, which is a pretty active program. We launch a sounding research rocket for either an internal scientist or an external researcher every couple weeks. We launch small-class rockets a couple times a year. We build—more right now, and for the last 10 years—probably more scientific satellites for the agency than any other outside company. And now we're involved in the Space Station Program, so it's a pretty wide array of things that we do for NASA.

HACKLER: How is it different working with the COTS team under a Space Act Agreement, as opposed to some of your other contractor arrangements?

THOMPSON: In the case of COTS, it's fundamentally our responsibility to define how the system is going to operate and to set the technical standards for how it's going to be designed, built, and

tested, subject to the safety constraints that are imposed for any vehicle approaching or operating in conjunction with the Space Station. We have a lot more autonomy to make technical decisions than we might ordinarily have if we were building a satellite that at the end of the contract was going to be delivered to NASA for NASA to operate for 10 years.

On the other hand, the expertise that exists in human spaceflight is primarily within NASA, so we have often found ourselves—I gave a couple examples earlier, and there are others that could be cited—asking for NASA's advice or assistance in a number of matters. The technical interaction has probably been about as intense as it would be in a traditional relationship, but NASA has been more of an advisor than in a position to mandate a certain design choice—as long as we're operating within the safety standards that exist.

It's been different, but I think it's been a good relationship. We'd recommend its use in future activities where the circumstances are aligned. It probably isn't going to be the right thing to do in all cases, but in general the Space Act Agreement approach as it relates to COTS has been a successful one from our standpoint. NASA has leveraged its investment by roughly a factor of two. The $350 million that NASA invested resulted in a total investment of about a billion dollars, so almost a two-to-one leverage.

What NASA and Orbital, and our customers in the future have obtained from all this is not only a system that can supply the Space Station, but also, in the separate elements, a new medium-class launch vehicle that can be used by both commercial and government satellites; a world-class launch complex at Wallops Island, way beyond what was there before; and a new spacecraft that can be the basis of not just cargo delivery to the Space Station, but things like satellite servicing in the future. Many of the technical capabilities required to rendezvous with and operate in close proximity to the Station are the same ones that you would need if you

wanted to rendezvous with and carry out some level of servicing of either a commercial or a government satellite. So I think it's been a pretty effective mechanism for NASA to get those new products.

WRIGHT: Thank you for your time. We know you're busy, and we appreciate you finding time for us this morning.

THOMPSON: You bet. I hope this is helpful.

HACKLER: Thank you, very much so.

[End of interview]