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NASA'S COMMERCIAL CARGO PROVIDERS: ARE THEY READY TO SUPPLY THE SPACE STATION IN THE POST–SHUTTLE ERA?

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

THURSDAY, MAY 26, 2011

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NASA'S COMMERCIAL CARGO PROVIDERS: ARE THEY READY TO SUPPLY THE SPACE STATION IN THE POST–SHUTTLE ERA?

THURSDAY, MAY 26, 2011

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Steve Palazzo [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
CHAIRMAN

EDDIE BERNICE JOHNSON, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
www.science.house.gov

Subcommittee Space and Aeronautics

NASA's Commercial Cargo Providers: Are They Ready to Supply the Space Station in the Post-Shuttle Era?

Thursday, May 26, 2011
10:00 a.m.-12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Mr. William H. Gerstenmaier
Associate Administrator, Space Operations Mission Directorate,
National Aeronautics and Space Administration

Ms. Cristina Chaplain
Director, Acquisition and Sourcing Management,
U.S. Government Accountability Office

Ms. Gwynne Shotwell
President, Space Exploration Technologies

Mr. Frank Culbertson, Jr
Senior Vice President and Deputy General Manager, Advanced Programs Group,
Orbital Sciences Corporation

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NASA's Commercial Cargo Providers; Are They Ready to Supply the Space Station in the Post-Shuttle Era?

Thursday, May 26, 2011
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Introduction

The last Space Shuttle mission is scheduled for the 8th of July. After that, how will NASA supply, maintain, and utilize the multi-billion dollar International Space Station (ISS)?

NASA plans to rely on new commercial launch service providers to supplement the international partners. NASA has spent $500 million since 2005 on the Commercial Orbital Transportation Services (COTS) program, intended to demonstrate commercial cargo delivery capabilities to the International Space Station (ISS) from two commercial partners, Space Exploration Technologies (SpaceX) and Orbital Science Corporation (Orbital). Despite initial assurances that NASA would not expend any money to buy services until these systems were fully demonstrated, NASA has spent over $466 million toward the purchase of cargo delivery services even though no demonstration flights to the ISS have been performed. Furthermore, last year NASA requested an additional $312 million "augmentation" (a 62 percent increase above initial COTS estimates) to reduce risk and improve the schedule. To date NASA has spent over $1.25 Billion on the Commercial Cargo effort without accomplishing a demonstration to the ISS. Questions for Congress include; 1) when will these systems be ready, 2) how much additional work, time, and money will be required to make the systems operational, and 3) where will the money come from?

Past Expenditures, Commercial Cargo FY2005 – FY2011[1]

$'s in Millions	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*Total*
Commercial Orbital Transportation Services (COTS)	$22.8	$101.2	$41.2	$130.7	$153.0	$39.0	$12.0	$500.0
Cargo Augmentation							$288.0†	$288.0
Commercial Resupply Services (CRS) [a]					$87.6	$231.0	$147.7	$466.3
Total	**$22.8**	**$101.2**	**$41.2**	**$130.7**	**$240.6**	**$270.0**	**$447.7**	**$1,254.3**

† Includes $20 million paid for CRS services [a] Included in amounts shown below

Projected Expenditures, Commercial Cargo (FY2011 – FY2016)

FY 2012 Budget Request $'s in Millions	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Total*
Commercial Resupply Services (CRS)	$516.5	$795.4	$801.3	$964.6	$998.5	$1,043.5	**$5,119.8**

[1] Phasing of the CRS funding reflects information provided by NASA subsequent to the original publishing date.

Witnesses

Mr. William H. Gerstenmaier, Associate Administrator, Space Operations Mission Directorate, National Aeronautics and Space Administration;

Ms. Cristina Chaplain, Director, Acquisition and Sourcing Management, Government Accountability Office

Ms. Gwynne Shotwell, President, Space Exploration Technologies

Mr. Frank L. Culbertson, Jr., Senior Vice President and Deputy General Manager, Advanced Programs Group, Orbital Sciences Corporation

Background

In the NASA Authorization Act of 2005 (§505, P.L. 109-155) Congress directed the agency to, *"...ensure that the International Space Station can have available, if needed, sufficient logistics and on-orbit capabilities to support any potential period during which the Space Shuttle or its follow-on crew and cargo systems are unavailable, and can have available, if needed, sufficient surge delivery capability or prepositioning of spares and other supplies needed to accommodate any such hiatus."*

Congress directed NASA to develop a contingency plan to ensure that vital equipment and supplies could be delivered to the ISS in case the Space Shuttle or an international partner's crew and cargo capability was unavailable. NASA's 2006 Strategic Plan established a goal of supporting a crew of six astronauts on the space station by the end of 2009 using 1) the Space Shuttle until its retirement; 2) vehicles developed by international partners; and 3) new commercial cargo service providers. In March 2006 *NASA's International Space Station Contingency Plan* proposed a two-phase development plan for the Commercial Orbital Transportation Services (COTS).

At that time the NASA-developed Constellation system (consisting then of the Ares 1 crew launch vehicle, Orion crew capsule, and Ares 5 heavy lift launch vehicle), was anticipated to be the government replacement for the Space Shuttle, expected to retire in 2010. The Ares launcher and Orion spacecraft could provide assured back-up for commercial cargo services. NASA's FY2009 budget request stated, *"It [Orion] will be capable of ferrying up to six astronauts (plus additional cargo) to and from the International Space Station if commercial transport services are unavailable."* The assumption that the Ares 1 and Orion capsule could be available in the 2013 timeframe gave the agency an opportunity to experiment by incentivizing industry to undertake a series of demonstration test flights of cargo delivery systems. According to NASA briefings the *"COTS approach is designed to lower barriers to entry for entrepreneurial space transportation companies,"* and act as a *"catalyst for technology demonstrations where the potential high return on investment outweighs the associated financial risk."*

Phase 1: Commercial Orbital Transportations Services (COTS) Demonstrations

NASA budgeted $500 million in FY2006-FY2010 for the first phase, the Commercial Orbital Transportation Services (COTS) and planned to use "*funded Space Act Agreements with one or more U.S. companies to develop and demonstrate the vehicles, systems, and operations to support a human space facility like the ISS. These commercial services may also be used to provide logistics support in case the Shuttle or its follow-on crew and cargo systems are not available at some point in the future.*" NASA expected these companies to develop and demonstrate end-to-end transportation systems including the launch vehicles, spacecraft, ground and mission operations, and berthing with the ISS.

Space Act Agreements are used to establish enforceable promises between NASA and another party requiring a commitment of NASA resources such as for funding or technical engineering support. According to GAO, "*generally speaking, other transaction authority (e.g. Space Act Agreements) enhances the government's ability to acquire cutting edge science and technology, in part through attracting companies that typically have not pursued government contracts because of the cost and impact of complying with government procurement requirements.*" NASA found Space Act Agreements advantageous because the government can share costs with the agreement partner, and limited government requirements allow companies to optimize the systems to meet their business needs. However, it is important to note that these types of agreements are not federal government contracts, and Space Act Agreements are not subject to the Federal Acquisition Regulations (FAR) which contain a number of accounting standards, reporting requirements, and other procurement rules designed to prevent fraud, waste and abuse. Using Space Act Agreements to procure such large and complex systems is a relatively new development, and the government has limited ability to influence the agreement partners. In briefings by senior NASA officials leading up to this hearing, committee staff was told, "NASA did not get the level of detail with Space Act Agreements that they expected." The Committee has asked the U.S. Government Accountability Office witness to give GAO's perspectives on the use of Space Act Agreements and Federal Acquisition Regulations for these types of procurements.

In August 2006, NASA awarded and funded Space Act Agreements for the COTS program to two companies; SpaceX and Rocketplane Kistler. Company briefings from that time show COTS flight demonstrations were projected as early as 2008 and demonstration test flights completed by 2010. Rocketplane Kistler was subsequently unable to meet financing requirements and was replaced by Orbital Sciences in February 2008.

SpaceX was awarded $278 million for three demonstration flights of the Falcon 9 launch vehicle and Dragon capsule, designed with the capability to return pressurized cargo mass to Earth. SpaceX develops and manufactures most of the Falcon 9 and Dragon components in-house in an effort to keep development costs low and avoid dependence on external suppliers. SpaceX launches from Complex 40 at Cape Canaveral Air Force Station, Florida. SpaceX has received $258 million in milestone payments for completing 18 of 22 COTS milestones. Please see Appendix 1 for Space X's schedule milestone chart.

Both Orbital and SpaceX are making steady progress toward accomplishing their COTS demonstration flights. SpaceX successfully completed its first COTS demonstration flight on December 8, 2010. The Dragon capsule orbited the Earth twice and was recovered from the Pacific off the California coast. That mission did not reach the altitude or orbit of the ISS, but did test the Falcon 9 launch vehicle and Dragon capsule during reentry. SpaceX's second test flight has recently slipped from July 2011 to November 2011. During the second test flight the Dragon capsule is slated to conduct orbital maneuvers, attain the altitude and orbit of the ISS, and maneuver in close proximity to the ISS. In SpaceX's third test flight the Dragon capsule is slated to approach the ISS, be grappled by the space station robotic arm, and berth to the ISS.

Orbital was awarded $170 million for one demonstration flight of the Taurus 2 and Cygnus capsule, designed to deliver pressurized cargo to ISS but not return to Earth. Orbital has teamed with several external and international space companies to develop and manufacture the Taurus 2 and Cygnus capsule in an effort to reduced development risk by using proven systems. Orbital plans to launch their first COTS demonstration flight in December, 2011 from the Mid-Atlantic Regional Spaceport at NASA's Wallops Island Flight Facility, Virginia. Orbital has received $157.5 million in milestone payments for completing 15 of 19 COTS milestones. Please see Appendix 1 for Orbital's schedule milestone chart.

Phase 2: Procurement of Commercial Resupply Services (CRS)

The second phase, purchase of Commercial Resupply Services (CRS), was to be a competitive procurement of demonstrated services to deliver pressurized and unpressurized cargo to the ISS. These commercial entities would provide all prelaunch assembly and integration, launch licensing, and launch activities – in the case of SpaceX including the landing and recovery of the Dragon capsule – under a firm, fixed-price contract. NASA cargo on these missions is not guaranteed or insured. In the event of a launch failure, the commercial entities are not liable for the replacement of the cargo or the launch vehicle. NASA assumes the risk of loss. Launch licensing from the Federal Aviation Administration's Office of Commercial Space Transportation would be required since NASA would not be managing or conducting these activities.

The CRS contract was to be awarded only *after* successfully demonstrating all the COTS resupply capabilities to the ISS. In the COTS Final Selection Statement NASA describes the second phase as, "*A potential competitive procurement of orbital transportation services to resupply the ISS with cargo...**if a capability is successfully demonstrated** and the Government determines it is in its best interest.*" [Emphasis added] After the initial COTS participants had successfully demonstrated the ability to access and berth with the ISS, NASA then planned to buy those delivery services using a FAR-based contract. This approach would minimize the financial and developmental risk to the U.S. Government by permitting NASA to select from among already proven and demonstrated systems and capabilities. However NASA did not follow this path.

By 2008, delays in the demonstration of COTS capabilities, the impending retirement of the Space Shuttle in 2010, and the long lead times needed to engage either COTS providers or international partners raised concerns that the ISS could not be maintained unless more supplies (including some large items only the Shuttle could carry) could be delivered. The following table shows the flight rate of the various systems.

Flight Rate to International Space Station

	2011	2012	2013	2014	2015
COTS Demonstration Flights					
SpaceX *Falcon 9/Dragon*	1	1			
Orbital *Taurus II/Cygnus*	2				
Commercial Resupply Services					
SpaceX *Falcon 9/Dragon*		3	3	3	3
Orbital *Taurus II/Cygnus*		2	2	2	2
International Partner Capabilities					
Russian *Progress*		4†	4	4	4
European *Autonomous Transfer Vehicle (ATV)*		1	1	1	
Japanese *H-II Transfer Vehicle (HTV)*		1	1	1	1

† does not include 0.5 metric ton (1102 pounds) of capacity assigned to U.S.

NASA's risk summary report states that a delay in 2010 by the commercial partner's vehicles would result in a significant scaling back of the ISS for scientific research. If delays extended into 2011, NASA could no longer support a space station crew of six astronauts. The capabilities of NASA's international partners to access the ISS with the Soyuz, Progress, ATV and HTV would enable limited functioning, but a loss of U.S. capability threatened to cause NASA to abandon the U.S. side of the ISS. This resulted in two significant events; 1) the addition of additional Shuttle flights, and 2) the initiation of the CRS contract including milestone progress payments to commercial providers before they had demonstrated any COTS capabilities.

The terms of the contracts awarded to SpaceX and Orbital call for delivery of at least 40 metric tons (approximately 88,160 pounds) of cargo to the space station between 2010 and 2015 for $3.5 billion. SpaceX was awarded $1.6 billion to deliver 20 metric tons on 12 cargo resupply missions. Orbital was awarded $1.9 billion to deliver 20 metric tons on 8 cargo resupply missions.

The following chart lists approximate costs to deliver one pound of cargo to the ISS under various programs. Development costs are not included in these calculations, and are considered proprietary information by the COTS partners.

	Space Shuttle *	**Russian Progress**	**Commercial Resupply Services (CRS)**
Approximate cost per pound to ISS	$21,268	$18,149	$26,770

*Calculated assuming four missions per year with a capability to deliver 16 metric tons (35,264 pounds) to the space station at a total annual program cost of $3.0 Billion. $3,000,000,000 ÷ (4 flights × 35,264 pounds/flight) = $21,268 per pound. Assumes no additional cost to transport 28 astronauts to the space station and return.

Costs for the Russian Progress and the Commercial Resupply program are NASA estimates.

The CRS estimate would be higher, at around $39,700 per pound, if derived using a method similar to that used for the Space Shuttle; i.e. Dividing the CRS program cost ($3.5 billion) by the mass delivered to the space station (40 metric tons, i.e. 88,160 pounds).

Delays in Commercial Cargo Systems Led to Additional Shuttle Flights

NASA estimates that the ISS requires about 83 metric tons (a metric ton equates to 2,204 pounds) of dry cargo between 2010 and 2015. Dry cargo consist of scientific experiments, tools, food, spare parts and other equipment, but does not include propellants, water, atmospheric gases and other liquids. Without the Space Shuttle, NASA's international partners lack sufficient capabilities to satisfy the ISS cargo resupply needs.

As a result, NASA faces a 40 metric ton (approximately 88,160 pounds) shortfall between 2010 and 2015. In 2008 Congress was aware that delays in the COTS cargo demonstration program threatened the scientific utilization of the space station. According to NASA, the projected delays of the commercial vehicles in 2010 would cause significant scaling back of NASA's use of the space station for scientific research. Delays extending into 2011 would mean NASA could no longer maintain a space station crew of six astronauts and the ability to conduct scientific research would be significantly compromised.

Thus, Sec. 611 of the NASA Authorization Act of 2008 [P.L.110-422] authorized two additional logistics flights, *"In addition to the Space Shuttle flights listed as part of the baseline flight manifest as of January 1, 2008, the Utilization flights ULF–4 and ULF–5 shall be considered part of the Space Shuttle baseline flight manifest and shall be flown prior to the retirement of the Space Shuttle, currently scheduled for 2010."*

Continuing launch delays for the first commercial COTS demonstration extended into the fall of last year as Congress negotiated the 2010 NASA Authorization Act. To reduce risk and ensure the viability of ISS, Congress authorized another Space Shuttle flight (STS-135, the last mission of the program, now scheduled for July 8th), *"The Administrator shall fly the Launch-On-Need Shuttle mission currently designated in the Shuttle Flight Manifest dated February 28, 2010, to the ISS in fiscal year 2011, but no earlier than June 1, 2011, unless required earlier by an operations contingency..."*

The need for a costly additional shuttle mission underscored the importance of a U.S. Government backup capability for assured access to ISS. Sec. 2(9) of the NASA Authorization Act of 2010 states, *"While commercial transportation systems have the promise to contribute valuable services, it is in the United States' national interest to maintain a government operated space transportation system for crew and cargo delivery to space."*

According to NASA, the STS-135 mission is critical because it will provide about one year of schedule margin. At the March 15th, 2011 Senate Commerce, Science and Transportation Committee hearing on *The Challenges Facing NASA*, Associate Administrator Bill Gerstenmaier explained the critical nature of the STS-135 mission given the concerns for commercial COTS schedule, *"We see that mission as extremely critical to us. What that mission provides for us is it gives us some margin that if the commercial providers are late and they don't fly in 2011 and 2012 as they plan, then we have got some time through 2012 that we will have enough supplies pre-positioned on Space Station that we can continue to do quality research, we continue to keep our crew size at six onboard station through that period of 2012 all the way until 2013. If we don't have that shuttle flight, then it's absolutely mandatory that the commercial cargo providers come on-line at the end of this year and early in 2012. I don't think that is a prudent strategy. We need some margin just as in the shuttle world, we thought we understood where we were going to go fly, then we had the tank problem that slowed us down a couple*

months. I would expect small problems to show up in the commercial providers as well. We need some margin to do that."

NASA Assumes Development Risk: Procures Commercial Resupply Services (CRS) before COTS Capabilities are Demonstrated

In December 2008, two years before the first COTS cargo demonstration would be performed; NASA awarded Commercial Resupply Services (CRS) contracts to the two COTS partners. Both companies are working under aggressive schedules and have experienced schedule slips which have delayed the COTS test and demonstration flights. In spite of the delays of the COTS demos, NASA has used the CRS contracts to make progress payments to the COTS partners for milestones associated with future CRS cargo delivery missions. To date NASA has paid SpaceX more than $185.6 million for milestones tied to four CRS missions, and has paid Orbital more than $280.7 million for milestones tied to three CRS missions. This $466 million does not include milestone payments that are funded by the recent cargo "augmentation."

By purchasing CRS years before the COTS systems had been demonstrated, NASA assumed significantly more risk for ensuring the success of the cargo providers. NASA has indicated that they are "too important to fail." This concept has important policy and budgetary implications for future commercialization proposals such as the Administration's proposed commercial crew efforts. Administrator Bolden has repeatedly told Congress that NASA would do "whatever it takes" to make these ventures succeed. According to briefings provided to Committee staff, "*NASA is depending on our commercial cargo partners. We need their COTS development efforts to succeed so that they can begin providing cargo resupply to the International Space Station...*" Legitimate questions have been raised about this approach since it differs from what was originally intended to be a merit-based and market-based competition.

Delays Result in a 62 Percent Increase for COTS Cargo Augmentation

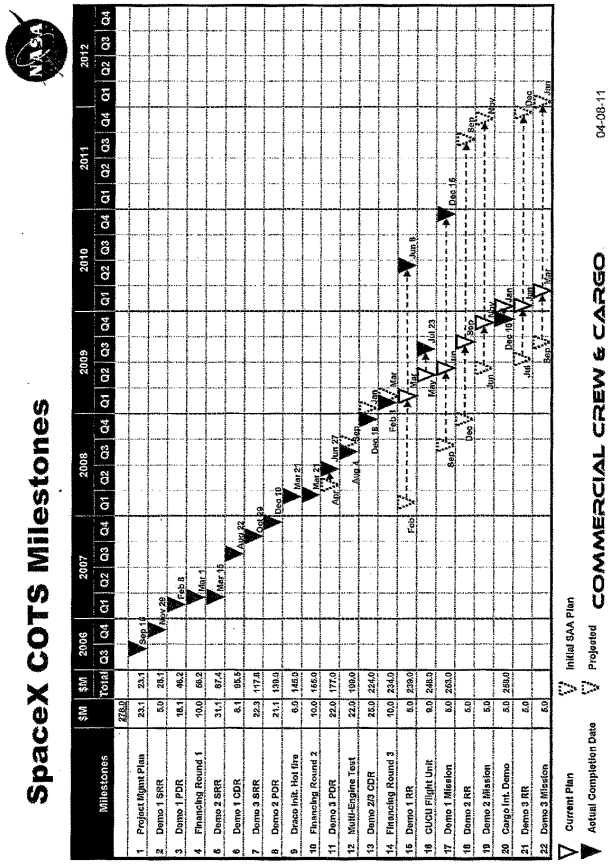
NASA's FY 2011 budget requested an additional $312 million—a 62% increase in the cost of the COTS program—in an attempt to speed up the COTS development activities and help ensure mission success. NASA worked with each COTS partner to develop a series of additional "risk reduction" milestones designed to improve the likelihood of successful COTS demonstrations. SpaceX and Orbital will each receive $128 million toward these milestones. To date SpaceX has been paid $40 million for the first seven augmentation milestones, and completed 25 out of a total of 40 COTS milestones. Orbital has been paid $64 million for four augmentation milestones, and completed 21 out of a total of 31 COTS milestones.

COTS Cargo Augmentation could Reduce a Mission for SpaceX and Add a Mission for Orbital

Last year, SpaceX asked NASA for permission to combine the second and third COTS demonstration missions. At that time NASA deferred any decision on a combined mission until after it had reviewed all the data from the first COTS mission. In January 2011 NASA gave SpaceX a list of the data it would need to evaluate the impacts and assess the risks of combining the second and third missions. NASA is now evaluating a range of safety and technical concerns and hopes to complete an assessment in mid-June. If the missions are combined and both sets of test objectives are accomplished, then presumably NASA would pay for meeting both sets of milestones and relieve SpaceX of the requirement to conduct a third demonstration flight.

Whereas SpaceX is doing much of their development in-house, Orbital's COTS concept takes advantage of a number of previously developed heritage systems. For example, Orbital's Taurus 2 uses two Aerojet AJ-26 engines, an ATK Castor 30 solid rocket motor second stage, and a standard service module derived from NASA's STAR and Dawn spacecrafts. Orbital's COTS demonstration consists of one mission of the Taurus 2 and Cygnus capsule to the ISS planned for December 2011. NASA is working with Orbital to evaluate adding a Taurus 2 demonstration flight in October 2011, prior to the first COTS demonstration to the ISS. Both Orbital and NASA wanted such a flight in the initial agreement, but it was not funded.

Appendix 1


SpaceX COTS Milestones
Milestones
$M
$M Total
2006
2007
2008
2009
2010
2011
2012
Q1 Q2 Q3 Q4
1 Project Mgmt Plan 23.1
2 Demo 1 SRR 5.0 28.1
3 Demo 1 PDR 18.1 46.2
4 Financing Round 1 10.0 56.2
5 Demo 2 SRR 31.1 87.4
6 Demo 1 CDR 8.1 95.5
7 Demo 3 SRR 22.3 117.8
8 Demo 2 PDR 21.1 139.0
9 Draco Init. Hot fire 6.0 145.0
10 Financing Round 2 10.0 155.0
11 Demo 3 PDR 22.0 177.0
12 Multi-Engine Test 22.0 199.0
13 Demo 2/3 CDR 25.0 224.0
14 Financing Round 3 10.0 234.0
15 Demo 1 RR 6.0 239.0
16 CUCU Flight Unit 9.0 248.0
17 Demo 1 Mission 5.0 253.0
18 Demo 2 RR 5.0
19 Demo 2 Mission 5.0 258.0
20 Cargo Int. Demo 5.0 263.0
21 Demo 3 RR 5.0
22 Demo 3 Mission 5.0
Sep 15
Nov 29
Feb 8
Mar 1
Mar 15
Nov 22
Oct 28
Dec 19
Mar 21
Mar 21
Apr 1
Jun 27
Aug 4
Sep
Dec 18
Jan
Feb 5
Mar
Feb
Mar
Mar
Jul 23
Jun 8
Sep 1
Dec
Dec 16
Jun
Sep
Dec 19
Jan
Jul
Mar
Sep 1
Mar
Sep
Nov
Dec
Jan
Current Plan
Actual Completion Date
Initial SAA Plan
Projected
COMMERCIAL CREW & CARGO
04-08-11

SpaceX Augmented COTS Milestones

	Milestones	$M	$M Total	2007 Q1	2007 Q2	2007 Q3	2007 Q4	2008 Q1	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4	2012 Q1	2012 Q2	2012 Q3	2012 Q4
		118.0																									
23	Modal Test Plan	5.0	5.0																Dec 16								
24	Modal Test	5.0	10.0																Dec 16								
25	LIDAR Test (open loop)	5.0	15.0																Dec 16								
26	Solar Array Deploy Test	5.0	20.0																Dec 16								
27	LIDAR Test Plan (closed loop)	5.0	25.0																	Mar 31							
28	Thermal Vacuum Test Plan	5.0	30.0																	Mar 1	Apr 6						
29	Infrastructure Plan	10.0	40.0																	Mar 1	May 10						
30*	Thermal Vacuum Test	20.0																			Jul						
31	Test site Infrastructure Implementation	5.0																			Jun						
32	Dragon Trunk Acoustic Test	10.0																			Jun						
33	LIDAR Test 6 DOF (closed loop)	5.0																				Aug					
34	Design Rev. Enhanced Powered Cargo Accom.	5.0																				Aug					
35	Design Rev. Pressurized Cargo Vol Increase	5.0																				Aug					
36	Dragon EMI/EMC Test (HITL)	10.0																				Jul					
37	Dragon Cargo Racks & Hatch Simulator	3.0																				Aug					
38	Ground Demo Enhanced Powered Cargo	5.0																				Sep					
39	Launch site Infrastructure Implementation	5.0																				Sep					
40	Production Infrastructure Implementation	5.0																				Sep					
	SAA Total	398.0	208.0																								

Current Plan

Actual Completion Date

Initial SAA Plan

Projected

COMMERCIAL CREW & CARGO

05-12-11

Orbital COTS Milestones

	Milestones	$M	$M Total	2008 Q1	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4	2012 Q1	2012 Q2	2012 Q3	2012 Q4
		170.0																					
1	Program Plan Review	10.0	10.0		Mar 31																		
2	Demo Mission SRR	20.0	30.0		Jun	Jul 17																	
3	UCM PDR	10.0	40.0		Jul	Aug 14																	
4	DELETED																						
5	COTS Int/Ops Facility	10.0	50.0			Sep 22	Oct																
6	PCM PDR	10.0	60.0			Oct 9	Nov																
7	DELETED																						
8	IP&CL Submission	10.0	70.0					Feb 18															
9	ISS Phase 1 SRP	10.0	80.0						Mar 27														
10	COTS System PDR	20.0	100.0			Sep		Apr	May 22														
11	PCM CDR	10.0	110.0							Jul 31													
12	Cygnus Avionics Test	10.0	120.0						Jun	Aug 13													
13	ISS Phase 2 SRP	10.0	130.0							Aug	Nov 6												
14	COTS System CDR	10.0	140.0					Mar		Sep		Mar 23											
15	SM Core Assembly Complete	7.5	147.5							Oct	Dec		Aug 30										
16	SM Test Readiness Review	7.5	155.0								Jan	Apr		Nov 17									
17	SM Initial CPT	5.0										May			Jun								
18	LV Stage I Assy. Complete	2.5											Sep			Sep							
19	Cargo Int. Demo	2.5	157.5												Dec 6								
20	Mission Readiness Review	2.5												Oct				Oct					
21	System Demo Flight	2.5													Dec				Dec				

Current Plan
Actual Completion Date
Initial SAA Plan
Projected

COMMERCIAL CREW & CARGO

03-30-11

Orbital Augmented COTS Milestones

Milestones	$M	$M Total	2008 Q1	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4	2012 Q1	2012 Q2	2012 Q3	2012 Q4
	113.0																					
22 TII Test Flight Mission Review	20.0	20.0																				
23 TII Test Flight Mission Analys.	10.0	30.0																				
24 Cygnus Mass Sim. (CMS) DR	10.0	40.0																				
25 Install Add'l PITL Simulators	5.0																					
26 PROX FEU Test Unit	5.0																					
27 TII Maiden Flt Stg 1 Core Del.	24.0	84.0																				
28 TII Maiden Flt Uppr Stage Del.	20.0																					
29 TII Maiden Flt CMS Delivered	10.0																					
30 TII Maiden Flt Stage 1 Assy.	10.0																					
31 TII Maiden Flight	4.0																					
SAA Total	298.0	221.6																				

Dec 15
Feb 23
Mar 03
Apr
May
May
Apr 28
Jun
Jun
Jul
Oct

Current Plan
Actual Completion Date
Initial SAA Plan
Projected

COMMERCIAL CREW & CARGO

04-28-11

Chairman PALAZZO. The Subcommittee on Space and Aeronautics will come to order. Good morning. Welcome to today's hearing entitled, "NASA's Commercial Cargo Providers: Are They Ready To Supply the Space Station in the Post-Shuttle Era?" In front of you are packets containing the written testimony, biographies, and truth in testimony disclosures for today's witness panel. I ask unanimous consent that the gentleman, Mr. Olson, from Texas and Mr. Flores from Texas be allowed to sit in at the dais with the Committee and participate in the hearing.

Hearing no objections, so ordered.

I now recognize myself for five minutes for an opening statement.

I would like to welcome everyone to today's subcommittee hearing examining NASA's commercial cargo programs. I also want to thank our witnesses for taking time out of their busy schedules to testify before us today. We have a lot of ground to cover, and I know Members want plenty of time to ask questions, so I will keep my remarks short.

I think we are all well aware that NASA is preparing to launch the final Space Shuttle mission to the International Space Station. The cargo bay of Atlantis will be filled with supplies and spare parts bound for the International Space Station, enough to provide up to a year's margin of safety. The flight was added in part because NASA and the commercial partners are behind schedule and have not yet demonstrated the capability to access the ISS. Without the Shuttle, and until commercial cargo flights begin flying, NASA must rely on the capabilities of the international partners.

NASA's international partners should be commended for doing a fine job, but they simply do not have enough cargo-carrying capacity by themselves to insure that sufficient equipment is on board the Station to support a research team of six astronauts.

NASA wrote the book on back-up systems, and thankfully with STS–135 the Space Shuttle can be called upon one last time to provide the much-needed cargo capability. But in the post-Shuttle era will NASA's commercial cargo providers be able to do that job?

Thus far we have very little by which to make an informed judgment. Only one of the two cargo resupply contractors has actually orbited a prototype vehicle, and that was only an orbital demonstration that was not intended to reach the Space Station orbit. Congress has generally been supportive of NASA's commercial cargo efforts, but too often requests for information have been met with a veil of secrecy and claims of company proprietary information.

I want to remind NASA and the commercial partners that you are spending taxpayer money and lots of it. So you will not be exempt from oversight and financial scrutiny.

I also want to remind everyone in this room that today we are talking about cargo and not capabilities to take astronauts into space or to the ISS. Whether or not commercially-developed, non-NASA launch systems can safely carry astronauts to orbit in an economical way is a question that will require some number of years before we have an answer and will be the topic of future hearings.

Today let us focus our attention on NASA's programs to commercially deliver cargo to the Space Station. NASA's commercial cargo programs have been in development for several years and have ex-

perienced delays. NASA has obligated over $1.25 billion and is poised to spend more than $4 billion over the next few years.

Yet, in spite of optimistic projections and even a successful SpaceX Falcon 9 launch and Dragon capsule recovery, NASA's commercial cargo partners have yet to demonstrate the ability to safely deliver cargo to the ISS.

I am hopeful that we will see some progress soon, and I look forward to hearing your testimony.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF THE HONORABLE STEVEN M. PALAZZO, CHAIRMAN
SUBCOMMITTEE ON SPACE AND AERONAUTICS

I would like to welcome everyone to today's subcommittee hearing examining NASA's Commercial Cargo programs. I also want to thank our witnesses for taking time out of their busy schedules to testify before us today. We have a lot of ground to cover and I know Members want plenty of time to ask questions so I will keep my remarks short.

I think we are all well aware that NASA is preparing to launch the final Space Shuttle mission to the International Space Station. The cargo bay of Atlantis will be filled with supplies and spare parts bound for the International Space Station; enough to provide up to a year's margin of safety. The flight was added in part, because NASA and the commercial partners are behind schedule and have not yet demonstrated a capability to access the ISS. Without the shuttle, and until commercial cargo flights begin flying, NASA must rely on the capabilities of the international partners.

NASA's international partners should be commended for doing a fine job, but they simply do not have enough cargo carrying capacity by themselves to ensure that sufficient equipment is onboard the station to support a research team of six astronauts. NASA wrote the book on backup systems, and thankfully with STS–135, the space shuttle can be called upon one last time to provide the much needed cargo capability. But in the post-shuttle era will NASA's commercial cargo providers be able to do the job? Thus far, we have very little by which to make an informed judgment. Only one of the two cargo resupply contractors has actually orbited a prototype vehicle, and that was only an orbital demonstration that was not intended to reach the space station orbit.

Congress has generally been supportive of NASA's commercial cargo efforts, but too often requests for information have been met with a veil of secrecy and claims of company proprietary information. I want to remind NASA and the commercial partners that you are spending taxpayer money, and lots of it. So you will not be exempt from oversight and financial scrutiny.

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I am hopeful that we will see some progress soon, and I look forward to hearing your testimony.

Chairman PALAZZO. I would now like to yield my remaining time to Science Committee Chairman Ralph Hall for a few brief comments.

Mr. HALL. Thank you, Mr. Chairman, for yielding some time.

NASA's commercial cargo program was initiated as we all know in 2006, five years ago, with the Commercial Orbital Transportation Systems Program. It was, and is, a technically-challenging

program to initiate two commercial launch systems, even for the seemingly-routine delivery of cargo to the International Space Station, but the procurement strategy also broke with NASA tradition by allowing the agency to use its Space Act Agreement authority to fund these developments of these two systems.

Two years later NASA signed contracts valued at 3.5 billion with the same two COTS-funded companies for cargo supply services, even though neither of these companies had flown any demonstration flights.

So what started as a reasonable step-by-step approach to develop and prove capabilities first, followed by competitive acquisition simply didn't happen. NASA simply ran out of time and is now gambling the future of Space Station on the success of two very new launch systems.

We, NASA, Congress, and our Space Station partners expect these companies to perform. It is my sincere hope and desire that they perform and meet their contract goals. There is no plan B if they encounter severe technical or schedule challenges, and I want them to succeed. I simply regret that there continues to be so much uncertainty about our Nation's ability to reliably get cargo to the Station with the final Shuttle flight now less than two months away.

It is unfortunate the decisions of the Administration have created so many questions and turmoil in the outlook for space. Thousands were handed unbelievable anxiety about their future, about their jobs, and about our Space Station.

I just want to review just very briefly an article that has been furnished to all of us up here. It simply points out that the last Space Shuttle mission is scheduled for July the 8th, just around the corner. After that how is NASA going to supply, maintain, and utilize the multi-billion dollar International Space Station?

NASA plans to rely on new commercial launch service providers to supplement the international partners. NASA has spent $500 million since 2005, on the Commercial Orbital Transportation Services Program intended to demonstrate commercial cargo delivery capabilities to the International Space Station from two commercial partners; Space Exploration Technologies and Orbital Science Corporation.

Despite initial assurances that NASA would not expend any money to buy services until these systems were fully demonstrated, NASA has spent over $466 million towards the purpose of cargo delivery services even though no, I emphasize no, demonstration flights to the ISS have been performed.

Furthermore, last year NASA requested an additional $312 million augmentation, a 62 percent increase, to reduce risk and improve the schedule. To date NASA has obligated at least $1.25 billion on the commercial cargo effort without accomplishing a single demonstration to the ISS.

Questions for the Congress include when will these systems be ready, how much additional work, time, and money will be required, and I join with Mr. Palazzo in welcoming our guests here. You have had and will have disappointments. Just don't over promise us as we work together and hopefully succeed together.

Let us remember those that blazed the way to the moon and back, the John Glenns, the Neil Armstrongs, the Buzz Aldrins, the Gene Cernans, the Mike Collins, the General Tom Staffords, and all those others who perished in missions that once thought routine. We owe them so much. Let us not let them down.

I yield back my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF THE HONORABLE RALPH M. HALL

Thank you, Mr. Palazzo, for yielding me some time to inject a couple of quick comments.

NASA's commercial cargo program was initiated in 2006, five years ago, with the Commercial Orbital Transportation Systems (COTS) program. It was—and is—a technically challenging program to stand-up two commercial launch systems, even for the seemingly routine delivery of cargo to the ISS. But the procurement strategy also broke with NASA tradition by allowing the agency to use its Space Act Agreement authority to fund the development of these systems. Two years later, NASA signed contracts valued at $3.5 billion with the same two COTS-funded companies for cargo resupply services, even though neither of these companies had flown any demonstration flights.

So what started as a reasonable step-by-step approach to develop and prove capabilities first, followed by a competitive acquisition, did not happen. NASA simply ran out of time and is now gambling the future of Space Station on the success of two very new launch systems.

We—NASA, Congress, our space station partners—expect these companies to perform. It is my sincere hope and desire that they perform and meet their contract goals. There is no plan B if they encounter severe technical or schedule challenges, and I want them to succeed. I simply regret that there continues to be so much uncertainty about our nation's ability to reliably get cargo to station with the final shuttle flight now less than two months away. It is unfortunate that the decisions of this Administration have created so many questions and turmoil in our outlook for space.

I join with Mr. Palazzo in welcoming our witnesses this morning, and I look forward to your testimony.

Chairman PALAZZO. Thank you, Chairman Hall.

The chair now recognizes Mr. Costello for an opening statement.

Mr. COSTELLO. Mr. Chairman, thank you, and Mr. Chairman, thank you for calling this hearing today.

First I want to congratulate Associate Administrator Bill Gerstenmaier, who is here with us this morning and his entire NASA team for the successful launch of STS–134, Space Shuttle Endeavor's final mission. We were all heartened that Congresswoman Giffords was present at the launch, and our thoughts are with the astronauts and their families for their safe return home.

In 2006, NASA envisioned a commercial cargo program that took into account the financial and programmatic risk to the United States government, allowing private companies to service the ISS. The initial plan 1) allowed NASA to partner with a commercial provider to develop and demonstrate a safe cargo mission to the ISS before signing a long-term resupply contract, and 2) provided a contingency plan to use Constellation vehicles and rockets if commercial providers could not meet their goals.

In the last five years the landscape of human spaceflight has changed. In 2008, NASA signed long-term resupply contracts with SpaceX and Orbital before either company had safely completed a cargo mission, and in 2010, NASA cancelled the Constellation Program and shifted its focus to deep space exploration. Under this new plan, commercial providers will be fully responsible for the

critical task of servicing the ISS when the Space Shuttle retires this year.

Orbital and SpaceX have made significant strides in achieving the goals laid out by NASA for providing commercial cargo services under their initial agreements, but to date, as the Chairman has noted and the Chairman of the full Committee has also noted, neither company has successfully completed a mission to and from the ISS.

However, both companies are under contract with NASA to begin flying cargo missions in 2012. After the final Space Shuttle launch brings supplies to the station this summer, NASA has no back-up plan if Orbital and SpaceX are not ready to launch in 2012. Without a robust and reliable commercial cargo service, NASA will not realize its plans to fully utilize the ISS as a research and development facility.

As chair of this Subcommittee, Congresswoman Giffords expressed these concerns about commercial providers. She strongly believed that commercial companies should be given the time to demonstrate that they could safely provide cargo services and felt NASA could not put the ISS or deep space exploration at risk by not providing a back-up plan if they fail.

I hope to hear today how NASA, Congress, and the commercial providers can work together to identify any remaining risks to reliable and timely commercial cargo operations, develop realistic expectations for the program, and ensure NASA has contingency options if commercial services are unavailable. We must ensure NASA has sustainable commercial cargo services for the life of the ISS without exposing the U.S. government to too much financial and programmatic risks.

Mr. Chairman, I welcome our panel of witnesses this morning, and I look forward to hearing their testimony.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY COSTELLO

Mr. Chairman, thank you for holding today's hearing to receive testimony on the readiness of commercial cargo providers to service the International Space Station (ISS) after the Space Shuttle retires this year.

First, I want to congratulate Bill Gerstenmaier and the entire NASA team for the successful launch of STS–134, Space Shuttle Endeavour's final mission. We were all heartened that Congresswoman Gabrielle Giffords was present at the launch, and our thoughts are with the astronauts and their families for their safe return home.

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I hope to hear today how NASA, Congress, and commercial providers can work together to identify any remaining risks to reliable and timely commercial cargo operations, develop realistic expectations for the program, and ensure NASA has executable contingency options if commercial services are unavailable. We must ensure NASA has sustainable commercial cargo services for the life of the ISS without exposing the U.S. government to too much financial and programmatic risk.

I welcome our panel of witnesses and look forward to their testimony. I yield back the balance of my time.

Chairman PALAZZO. Thank you, Mr. Costello. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our witness panel. Our first witness will be Mr. Bill Gerstenmaier, Associate Administrator for Space Operations at NASA. Mr. Gerstenmaier began his career at NASA in 1977, and has worked on a number of projects and programs including Shuttle, Space Station Freedom, and the ISS.

Our second witness is Ms. Cristina Chaplain, Director of Acquisition and Sourcing Management at the U.S. Government Accountability Office. She has responsibility for GAO assessments of military space acquisitions, NASA, and the Missile Defense Agency. She has been with the GAO for 20 years.

Our third witness is Mr. Frank Culbertson, Senior Vice President and General Manager of Orbital's Advanced Programs Group. Mr. Culbertson is a graduate of the U.S. Naval Academy. He was a naval aviator and served for 18 years as a NASA astronaut, spending 144 days in space as Shuttle commander, pilot, and station crew member.

And for our final witness introduction I recognize Mr. Flores for two minutes.

Mr. FLORES. Thank you, Mr. Chairman. I appreciate the courtesy of each of you allowing me to introduce Gwynne Shotwell, the President of Space Exploration Technologies. I also appreciate the Committee holding this important hearing on NASA's Commercial Cargo Providers.

As you are aware, this option will soon be the only domestic American capability to transport cargo to the International Space Station. All Americans know that Texas has had a long and prominent role to play in spaceflight, and I am proud that the City of McGregor in McClennan County is playing a key role in this next phase of our space program.

I am pleased to introduce Gwynne Shotwell, whose company, SpaceX, is bringing exciting new engineering and technical jobs to McGregor. Since 2003, SpaceX has invested more than $50 million in its McGregor facility to develop state-of-the-art—to develop a state-of-the-art rocket development facility which sits on more than 600 acres of land and employs more than 120 Texans.

Mr. Chairman, I have had the opportunity to visit SpaceX McGregor test site and meet with its employees, and I can tell you it is an impressive place. There is a lot of energy and excitement and to me it exemplifies the spirit of American ingenuity and innovation. Not only was I able to see the Dragon spacecraft, which successfully twice orbited the earth in December of last year, but I was also able to see the great engineers and technicians at work test firing one of SpaceX's Merlin rocket engines.

My constituents all across our district have told me how proud they are to have such an innovative and exciting company in the community, and I am proud of what they are doing to develop a safe and affordable domestic alternative to offset a pending sole reliance on Russian spacecraft to deliver cargo and ultimately crew into space. McGregor is a busy place today and getting more industrious and busy by the minute. Every SpaceX Merlin engine that powers the Falcon 9 rocket and every Draco thruster that controls its Dragon spacecraft is first tested on the ground in McGregor before launch.

SpaceX is now averaging about one test firing per day. This frequency will only grow and increase as SpaceX expands to support dozens of upcoming launches for its government and commercial customers. And now that NASA is working with SpaceX under its commercial crew development program, development of SpaceX's innovative new integrated launch aboard system for the Dragon spacecraft will be McGregor.

Again, Mr. Chairman, thank you for allowing me the time to introduce Gwynne and SpaceX. Speaking from my experience in the private sector, I support the principle that American private industry leads the world in fostering innovation. It is important that we in Congress do all that we can to make sure that we highlight companies such as SpaceX. They robustly exhibit the commitment to American innovation, and they are doing it by creating jobs here in America instead of overseas.

And I wholeheartedly believe that NASA, working with companies like SpaceX, the United States can and will maintain its lead in space exploration. Thank you.

Chairman PALAZZO. Thank you, Mr. Flores.

As our witnesses should know, spoken testimony is limited to five minutes each, after which the Members of the Committee will have five minutes each to ask questions.

I now recognize our first witness, Mr. William Gerstenmaier, Associate Administrator of the Space Operations Mission Directorate at NASA.

STATEMENT OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, SPACE OPERATIONS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GERSTENMAIER. Thank you, Chairman Palazzo and Members of this Subcommittee. Thank you for the opportunity to appear before you today to discuss the status of NASA's commercial cargo efforts.

Tonight the crew onboard the Space Shuttle Endeavor will begin their fourth EVA or spacewalk for the mission. This will be a sig-

nificant milestone as this will be the last spacewalk based solely on Shuttle crew support. So tonight if things go as planned the total spacewalk time associated with the Space Station will be 1,000 hours. So we have spent—and that is just building the Space Station. So we spent quite a bit of time building the station, assembling it, and it culminates this evening with the final spacewalk based from the Shuttle.

We have been preparing for the Shuttle retirement for almost six years. In doing so we had to change the entire maintenance philosophy for the Space Station. We used to deliver spares to Space Station, return those spares to the ground, refurbish them, and launch them again. When we changed the cargo delivery system, we needed to change to a system where we essentially replaced the units on orbit and disposed of them in space.

So it is—not only did we need to develop and establish a cargo supply system, we needed to change the basic way we bring cargo to and from Space Station. This retirement of the Shuttle Program has entailed many years of preparation and required efforts beyond just the cargo delivery activities that we will talk about today. The ISS is entering a new phase focusing on research and utilization. The unique capabilities of the Shuttle are no longer required, and I think the simpler systems for cargo resupply will better serve this new phase of ISS utilization.

The cargo delivered by these new providers will be absolutely critical to the effective utilization of Space Station. The next phase of Space Station will focus on research, both fundamental and applied.

The agency has divided its commercial cargo efforts into two unique activities. The Commercial Orbital Transportation Services and that was to demonstrate commercial cargo systems, and then the second activity was commercial resupply services to procure cargo services to and from the ISS. These are unique activities as one is based on Space Act as was discussed earlier and the other is based on a fixed price of federal acquisition requirements for our FAR-based services contract.

Both COTS partners continue to make progress in developing their systems. NASA sees no reason to doubt either company's ability to achieve its desired objectives. Both partners have forward-leaning schedules and are facing challenges typical of a spaceflight development program. Both have experienced some milestone delays and have overcome significant technical and programmatic challenges in the past. This was not unexpected.

Establishing a regular flight rate after the initial flights will not be easy. NASA and the ISS Program are prepared for these startup problems, however, NASA expects these providers to deliver the services as required by the contracts that they have signed.

On December 8, 2010, SpaceX successfully completed its first COTS demonstration flight. This was a significant event and has been talked about earlier. Orbital is currently expected to complete their maiden test flight of its Taurus II launch vehicle from the new launch pad at Wallops Flight Facility this October and its demonstration flight to the ISS for NASA in December.

On the commercial resupply services contract on December 23, 2008, NASA awarded these contracts to Orbital and SpaceX with

a delivery of cargo to ISS after retirement of the Shuttle. This activity was separate from the COTS activity as I had just mentioned. NASA anticipates both providers will have their systems operational in 2012.

Again, I think both the companies are well prepared to move forward. We are prepared for the problems that will occur as we move forward. We anticipated these inevitable startup challenges associated with the technologically-ambitious endeavor. Both NASA and these providers have spent many years preparing for the utilization of Space Station. Now is the time when we will begin to see the fruits of this planning and development. NASA is ready for the ISS utilization, and with the help and dedication of these providers, ISS will be fully utilized and demonstrate the benefits of space-based research to the world.

Chairman Palazzo and Members of the Subcommittee, I would like to conclude my remarks by thanking you, again, for your continued support for NASA and its human spaceflight program including our commercial cargo efforts. I will be pleased to answer your questions as we go through the hearing. Thank you.

[The prepared statement of Mr. Gerstenmaier follows:]

PREPARED STATEMENT OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, SPACE OPERATIONS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Chairman Palazzo and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the status of NASA's commercial cargo efforts, which the Agency has divided into two programs—the Commercial Orbital Transportation Services (COTS) Program and the Commercial Resupply Services (CRS) Program.

Under COTS, NASA has helped fund the development of commercial cargo systems, and under CRS, NASA has entered into contracts to procure future cargo transportation services to and from the International Space Station (ISS). Together and along with NASA's initial Commercial Crew Development efforts, NASA is continuing to expand the opportunity for commercial access to space, thereby creating multiple means for NASA to access low-Earth orbit (LEO). Additionally, by investing in these commercial efforts, NASA is helping to facilitate the commercial uses of space, to help lower costs for commercial space services and to spark an engine for long-term U.S. job growth in the aerospace industry.

My testimony today will outline the progress made by our COTS and CRS partners: Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (OSC). Both companies competed as part of separate competitions under COTS and CRS, and were initially selected for the COTS development phase in 2006 and 2008, respectively, and later for the CRS phase in December 2008.

NASA is pleased with the steady progress both companies continue to make in their cargo development efforts. While both companies have experienced technical and schedule challenges to date, that is not uncommon with major aerospace development efforts. However, there still remain significant challenges to developing reliable, regular cargo transportation to the ISS. We need to anticipate and be prepared for the inevitable start-up challenges associated with a technologically ambitious endeavor, such as cargo delivery to the ISS.

We anticipate that the final COTS demonstration flights will conclude by early 2012. The first CRS resupply flights are also planned take place in 2012, thereby providing a critical capability that will enable us to maintain the ISS following the retirement of the Space Shuttle, thereby providing a critical capability that will enable us to maintain the ISS following the retirement of the Space Shuttle.

Commercial Orbital Transportation Services

In 2005, NASA established the Commercial Crew and Cargo Program Office at Johnson Space Center. The objectives of the Program, which oversees the COTS projects, is to further the implementation of U.S. space policy with investments to stimulate the commercial space industry, facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving

safe, reliable, cost-effective access to LEO, and create a market environment in which commercial space transportation services are available to Government and private sector customers. NASA believes the eventual availability of safe, reliable and economical service to LEO through the private sector will help NASA achieve the Nation's space exploration goals following retirement of the Space Shuttle, thereby allowing NASA to focus on developing new space transportation capabilities to support exploration beyond LEO.

As part of COTS, NASA entered into partnerships using funded Space Act Agreements (SAAs) with emerging and established space transportation providers to demonstrate the delivery of cargo to an on-orbit destination. The SAAs include a schedule of performance milestones that each partner is expected to achieve along with a fixed milestone payment to be made upon successful completion of performance.

These milestones culminate in a flight demonstration where the participant's vehicle will launch, rendezvous and berth with the ISS as the demonstration testbed, and re-enter or return safely to Earth. If a partner does not complete a milestone, as defined in the SAA, and to NASA's satisfaction, they are not paid. Should a milestone be missed, NASA would ascertain the cause of the failure, evaluate partner progress made and determine whether additional efforts are in the best interest of the Government. NASA does not pay for a milestone until the work has been completed successfully.

It is important to understand that both NASA and the partners themselves act as investors during the development and demonstration of commercial cargo services under COTS. The partners (and their other private investors) are investors because they partake in the financial burden, and stand to reap the financial benefits of developing a proven commercial space transportation capability that they can sell to NASA and other customers. NASA's intended benefit is the future availability of commercial providers, to enable less expensive cargo-transportation costs and elimination of the operations burden for routine LEO transportation.

Currently, NASA has two funded COTS partners, SpaceX and OSC. NASA signed funded SAAs with SpaceX in 2006 and with Orbital in 2008. Prior to awarding a funded SAA to OSC, NASA had an SAA with Rocketplane Kistler (RpK). However, RpK failed to meet certain negotiated milestones. In October 2007, after working with RpK for several months, NASA decided that it was in the best interest of the Agency to terminate the RpK agreement and re-compete the remaining funding. After the re-competition, NASA selected OSC for a funded SAA in February 2008.

Both SpaceX and OSC continue to make progress in developing their cargo transportation systems, based in part on NASA's financial and technical assistance, coupled with that of the industry partner's own financial contributions and technical expertise. NASA sees no reason to doubt either company's ability to achieve its desired objectives—that of demonstrating commercial cargo delivery to and from LEO. Both partners have aggressive, success-oriented schedules, and are facing challenges typical of a spaceflight development program. Both partners have experienced some milestone delays. However, these milestone delays are not unexpected, and have not required any additional NASA funding of specific milestones, since the partners are paid only fixed amounts for achieving milestones. Development costs beyond NASA's milestone payments have been borne by the companies and/or other investors.

A detailed schedule of each partner's COTS progress is provided as Attachment 1.

A review of what has occurred since SpaceX signed its COTS agreement with NASA in August 2006 shows that:

- To date, SpaceX has completed 25 of 40 negotiated milestones for COTS work, receiving $298 million out of a potential $396 million, including augmented funding.
- On December 8, 2010, SpaceX successfully completed the first COTS demonstration flight, demonstrating launch of the Falcon 9 booster, separation of the Dragon spacecraft and completion of two orbits, orbital maneuvering and control, reentry, parachute decent and spacecraft recovery after splashdown in the Pacific Ocean.
- SpaceX's remaining demonstration flights for NASA are scheduled for November 2011 and January 2012. NASA is reviewing a SpaceX proposal to accelerate the third demonstration flight test objectives, which include berthing to the ISS, during the second demonstration flight. Initial safety and technical assessments are expected to be completed by the end of May to enable a decision on berthing with the ISS on the earlier mission.

A review of what has occurred since OSC signed its agreement with NASA in February 2008 shows that:

- To date, OSC has completed 21 of 31 negotiated milestones for COTS work, receiving $221.5 million out of a potential $288 million, including augmented funding.
- Recently, OSC began integration and testing of its Cygnus Service Module and Taurus II launch vehicle.
- OSC is expected to complete its maiden test flight of the Taurus II launch vehicle from the new launch pad at the Wallops Flight Facility (WFF) in Virginia in October 2011, and its demonstration flight for NASA in December 2011.

Overall, NASA has invested $552 million in the COTS effort, which includes funding invested with the two current funded partners, as well as funding that was invested with Rocketplane Kistler that was terminated for failure to perform in 2007. By the conclusion of the COTS effort, NASA anticipates it will have invested $800 million in the COTS project—not including in-kind and infrastructure support that NASA has provided to the COTS partners. The $800 million includes the original $500 million authorized for COTS milestone payments and programmatic administrative costs, plus $300 million for augmented cargo milestone payments and associated administrative costs to help accelerate technical development, conduct flight tests and develop ground infrastructure, as authorized by the NASA Authorization Act of 2010 and funded under the FY 2011 Full-Year Continuing Appropriations Act (P.L. 112–10). To be clear, this augmented funding is being used for additional content and risk reduction measures, and therefore represents additional content and new work.

In total, NASA anticipates providing SpaceX and OSC $128 million each in augmented funding via modifications to their respective funded COTS SAAs and via the CRS contract during FY 2011, utilizing Exploration funds under the FY 2011 Full-Year Continuing Appropriations Act. To date, NASA has executed three SAA amendments (known as Quarter 1, Quarter 2, and Quarter 3/4 augmentations) for each COTS partner with respect to the augmentation milestones authorized by the NASA Authorization Act of 2010. These amendments outline the milestones that each partner must successfully complete before receiving associated NASA funding: For SpaceX, the augmentation milestones and associated funding will improve the chance of mission success by adding ground and flight testing, accelerating development of enhanced cargo capabilities, or further developing the ground infrastructure needed for commercial cargo capabilities. More specifically, the additional SpaceX milestones include rendezvous and proximity operations sensor testing, system level spacecraft testing (thermal vacuum electromagnetic interference, and acoustic testing), and infrastructure improvements at the launch, production and test sites.

For OSC, the augmentation milestones and associated funding will support a maiden test flight of the Taurus II in the October 2011 timeframe, thereby helping to significantly reduce the risks associated with a new launch vehicle development. The milestones also enable additional software and control system testing.

Commercial Resupply Services

The ISS has transitioned from the construction era to an operations and research era, with a six-person permanent crew, three major science labs, and an operational lifetime through at least 2020. The ISS is the largest crewed spacecraft ever assembled, measuring 243 by 356 feet, with a habitable volume of over 30,000 cubic feet and a mass of 846,000 pounds, and is powered by arrays which generate over 700,000 kilowatt-hours per year. The ISS represents a unique research capability, aboard which the United States and its partner nations can conduct a wide variety of research in biology, chemistry, physics and engineering fields that will help us better understand how to keep astronauts healthy and productive on long-duration space missions. In addition to conducting research in support of future human missions into deep space, astronauts aboard the ISS will carry out experiments with terrestrial applications.

While the ISS is serviced by a fleet of cargo vehicles, including the Russian Progress vehicle, European Automated Transfer Vehicle (ATV), and Japanese H–II Transfer Vehicle (HTV), NASA will be depending on U.S. industry to provide resupply services to and from the Station following the retirement of the Space Shuttle. On December 23, 2008, NASA awarded CRS contracts to OSC and SpaceX for the delivery of cargo to the ISS after the retirement of the Shuttle. The companies will enable operation of vehicles that can: 1) fly to the ISS orbit; 2) operate in close proximity to the ISS and other docked vehicles; 3) dock to ISS; and, 4) remain docked for extended periods of time. NASA anticipates that both providers will have their systems operational in 2012.

The CRS contracts are firm-fixed price, Indefinite Delivery Indefinite Quantity procurements with a period of performance through Dec. 30, 2015. The contract allows the contractor to make deliveries for one year following the end of the period of performance. This allows the contractors adequate time to complete missions ordered for CY 2015 that may move into CY 2016. The contracts are based on milestone payments scheduled in terms of months from launch, and the payment plan must meet the current requirements of the payment clause. For example, total milestone payments through Mission Integration Review shall not exceed 50 percent of the mission cost. The contracts allow the flexibility to add or modify mission payments in the work plans to accommodate specific mission tasks. Under Federal Acquisition Regulation (FAR) Pt. 12 commercial services contracts, payments are viewed as financing payments to the contractor. The government pays incrementally for an end item service to avoid the cost of financing that would be levied in the overall mission price if payment was not made until the end. This is a standard practice for launch services contract. Even though these are financing payments, the CRS contractors are required to demonstrate that they are making key progress toward providing the service and therefore the payments are typically tied to major reviews or manufacturing milestones.

NASA ordered 12 CRS flights valued at $1.59 billion from SpaceX.

- SpaceX will provide pressurized and unpressurized upmass and return services.
- SpaceX currently has completed 14 funding milestones for the four CRS missions in process in FY 2011. In addition, one more CRS mission may be turned on if progress continues. Finally, two milestones in support of COTS demonstration cargo have been paid.
- The schedule margin that existed when the CRS contracts were initially awarded has gotten smaller over the last two years. Parallel development and mission activities have been challenging for a relatively small company that depends heavily on in-house capabilities, yet both cargo and external integration activities have begun and are proceeding. This next year will demonstrate the company's ability to manage multiple missions. The first SpaceX CRS flight is currently scheduled for late January 2012, and the company is currently slated to fly three CRS missions each fiscal year from 2012 through 2015. The January 2012 date is dependent on SpaceX's successful completion of its COTS demo flights.

To date, NASA has paid SpaceX $181 million for 14 CRS mission milestones and $4.8 million for two demonstration cargo milestones (the latter from the above-mentioned augmentation funding).

NASA ordered eight CRS flights valued at $1.88 billion from OSC.

- OSC will provide pressurized upmass and disposal services.
- OSC currently has completed seven additional funding milestones for three CRS missions in process in FY 2011.
- OSC uses a different mission model than the in-house focused work of SpaceX—one which involves using proven suppliers. The distributed network of suppliers helps with the multiple mission flows, and OSC has demonstrated an understanding of cargo and mission integration interfaces and processes.
- The company is relying on NASA assets at Stennis Space Center in Mississippi (for engine testing) and Wallops Flight Facility (for launch vehicle processing and integration).
- The first OSC CRS flight is currently scheduled for the end of the first quarter of calendar year 2012, and the company is currently slated to fly two CRS missions each fiscal year from 2012 through 2015.

To date, NASA has paid OSC $273 million for 11 CRS mission milestones and $7.5 million for two demonstration cargo milestones (the latter from the above-mentioned augmentation funding).

NASA has considerable insight into the progress that SpaceX and OSC are making during the demonstration missions and for the CRS milestones that have been given Authority to Proceed, or are in process. The program has weekly meetings with representatives of the companies to discuss schedule and technical issues. Both CRS providers are making progress on their missions, and this year will be key to demonstrating that their mission profiles are achievable. A number of challenges confront both CRS providers, as even successful new rockets tend to require adjustments following their initial launches. In addition, new spacecraft themselves re-

quire adjustments—both ATV and HTV required upgrades between their first and second missions—and they must be integrated with their launch vehicles. Additional challenges arise from the difficulties inherent in mastering automated rendezvous, proximity operations, and docking with a crewed spacecraft. While these tasks have been demonstrated many times by the Russian Progress vehicle, and twice each by the European ATV and Japanese HTV, the technologies and techniques required for their achievement are difficult, but clearly not impossible, to develop.

All commercial cargo vehicles intended to dock or berth to the ISS must meet the same visiting vehicle standards for each of their ISS missions. These requirements are laid out in the ISS Visiting Vehicle Requirements document. These standards include requirements for automated rendezvous and joint proximity operations, physical and software interfaces, and overall safety. These requirements are consistent with those provided for the ATV and HTV. NASA has been working closely with the commercial partners through the demonstration phase and will continue to work with them through the CRS missions to ensure that each mission meets these requirements.

There is now little to no schedule margin for significant delays in the CRS missions, and this is a risk for consistent cargo resupply to the ISS. NASA is pre-positioning maintenance and logistics items on the final Space Shuttle mission as a contingency to mitigate any risk to ISS operations due to a delay in the availability of the CRS vehicles. The final Shuttle mission, STS–135, is targeted for launch in early July. During the STS–135 mission, Atlantis will carry the Raffaello multipurpose logistics module to deliver critical supplies, logistics and spare parts for the ISS, as well as a system to investigate the potential for robotically refueling existing spacecraft. This will help reduce the risk to ISS operations and maintenance should the CRS vehicles not meet their current launch dates. If the contracted commercial cargo services are not available at the beginning of calendar year 2012, there would be minimal impact to ISS operations. If commercial cargo services are not available by the end of calendar year 2012, there would be a reduction in utilization of the ISS. In that case, NASA would have to consider reducing the Station's crew size to three in order to conserve supplies; this would in turn result in a reduced ability to conduct research aboard ISS. The final Shuttle flight will give the ISS the flexibility to maintain a six-person crew into FY 2013 without any commercial cargo flights, effectively increasing the schedule margin by about a year.

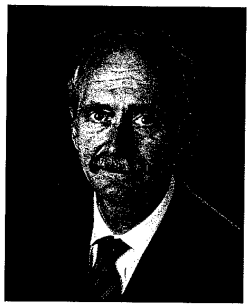
Another risk reduction option is the availability of the ATV and HTV spacecraft. NASA already relies on bartered cargo transportation services provided by the European Space Agency and the Japanese Aerospace Exploration Agency using these vehicles, and such barter agreements could be used to ensure a limited U.S. cargo delivery capacity, on the currently planned vehicles, as a stop-gap measure until the CRS vehicles are operationally available. NASA has also purchased cargo delivery services from the Russian Space Agency through 2011, though there are no plans to extend this service beyond the end of this year.

NASA has contracted for a minimum of 40 metric tons of cargo delivered to the ISS from 2011 through 2015 under the CRS contracts, and the Agency plans to continue to rely on CRS for cargo transportation beyond FY 2015. This will require new contract action by NASA. NASA is counting on its CRS suppliers to carry cargo to maintain the ISS. It is hoped that these capabilities, initially developed to serve the Station, may find other customers as well, and encourage the development of further space capabilities and applications and the LEO economy.

Summary

Chairman Palazzo and Members of this Subcommittee, I would summarize by saying again that NASA is pleased with the steady progress both companies continue to make in their cargo development efforts. I would also like to conclude my remarks by thanking you again for your continued support for NASA and its human spaceflight programs, including our commercial cargo efforts. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

Biography



William H. Gerstenmaier
Associate Administrator for Space Operations

Graduated from East High School, Akron, OH in 1973; received a bachelor of science in aeronautical engineering from Purdue University, in 1977; and a Master of Science degree in mechanical engineering from the University of Toledo in 1981; and completed course work for a Ph.D. in dynamics and control with a minor in propulsion at Purdue University 1992 & 1993.

Residence:
Washington, DC

Marital Status:
Married to the former Marsha Ann Johnson, Houston, TX

Children:
Katie S., February 26, 1983, and Lora K., November 24, 1986.

Current Assignment:
William H. Gerstenmaier is the Associate Administrator for Space Operations at NASA Headquarters in Washington, DC. In this position, Gerstenmaier directs NASA's human exploration of space. He also has programmatic oversight for the International Space Station, Space Shuttle, space communications and space launch vehicles.

Special Honors and Awards:
Certificate of Commendation -1981, Certificate of Commendation -1987. Certificate of Commendation - 1991. NASA Exceptional Service Medal - 1992. Aviation Week & Space Technology Laurels Award for Outstanding Achievement in the Field of Space – 1996, Rotary Stellar Award -1997. NASA Exceptional Service Medal -1999. Senior NASA Outstanding Leadership Medal - 2001. Twice awarded the Aviation Week & Space Technology's Laureate Award for" Outstanding Achievement in the Field of Space." Meritorious Executive Presidential Rank Award for - 2003; Outstanding Aerospace Engineer Award, Purdue University - 2003, Distinguish Executive Presidential Rank Award – 2005; AIAA International Cooperation Award – 2005. The National Space Club Astronautics Engineer Award - 2006, National Space Club Von Braun Award – 2006; the Federation of Galaxy Explores, Space Leadership Award 2007, AIAA International Award 2006, the AIAA Fellow- 2007; Purdue University Distinguished Alumni Award and Honored at Perdue as an Old Master in the Old Masters Program 2008; and recipient of the 2010 Rotary National Award for Space Achievement's National Space Trophy (RNASA).

Experience:
1977-1980 Mr. Gerstenmaier began his NASA career at NASA Lewis performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

1988-1990 Mr. Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at Johnson Space Center (JSC). He was responsible for all aspects of OMV operations at JSC, including development of a ground control center and training facility for OMV, operations support to vehicle development, and personnel and procedures development to support OMV operations.

1990-1992 Mr. Gerstenmaier was head of Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division. He was responsible for resolving technical assembly issues and developing assembly strategies.

1994-1995 Mr. Gerstenmaier was Chief, Projects and Facilities Branch, Flight Design and Dynamics Division, which oversaw all projects managed within the division including an upgrade of trajectory processes and software required for Space Shuttle ascent performance enhancements needed to support Space Station flights.

1995-1997 Mr. Gerstenmaier was Shuttle/Mir Program Operations Manager, serving as primary interface to the Russian Space Agency for operational issues. He negotiated all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations from Russia, January 1996 through September 1996 that included responsibility for daily activities as well as the health and safety of NASA crewmember on Mir. He scheduled science activities, public affairs activities, monitored Mir systems and communicated with the NASA astronaut on Mir.

1998-2000 In 1998, Mr. Gerstenmaier was named Manager, Space Shuttle Program Integration, responsible for the overall management, integration, and operations of the Space Shuttle Program. This included development and operations of all Space Shuttle elements, including the orbiter, external tank, solid rocket boosters, and Space Shuttle main engines as well as the facilities required to support ground processing and flight operations.

2000-2002 In December 2000, Mr. Gerstenmaier was named Deputy Manager, International Space Station Program. He shared associate responsibility for the day-to-day management, development, integration, and operation of the International Space Station. This included recommending and implementing Program policy; establishing and controlling scheduling; planning and directing the Program's development, test, production, and operations; managing the integration of all elements of the Program into a single operational system; ensuring effective cost control of the total Program; and establishing and controlling requirements and configuration.

2002-2005 As Manager, International Space Station Program, Mr. Gerstenmaier was responsible for the overall management, development, integration, and operation of the International Space Station. This included the design, manufacture, testing, and delivery of complex space flight hardware and software, and for its integration with the elements from the International Partners into a fully functional and operating International Space Station.

December 2010

Chairman PALAZZO. Thank you, Mr. Gerstenmaier.

I now recognize our second witness, Ms. Cristina Chaplain, Director of Acquisition and Sourcing Management for the U.S. Government Accountability Office.

STATEMENT OF MS. CRISTINA CHAPLAIN, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Ms. CHAPLAIN. Mr. Chairman and acting Ranking Member Costello, thank you for asking the GAO's views for today's hearing. Our testimony provides more details on the current status of the COTS Program, reasons for delays, milestones that have been recently added, and our perspectives on the use of Space Act Agreements for COTS.

I would like to make a few points based on our COTS work as well as broader work on government space acquisitions. We assessed the COTS Program in 2009, and found that the program incorporated criteria and processes that help provide insight into the progress of the COTS providers. We also found that while progress had been made in developing the COTS vehicles, there were development risks that could slow down the effort and schedules were aggressive.

Since our report the COTS partners have experienced schedule delays. The delays reflect a combination of inherent risks associated with development efforts and some schedule optimism. NASA has added money to further stem delays as well as reduce risks. For example, by adding testing activities it would normally undertake in the development of its own launch vehicles and spacecraft.

NASA is also taking steps to lessen the impact of the COTS delay on the utilization of the ISS, for example, by pre-positioning spares. These steps seem reasonable, particularly because the landscape for COTS has changed considerably since our last report. Principally, when COTS was started, NASA envisioned that the Ares launch vehicle and Orion Capsule would be available to initially service the Space Station. Now it is unknown when any mass of vehicles will be available, and reliance on COTS has grown. In other words, the COTS Program has been elevated from plan B to plan A.

While reasonable steps are being taken to address risks, there is still no guarantee that this approach will deliver results when needed. It is likely additional delays will occur, and additional money may be needed. At the same time, it is important to recognize a significant amount of progress has been made within a relatively short period of time and within a reasonable cost. Moreover, the approach offers NASA lessons in new ways of doing business.

In addition, regardless of whether NASA is acquiring a capability or service under traditional contracts or more non-traditional arrangements like Space Act Agreements, it is important that the fundamentals of good management persist. These include ensuring decisions are based on concrete quantitative and qualitative knowledge, delaying program starts until critical technologies are invented and understood, developing sound cost and schedule estimates, providing transparency and accountability for oversight,

having the right incentives for partners, and having strong risk management plans and practices.

Overall, we have found that these fundamentals tend not to be fully present in either traditional or commercial-like approaches. Going forward it will be important for both NASA and the commercial sector to also avoid hinging strategies on assumptions that we know negatively impacted previous efforts to adopt commercial-like approaches in space. These assumptions include such things as one, a commercial-like approach requires very little or no government involvement, and two, by backing off the government is guaranteed it will receive a product faster, better, and cheaper.

In conclusion, given the critical need, the government bears the risk for having to make additional investments to get what it wants when it wants. The additional investment required, however, can be lessened by ensuring that accurate knowledge about requirements, costs, schedule, and risk is achieved early on and used to make decisions.

Thank you. This concludes my statement.

[The prepared statement of Ms. Chaplain follows:]

United States Government Accountability Office

GAO

Testimony

Before the Subcommittee on Space and Aeronautics, Committee on Science, Space and Technology, House of Representatives

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COMMERCIAL LAUNCH VEHICLES

NASA Taking Measures to Manage Delays and Risks

Statement of Cristina T. Chaplain, Director
Acquisition and Sourcing Management

GAO-11-692T

May 26, 2011

GAO
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Highlights

Highlights of GAO-11-692T, a report to the Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology, House of Representatives

COMMERCIAL LAUNCH VEHICLES

NASA Taking Measures to Manage Delays and Risks

Why GAO Did This Study

Since the National Aeronautics and Space Administration (NASA) created the strategy for the Commercial Orbital Transportation Services (COTS) project in 2005, the space landscape has changed significantly—the Space Shuttle program is retiring and the Ares I will not be available—increasing the importance of the timely development of COTS vehicles. The lack of alternatives for supplying the International Space Station and launching science missions have all contributed to an increased need for the COTS vehicles. The two COTS project partners, Orbital and SpaceX, have made progress in the development of their respective vehicles; however, both providers are behind schedule. As a result, the project recently received an additional $300 million to augment development efforts with risk reduction milestones.

This testimony focuses on: (1) COTS development activities, including the recent funding increase; (2) the extent to which any COTS demonstration delays have affected commercial resupply services (CRS) missions and NASA's plans for meeting the space station's cargo resupply needs; and (3) lessons learned from NASA's acquisition approach for COTS.

To prepare this statement, GAO used its prior relevant work and conducted additional audit work, such as analyzing each partner's agreement with NASA and interviewing NASA officials. New data in this statement was discussed with agency and company officials who provided technical comments, which we included as appropriate.

View GAO-11-692T or key components. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

SpaceX and Orbital continue to make progress completing milestones under their COTS agreements with NASA, but both partners are working under aggressive schedules and have experienced delays in completing demonstration missions. SpaceX successfully flew its first demonstration mission in December 2010, but the mission was 18 months late and the company's second and third demonstration missions have been delayed by almost 2 years due to design, development, and production challenges with the Dragon spacecraft and Falcon 9 launch vehicle. Orbital faced technical challenges developing the Taurus II launch vehicle and the Cygnus spacecraft and in constructing launch facilities, leading to multiple delays in completing program milestones, including its demonstration mission. NASA has amended its agreements with the partners to include a number of new milestones, such as additional ground and flight tests, to reduce remaining developmental and schedule risks; most of the new milestones completed thus far were finished on time, but many milestones remain.

Based on the current launch dates for SpaceX's and Orbital's upcoming COTS demonstration missions, it is likely that neither will launch its initial CRS mission on time, but NASA has taken steps to mitigate the short-term impact to the space station. The launch windows for SpaceX's first and second CRS flights are scheduled to occur either before or during its upcoming COTS demonstration flights and will need to be rescheduled. Orbital's first CRS flight will also likely shift due to a Taurus II test flight. NASA officials said that the agency will have to renegotiate the number of flights needed from each partner and re-baseline the launch windows for future CRS missions once COTS demonstration flights are completed. NASA has taken steps to mitigate the short-term impact of CRS delays through prepositioning of cargo, some of which will be delivered on the last space shuttle flight. Despite these efforts, NASA officials said they would still need one flight in 2012 from SpaceX's and Orbital's vehicles to meet science-related cargo needs.

In considering the use of a Space Act agreement for COTS, NASA identified several advantages. These advantages include sharing costs with agreement partners and promoting innovation in the private sector. A disadvantage, however, is that NASA is limited in its ability to influence agreement partners in their approach. At the time the agreements were awarded, NASA was willing to accept the risks of using a Space Act agreement given the goals of the project and alternative vehicles that were available to deliver goods to the space station. As the project has progressed, however, and these alternatives are no longer viable or available, NASA has become less willing to accept the risk involved and has taken steps aimed at risk mitigation. Given a critical need, the risk is present that the government will be required to make additional investments to meet mission needs. The amount of investment can be lessened by ensuring that accurate knowledge about requirements, cost, schedule, and risks is achieved early on. GAO has made recommendations to NASA and NASA is taking steps to help ensure that these fundamentals are present in its major development efforts to increase the likelihood of success.

Mr. Chairman and Members of the Subcommittee:

Thank you for inviting me here today to discuss the status of the National Aeronautics and Space Administration's (NASA) Commercial Orbital Transportation Services (COTS) project. GAO conducted work examining the COTS project in 2009 and reported that progress was being made, but several risks persisted given aggressive project schedules.[1] Since NASA devised its strategy for the COTS project in 2005, the space landscape has changed quite significantly, increasing the importance of the timely development and success of COTS vehicles to NASA. Specifically, with the impending retirement of the space shuttle in July 2011, the United States will lack a domestic capability to send crew and cargo to the International Space Station and face a cargo resupply shortfall between 2012 and 2020 that cannot be met by international partners' space vehicles alone.[2] The Ares I project, which was originally intended to be operational in 2010 and to fill the gap between the retirement of the Space Shuttle program and the availability of the COTS vehicles, pushed its launch readiness date to 2015 and is now being restructured into a new program that will not be operational until at least 2016. Further, the Delta II launch vehicle, which has carried the majority of NASA's science missions over the last several years, is retiring, the impact of which is beginning to be felt by NASA's science projects.[3] These changes have resulted in an increased need for the vehicles being developed for COTS not only to address the cargo resupply shortfall as intended, but also to support a large number of future science missions at a reasonable cost to NASA. While COTS partners have made progress in the development of their vehicles, they have also experienced delays and NASA has provided additional funding to the partners to reduce the risk that their vehicles would experience further delays.

Against this backdrop, my testimony today will focus on: (1) the COTS development activities, including a discussion of the need for the recent

[1]GAO, *NASA: Commercial Partners Are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities*, GAO-09-618 (Washington, D.C.: June 16, 2009).

[2]International partners' vehicles include the Russian Federal Space Agency's Progress (cargo) and Soyuz (crew), the European Space Agency's Automated Transfer Vehicle (cargo), and the Japan Aerospace Exploration Agency's H-II Transfer Vehicle (cargo).

[3]GAO, *NASA: Medium Launch Transition Strategy Leverages Ongoing Investments but is Not Without Risk*, GAO-11-107 (Washington, D.C.: Nov. 22, 2010).

funding augmentation; (2) the extent to which any COTS demonstration delays have affected Commercial Resupply Services (CRS) missions to the space station and NASA's plans for meeting space station cargo resupply needs; and (3) lessons learned from NASA's acquisition approach for COTS.

In preparing this statement, we relied on our prior report related to the COTS project and conducted additional audit work in May 2011 to update information from that report.[4] Specifically, we analyzed each COTS partner's agreement with NASA, amendments to those agreements, documentation from NASA and partner quarterly program management reviews, and each partner's CRS contract. We interviewed NASA COTS and International Space Station program officials and company officials. We discussed new information presented in this statement with agency and company officials who provided technical comments that we incorporated as appropriate. Our prior work on the COTS project, as well as the work conducted for this statement, was performed in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

In 2004, President George W. Bush announced his Vision for Space Exploration that included direction for NASA to pursue commercial opportunities for providing transportation and other services to support the space station after 2010. When the project was established in 2005, the approach that NASA laid out was a marked change in philosophy for how the agency planned to service the space station—by encouraging innovation in the private sector with the eventual goal of buying services at a reasonable price. As a result, the agency chose to utilize its other transaction authority under the National Aeronautics and Space Act of 1958,[5] as opposed to a more traditional Federal Acquisition Regulation (FAR) based contract. Generally speaking, other transaction authority

[4]GAO-09-618.

[5]Pub. L. No. 85-568, § 203 (1958). This act is commonly referred to as the Space Act and agreements signed utilizing NASA's other transaction authority are known as Space Act agreements.

enhances the government's ability to acquire cutting-edge science and technology, in part through attracting companies that typically have not pursued government contracts because of the cost and impact of complying with government procurement requirements. These types of agreements are not considered federal government contracts, and are therefore generally not subject to those federal laws and regulations that apply to federal government contracts.

NASA established the Commercial Crew and Cargo program office at Johnson Space Center in 2005 and budgeted $500 million for fiscal years 2006 through 2010 for the development and demonstration of cargo transport capabilities. COTS partners, Orbital Sciences Corporation (Orbital) and Space Exploration Technologies Corporation (SpaceX), have also made significant investments in developing these capabilities. The COTS project was originally intended to be executed in two sequential phases: (1) private industry development of cargo transport capabilities in coordination with NASA and (2) procurement of commercial resupply services to the space station once cargo transport capabilities had been successfully demonstrated. In August 2006, NASA competitively awarded a $278 million Space Act agreement to SpaceX to develop and demonstrate end-to-end transportation systems, including the development of the Falcon 9 launch vehicle and Dragon spacecraft, ground operations, and berthing with the space station. In February 2008, NASA awarded a $170 million Space Act agreement to Orbital to develop two COTS cargo capabilities, unpressurized and pressurized[6] cargo delivery and disposal, to culminate in one demonstration flight of its Taurus II launch vehicle and Cygnus spacecraft.[7]

Before either partner had successfully demonstrated its COTS cargo transport capabilities, the International Space Station program office awarded two CRS contracts in December 2008 to Orbital and SpaceX under a separate competitive procurement from COTS. These FAR-based contracts were for the delivery of at least 40 metric tons (approximately

[6]Pressurized cargo refers to cargo that is carried inside the spacecraft. This cargo includes items such as food, water, and materials to support scientific experiments.

[7]NASA originally awarded a $207 million Space Act agreement to Rocketplane Kistler (RpK), but the agreement was terminated in October 2007 after RpK had missed technical and financial milestones. Subsequently, Orbital was awarded the remaining funds—$170 million. In March 2009, Orbital and NASA amended this agreement, removing its unpressurized cargo demonstration and replacing it with a pressurized demonstration, scheduled for March 2011.

88,000 pounds) to the space station between 2010 and 2015. Orbital was awarded 8 cargo resupply missions for approximately $1.9 billion and SpaceX was awarded 12 cargo resupply missions for approximately $1.6 billion.

In June 2009, we found that while SpaceX and Orbital had made progress against development milestones, the companies were working under aggressive schedules and had experienced schedule slips that delayed upcoming demonstration launch dates by several months. In addition, we reported that the vehicles being developed through the COTS project were essential to NASA's ability to fully utilize the space station after its assembly was completed and the space shuttle was retired. Finally, we found that NASA's management of the COTS project generally adhered to critical project management tools and activities.

Since our 2009 report, the two COTS project partners, Orbital and SpaceX, have made progress in the development of their respective vehicles. SpaceX successfully flew its first COTS demonstration mission in December 2010 and Orbital is planning to fly its COTS demonstration mission in December 2011. Both providers, however, are behind schedule—SpaceX's first COTS demonstration mission slipped 18 months and Orbital's first mission was initially planned for March 2011. Such delays are not atypical of development efforts, especially efforts that are operating under such aggressive schedules. Nonetheless, the criticality of these vehicles to the space station's operations, as well as NASA's ability to affordably execute its science missions has heightened the importance of their timely and successful completion and lessened the level of risk that NASA is willing to accept in this regard. As a result, the project recently requested and received an additional $300 million to augment the partner development efforts with, according to NASA, risk reduction milestones.

Demonstration Missions Have Been Delayed, but Progress Against New Milestones Could Reduce Further Technical and Schedule Risk

SpaceX: Performance Against Prior Milestones

SpaceX has successfully completed 18 of 22 milestones to date, but has experienced lengthy delays in completing key milestones since we last reported on the company's progress in June 2009. SpaceX's agreement with NASA established 22 development milestones that SpaceX must complete in order to successfully demonstrate COTS cargo capabilities. SpaceX's first demonstration mission readiness review was completed 15 months behind schedule and its successful first demonstration mission was flown in December 2010, 18 months late. The company's second and third demonstration missions have been delayed by almost 2 years to November 2011 and January 2012, respectively.[8] Several factors contributed to the delay in SpaceX's first demonstration mission readiness review and demonstration mission. These factors include, among others, delays associated with (1) launching the maiden Falcon 9 (non-COTS mission), such as Falcon 9 software and database development; (2) suppliers; (3) design instability and production; (4) Dragon spacecraft testing and software development; and (5) obtaining flight safety system approval. For example, SpaceX encountered welding issues during production of the Dragon propellant tanks and also had to redesign the Dragon's battery.

In preparing for its second COTS demonstration flight, SpaceX has experienced additional design, development, and production delays. For example, several propulsion-related components needed to be redesigned,

[8]According to the COTS program manager, NASA is also discussing with SpaceX about the possibility of combining the second and third demonstration missions into a single mission. SpaceX officials told us they have already begun building the Dragon spacecraft for the second COTS demonstration mission so that it can be fully capable of berthing with the space station.

the Dragon spacecraft's navigation sensor experienced development testing delays, and delays were experienced with launch vehicle tank production. For example, SpaceX's decision to incorporate design changes to meet future CRS mission requirements has delayed the company's second demonstration mission. Integration challenges on the maiden Falcon 9 launch and the first COTS demonstration mission have also kept SpaceX engineers from moving on to the second COTS demonstration mission.

SpaceX officials cited the completion of Dragon development efforts, NASA's safety verification process associated with berthing with the space station, and transitioning into efficient production of the Falcon 9 and Dragon to support space station resupply missions as key drivers of technical and schedule risk going forward. For completing 18 of the 22 milestones, SpaceX has received $258 million in milestone payments thus far, with $20 million yet to be paid. Appendix I describes SpaceX's progress meeting the COTS development milestones in its agreement with NASA.

Orbital: Performance Against Prior Milestones

Orbital has successfully completed 15 of 19 COTS milestones to date—8 more than when we initially reported on the program in June 2009. Programmatic changes and developmental difficulties, however, have led to multiple delays of several months' duration and further delays are projected for completing the remaining milestones. For example, according to Orbital officials, the demonstration mission of Orbital's Taurus II launch vehicle and Cygnus spacecraft has been delayed primarily due to an increase in design effort to develop a pressurized cargo carrier in place of the original Cygnus unpressurized cargo design. After NASA awarded Orbital a CRS contract for eight pressurized cargo missions, NASA and Orbital amended their COTS demonstration agreement to replace the unpressurized cargo demonstration mission with a pressurized cargo demonstration. This delayed existing milestones, and the schedule was revised to shift the COTS demonstration mission from December 2010 to March 2011. Since that time, the schedule for some of Orbital's milestones has been revised again and the demonstration mission is now planned for December 2011.

COTS program and Orbital officials also noted technical challenges as reasons for milestone delays. For example, Orbital officials said there are several critical Taurus II engine and stage one system tests that need to be completed by the end of the summer, but that the risk inherent in these tests is mitigated through an incremental approach to testing. Specifically, single engine testing has been successfully completed, and testing will be

extended this summer to the full stage one (i.e., two-engine) testing. COTS program and Orbital officials also noted delays in Cygnus avionics manufacturing, primarily driven by design modifications aimed at increasing the safety and robustness of the system. According to these officials, integration and assembly of the first Cygnus spacecraft has begun and is now in the initial electrical testing phase.

Additionally, the completion of the company's launch facilities at the Mid-Atlantic Regional Space Port in Wallops Island, Virginia, remains the key component of program risk. NASA COTS program and Orbital officials cite completion of the Wallops Island launch facilities as the critical factor for meeting the COTS demonstration mission schedule. Orbital officials said additional resources have been allocated to development of the launch complex to mitigate further slips, and an around-the-clock schedule will be initiated later this summer to expedite the completion of verification testing of the liquid fueling facility, which is the primary risk factor in completing the launch facility.

For completing 15 of the 19 milestones, Orbital has received $157.5 million, with $12.5 million remaining to be paid. Appendix I depicts Orbital's progress in meeting the COTS development milestones in its agreement with NASA.

Risk Reduction Milestones Recently Added to COTS Agreements

In addition to the prior milestones negotiated under the COTS project, NASA has amended its agreements with SpaceX and Orbital to include a number of additional milestones aimed at reducing remaining developmental and schedule risks. COTS officials told us that some milestones reflect basic risk reduction measures, such as thermal vacuum testing, that NASA would normally require on launch vehicle or spacecraft development. A series of amendments were negotiated from December 2010 to May 2011 after Congress authorized $300 million for commercial cargo efforts in fiscal year 2011. These amendments add milestones to (1) augment ground and flight testing, (2) accelerate development of enhanced cargo capabilities, or (3) further develop the ground infrastructure needed for commercial cargo capabilities. These milestones were added incrementally due to NASA operating under continuing resolutions through the first half of fiscal year 2011.

In May 2009, the President established a Review of U.S. Human Space Flight Plans Committee composed of space industry experts, former astronauts, government officials, and academics.[9] In its report, the committee stated that it was concerned that the space station, and particularly its utilization, may be at risk after Shuttle retirement as NASA would be reliant on a combination of new international vehicles and as-yet-unproven U.S. commercial vehicles for cargo transport. The committee concluded that it might be prudent to strengthen the incentives to the commercial providers to meet the schedule milestones. NASA officials stated that if funding were available, negotiating additional, risk reduction milestones would improve the chance of mission success, referring specifically to the companies' COTS demonstration missions. Of the $300 million, $236 million, divided equally between SpaceX and Orbital, will be paid upon completion of the additional milestones.[10] Additionally, NASA officials stated the International Space Station program office will pay SpaceX and Orbital $10 million each to fund early cargo delivery to the space station on the companies' final COTS demonstration missions. The COTS program manager stated that SpaceX and Orbital recognize their responsibility under the COTS agreements for any cost overruns associated with their development efforts, and that the companies did not come to NASA with a request for additional funding.

SpaceX has completed 4 of its new milestones on time but has experienced minor delays in completing 3 others. SpaceX's agreement with NASA was amended three times between December 2010 and May 2011 to add 18 development milestones that SpaceX must complete in order to successfully demonstrate COTS cargo capabilities. Some of the new milestones, for example, are designed to increase NASA's confidence that SpaceX's Dragon spacecraft will successfully fly approach trajectories to the space station while others are intended to improve engine acceptance rates and vehicle production time frames. Milestones completed thus far include a test of the spacecraft's navigation sensor and thermal vacuum tests. For completing 7 of the 18 milestones, SpaceX has

[9]Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation* (Washington, D.C.: October 2009).

[10]The COTS program manager reported that $34 million of the $300 million was for NASA Headquarters and Johnson Space Center program support and administration as well as technical and mission support for the remaining COTS demonstration flights and $10 million would be spent on milestone payments for Orbital's Milestones 20 and 21 and SpaceX's Milestone 22.

received $40 million in milestone payments thus far, with $78 million yet to be paid.

Orbital has completed 4 of its 10 new milestones on schedule and 1 of the new milestones was delayed by about 1 month. In concurrence with NASA's request, Orbital agreed to add an initial flight test of the Taurus II launch vehicle to reduce overall cargo service risk. The test flight not only separates the risks of the first flight of Taurus II from the risks of the first flight of the Cygnus spacecraft, but provides the opportunity to measure the Taurus II flight environments using an instrumented Cygnus mass simulator. The Taurus II test flight is scheduled for October 2011. Overall technical risks associated with Cygnus development are expected to be reduced through additional software and avionics tests. Milestones completed thus far include early mission analyses and reviews, as well as delivery of mission hardware. For completing the first 5 new milestones, Orbital has received $69 million, with $49 million remaining to be paid. Appendix I describes SpaceX's and Orbital's progress meeting the new COTS development milestones in their agreements with NASA.

COTS Delays Will Likely Cause Resupply Flights to Slip, but NASA Has Taken Steps to Mitigate Short-Term Impact

Based on the current launch dates for SpaceX's and Orbital's upcoming COTS demonstration missions, it is likely that both commercial partners will not launch their initial CRS missions on time, but NASA has taken steps to mitigate the short-term impact to the space station. The launch window for SpaceX's first CRS flight is from April to June 2011 and from October to December 2011 for its second CRS flight. These launch windows are either scheduled to occur before or during SpaceX's upcoming COTS demonstration flights and thus will need to be rescheduled. In the case of Orbital, NASA officials told us that the launch window for its first CRS flight is from January to March 2012, but will likely slip from those dates given the Taurus II test flight added to its milestone schedule. NASA officials added that once SpaceX and Orbital have finished completing their COTS demonstration flights, NASA will have to renegotiate the number of flights needed from each partner and re-baseline the launch windows for future CRS missions.

International Space Station program officials told us they have taken steps to mitigate the short-term impact of CRS flight delays through prepositioning of cargo on the last space shuttle flights, including cargo that is being launched on the planned contingency space shuttle flight in early July 2011. Officials added that these flights and the planned European Space Agency's Automated Transfer Vehicle and Japan's H-II Transfer Vehicle flights in 2012 will carry enough cargo to sustain the six

person space station crew through 2012 and to meet science-related cargo needs through most of 2012. Despite these steps, NASA officials said they would still need one flight each from SpaceX's and Orbital's vehicles in order to meet science-related cargo needs in 2012. Beyond 2012, NASA is highly dependent on SpaceX's and Orbital's vehicles in order to fully utilize the space station. For example, we reported in April 2011 that 29 percent of the flights planned to support space station operations through 2020 were dependent on those vehicles.[11] In addition, NASA officials confirmed that the agency has no plans to purchase additional cargo flights on Russian Progress vehicles beyond 2011 and the European Space Agency and the Japan Aerospace Exploration Agency have no current plans to manufacture additional vehicles beyond their existing commitments or to accelerate production of planned vehicles. We reported previously that if the COTS vehicles are delayed, NASA officials said they would pursue a course of "graceful degradation" of the space station until conditions improve. In such conditions, the space station would only conduct minimal science experiments.[12]

Even With Identified Advantages, NASA Has Taken Measures to Address Risks to COTS Strategy

NASA's intended use of the COTS Space Act agreements was to stimulate the space industry rather than acquiring goods and services for its direct use. Traditional FAR contracts are to be used when NASA is procuring something for the government's direct benefit.[13] NASA policy provides that funded Space Act agreements can only be used if no other instrument, such as a traditional FAR contract, can be used.[14] Therefore, Space Act agreements and FAR-based contracts are to be used for different purposes. In considering the use of funded Space Act agreements for COTS, NASA identified several advantages. For example:

- The government can share costs with the agreement partner with fixed government investment.
- Payment to partner is made only after successful completion of performance-based milestones.

[11]GAO, *International Space Station (ISS) – Ongoing Assessments for Life Extension Appear to be Supported*, GAO-11-519R (Washington, D.C.: Apr. 11, 2011).

[12]GAO, *International Space Station: Significant Challenges May Limit Onboard Research*, GAO-10-9 (Washington, D.C.: Nov. 25, 2009).

[13]31 U.S.C. § 6303.

[14]NASA Policy Directive 1050.1I, Authority to Enter into Space Act Agreements (Dec. 23, 2008).

- The government can terminate the agreement if the partner is not reasonably meeting milestones.
- Limited government requirements allow optimization of systems to meet company's commercial business needs.

These types of agreements can also have disadvantages, however. For example, Space Act agreements may have more limited options for oversight as compared to other science mission and human spaceflight development efforts that are accomplished under more traditional FAR contracts. NASA identified other disadvantages of using a Space Act agreement. For example:

- The government has limited ability to influence agreement partners in their approach.
- The government lacks additional management tools (beyond performance payments at milestones) to incentivize partners to meet technical and schedule performance.

Given the intended goals of the project and the availability of alternative vehicles to deliver goods to the space station when the COTS agreements were signed, NASA was willing to accept the risks associated with the disadvantages of using a Space Act agreement.[15] As the project has progressed, however, and these alternatives are no longer viable or available, NASA has become less willing to accept the risks involved. As a result, the agency took steps aimed at risk mitigation, primarily through additional funding.

I would like to point out that neither Space Act agreements nor more traditional FAR contracts guarantee positive outcomes. Further, many of the advantages and disadvantages identified by NASA for using a Space Act agreement can also be present when using FAR-based contracts, depending on how the instrument is managed or written. For example, both a FAR contract and a Space Act agreement can provide for cost sharing and the government also has the ability to terminate a FAR contract or a Space Act agreement if it is dissatisfied with performance.

[15]NASA goals were to: (1) implement Space Exploration policy with investments to stimulate the commercial space industry; (2) facilitate U.S. private industry demonstrations of cargo and crew space transportation capabilities with the goal of achieving safe, reliable, cost-effective access to low-Earth orbit; and (3) create a market environment where commercial services are available to the government and private sector customers.

The ineffective management of the instrument can be an important contributor to poor outcomes. For example, although a Space Act agreement may lack management tools to incentivize partners, we have reported in the past that award fees, which are intended to incentivize performance on FAR-based contracts, are not always applied in an effective manner or even tied to outcomes.[16] Additionally, the oversight that NASA conducts under a FAR-based contract has not always been used effectively to ensure that projects meet cost and schedule baselines.[17]

Even with the advantages and disadvantages that can be present in various instruments, given a critical need, the government bears the risk for having to make additional investments to get what it wants, when it wants it. The additional investment required, however, can be lessened by ensuring that accurate knowledge about requirements, cost, schedule, and risks is achieved early on. We have reported for years that disciplined processes are key to ensuring that what is being proposed can actually be accomplished within the constraints that bind the project, whether they are cost, schedule, technical, or any other number of constraints.[18] We have made recommendations to NASA and NASA is taking steps to address these recommendations to help ensure that these fundamentals are present in its major development efforts to increase the likelihood of success.

Mr. Chairman, this concludes my prepared statement. I would be happy to respond to any questions you may have at this time.

[16]GAO, *NASA Procurement: Use of Award Fees for Achieving Program Outcomes Should Be Improved*, GAO-07-58 (Washington, D.C.: Jan. 17, 2007).

[17]GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-11-239SP (Washington, D.C.: Mar. 3, 2011).

[18]GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-09-306SP (Washington, D.C.: Mar. 2, 2009); GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-10-227SP (Washington, D.C.: Feb. 1, 2010); and GAO-11-239SP.

Appendix I: COTS Partners' Progress Completing Prior and New Milestones

Table 1: SpaceX's Progress Completing Prior COTS Development Milestones

Milestone number	Milestone description	Scheduled completion date	Completed on time (Yes/No)	Delay if applicable (months)	Payment amount (millions)
1	Project Management Plan Review	Sept. 2006	Y	-	$23.1
2	Demo 1 System Requirements Review	Nov. 2006	Y	-	$5
3	Demo 1 Preliminary Design Review	Feb. 2007	Y	-	$18.1
4	Financing Round 1	Mar. 2007	Y	-	$10
5	Demo 2 System Requirements Review	Mar. 2007	Y	-	$31.1
6	Demo 1 System Critical Design Review	Aug. 2007	Y	-	$8.1
7	Demo 3 System Requirements Review	Oct. 2007	Y	-	$22.3
8	Demo 2 Preliminary Design Review	Dec. 2007	Y	-	$21.1
9	Draco Initial Hot-Fire	Mar. 2008	Y	-	$6
10	Financing Round 2	Mar. 2008	Y	-	$10
11	Demo 3 Preliminary Design Review	Jun. 2008	Y	-	$22
12	Multi-engine Test	Sept. 2008	Y	-	$22
13	Demo 2/Demo 3 System Critical Design Review	Dec. 2008	Y	-	$25
14	Financing Round 3	Mar. 2009	Y	-	$10
15	Demo 1 Readiness Review	Mar. 2009	N	15	$5
16	Communications Unit Flight Unit Design, Accept, Delivery	May 2009	N	2	$9
17	Demo 1 Mission	Jun. 2009	N	18	$5
18	Demo 2 Readiness Review	Sept. 2009[a]	N	24 (projected)	$5
19	Demo 2 Mission	Nov. 2009[a]	N	24 (projected)	$5
20	Cargo Integration Demonstration	Jan. 2010	Y	-	$5
21	Demo 3 Readiness Review	Jan. 2010[a]	N	23 (projected)	$5
22	Demo 3 Mission	Mar. 2010[a]	N	22 (projected)	$5
				Total:	**$278 million for the completion of all milestones** **$258 million paid to date**

Source: NASA and SpaceX.

[a]NASA is currently reviewing a proposed amendment that would change the completion dates for milestones 18, 19, 21, and 22. In particular, Demo Mission 2 (milestone 19) would take place in November 2011 and Demo Mission 3 in January 2012.

Table 2: Orbital's Progress Completing Prior COTS Development Milestones

Milestone number	Milestone description	Scheduled completion date	Completed on time (Yes/No)	Delay, if applicable (months)	Payment amount (millions)
1	Program Plan Review	Mar. 2008	Y	-	$10
2	Demo Mission System Requirements Review	Jun. 2008	Y	-	$20
3	Unpressurized Cargo Module Preliminary Design Review	Jul. 2008	Y	-	$10
4	DELETED COTS System Preliminary Design Review was milestone 4, but it has been renumbered as milestone 10	No longer applicable	No longer applicable	-	No longer applicable
5	COTS Integration/Operations Facility Review	Sept. 2008	Y	-	$10
6	Pressurized Cargo Module Preliminary Design Review	Oct. 2008	Y	-	$10
7	DELETED Unpressurized Cargo Module Critical Design Review	No longer applicable	No longer applicable	-	No longer applicable
8	Instrumentation Program and Command List	Feb. 2009	Y	-	$10
9	Completion of ISS Phase 1 Safety Review	Mar. 2009	Y	-	$10
10	COTS System Preliminary Design Review	Apr. 2009	N	1	$20
11	DELETED Unpressurized Cargo Module Fabrication Started	No longer applicable	No longer applicable	-	No longer applicable
11	Pressurized Cargo Module Critical Design Review	Jul. 2009	Y	-	$10
12	Cygnus Avionics Test	Aug. 2009	Y	-	$10
13	Completion of ISS Phase 2 Safety Review	Aug. 2009	N	3	$10
14	COTS System Critical Design Review	Sept. 2009	N	6	$10
15	Service Module Core Assembly Completed	Dec. 2009	N	8	$7.5
16	Service Module Test Readiness Review	Apr. 2010	N	7	$7.5
17	Service Module Initial Comprehensive Performance Test	Jul. 2010[a]	N	11 (projected)	$5
18	Launch Vehicle Stage 1 Assembly Complete	Oct. 2010[a]	N	11 (projected)	$2.5
19	Cargo Integration Demonstration	Dec. 2010	Y	-	$2.5
20	Mission Readiness Review	Feb. 2011[a]	N	8 (projected)	$2.5
21	System Demonstration Flight	Mar. 2011[a]	N	9 (projected)	$2.5
			Total:		**$170 million for completion of all milestones $157.5 million paid to date**

Source: NASA and Orbital.

Note: When Orbital amended its agreement with NASA in March 2009, it deleted milestones 7 and 11, and moved milestone 4 to become milestone 10. These changes are indicated in this revised schedule.

[a]Milestones 17, 18, 20, and 21 were amended in March 2011 to reflect updated milestone descriptions and completion dates. In particular, the System Demonstration Flight (milestone 21) is now planned for December 2011.

Table 3: SpaceX's Progress Completing New COTS Development Milestones

Milestone number	Milestone description	Scheduled completion date	Completed on time (Yes/No)	Delay if applicable (months)	Payment amount (millions)
23	Modal Test Plan and Setup	Nov. 2010	Y[a]	-	$5
24	Modal Test	Dec. 2010	Y	-	$5
25	Light Detection and Ranging (LIDAR) Test (open loop)	Dec. 2010	Y	-	$5
26	Solar Array Deployment and Component Thermal Vacuum Tests	Dec. 2010	Y	-	$5
27	Light Detection and Ranging (LIDAR) Test Plan (closed loop)	Mar. 2011	N	< 1[b]	$5
28	Thermal Vacuum System Test Plan and Procurement	Mar. 2011	N	< 1[c]	$5
29	Overall Infrastructure Plan and Long Lead Procurement	Mar. 2011	N	< 2[d]	$10
30	Thermal Vacuum System Tests	Jul. 2011	-	-	$20
31	Test Site Infrastructure Implementation	Jun. 2011	-	-	$5
32	Dragon Trunk Acoustic Test	Jun. 2011	-	-	$10
33	Light Detection and Ranging (LIDAR) Test (closed loop)	Aug. 2011	-	-	$5
34	Design Review of Enhanced Powered Cargo Accommodations	Aug. 2011	-	-	$5
35	Design Review of Pressurized Cargo Volume Increase	Aug. 2011	-	-	$5
36	Full Dragon Electromagnetic Interference/Capability Test and Second Flight-Like Hardware in the Loop Simulator	Jul. 2011	-	-	$10
37	Dragon Cargo Racks and Hatch Simulator	Aug. 2011	-	-	$3
38	Ground Demonstration of Enhanced Powered Cargo	Sept. 2011	-	-	$5
39	Launch Site Infrastructure Implementation	Sept. 2011	-	-	$5
40	Production Infrastructure Implementation	Sept. 2011	-	-	$5
				Total:	**$118 million for the completion of all milestones** **$40 million paid to date**

Source: NASA and SpaceX.

[a]The fifth amendment to SpaceX's agreement with NASA included Milestone 23 with a due date of November 2010. Because NASA did not sign this amendment until December 2010 and SpaceX completed the milestone that same month, NASA views this milestone as having been completed on time.

[b]SpaceX successfully completed Milestone 27 on April 18, 2011.

[c]SpaceX successfully completed Milestone 28 on April 28, 2011.

[d]SpaceX successfully completed Milestone 29 on May 10, 2011.

Table 4: Orbital's Progress Completing New COTS Development Milestones

Milestone number	Milestone description	Scheduled completion date	Completed on time (Yes/No)	Delay, if applicable (months)	Payment amount (millions)
22	Mission Concept Review for Taurus II Maiden Test Flight	Dec. 2010	Y	-	$20
23	Taurus II Maiden Flight Preliminary Mission Analysis	Feb. 2011	Y	-	$10
24	Cygnus Mass Simulator Design Review	Mar. 2011	Y	-	$10
25	Installation of Additional Processor in the Loop Simulators	Apr. 2011	N	< 1[a]	$5
26	PROX Flight Equivalent Unit Test Unit	May 2011	-	-	$5
27	Taurus II Maiden Flight Stage 1 Core delivered to Wallops Flight Facility (WFF)	Apr. 2011	Y	-	$24
28	Taurus II Maiden Flight Upper Stage delivered to WFF	Jun. 2011	-	-	$20
29	Taurus II Maiden Flight Cygnus Mass Simulator at WFF in preparation for integration with Taurus II Maiden Flight Launch Vehicle	Jun. 2011	-	-	$10
30	Taurus II Maiden Flight Launch Vehicle Stage 1 Assembly Complete	Jul. 2011	-	-	$10
31	Taurus II Maiden Flight	Oct. 2011	-	-	$4
				Total:	**$118 million for the completion of all milestones** **$69 million paid to date**

Source: NASA and Orbital

[a]Orbital successfully completed Milestone 25 on May 20, 2011.

Appendix II: GAO Contacts and Staff Acknowledgments

GAO Contacts

For questions about this statement, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this testimony.

Staff Acknowledgments

Individuals making key contributions to this statement include Shelby S. Oakley, Assistant Director; Jeff Hartnett; Andrew Redd; Megan Porter; Laura Greifner; and Alyssa Weir.

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Chairman PALAZZO. Thank you, Ms. Chaplain.

I now recognize our third witness, Mr. Frank Culbertson, Senior Vice President and Deputy General Manager of the Advanced Programs Group at the Orbital Sciences Corporation.

STATEMENT OF MR. FRANK CULBERTSON, JR., SENIOR VICE PRESIDENT AND DEPUTY GENERAL MANAGER, ADVANCED PROGRAMS GROUP, ORBITAL SCIENCES CORPORATION

Mr. CULBERTSON. Good morning Chairman Palazzo, Ranking Member Costello and Chairman Hall and Members of the Subcommittee. It is an honor to be a participant with this distinguished panel as we address commercial cargo delivery to low earth orbit and the status of the Orbital Sciences Corporation development of that capability to help maximize the return on investment from the International Space Station.

Before I go further, though, I would like to note the absence of our stalwart space supporter, Representative Gabrielle Giffords, whose presence in this discussion is sorely missed. I certainly join all of you in continuing to hope and pray for her speedy recovery and for her return soon to provide us with her candor and ardor.

I also want to recognize the success to date of the crew of Endeavor and combined with the ISS crew under Mark Kelly's leadership, as well as the entire Shuttle team around the country for their commitment in excellence. This country owes that team a lot. Mark, by the way, was the pilot on Endeavor on my most recent return home from the ISS. So we go way back.

It is especially fitting that we are meeting one day after the 50th anniversary of President Kennedy's speech boldly committing our Nation to landing on the moon. However, it is not entirely clear to me what our Nation's, or the world's, next audacious goal in space will be, but I know for sure that the next great achievement will not be possible without maximum safe, efficient, and continuous use of the ISS as a waypoint on that journey. Just as Mercury, Gemini, X–1, and X–15 paved the way for Apollo and Shuttle, the ISS, through effective use of both commercial and government transportation systems, will pave the way for human exploration of the rest of the solar system.

Its potential as a national research laboratory, a development center, and an engineering test bed must be fully realized in order to take the higher-risk steps necessary to send crews beyond low-earth orbit for extended periods of time.

Mr. Chairman, you have asked us to cover a lot of ground in a short time today, so I have submitted a very thorough written testimony which covers our program status fully, as well as addresses the specific questions we were asked. I have also as requested provided you with a one-page summary of the points I will address briefly in the time allotted.

Our launch vehicle and launch facilities are on track for our first launch, as was mentioned, in October of this year. Our Cygnus Spacecraft is scheduled for its demonstration flight to the ISS with birthing in December of this year. You will be able to see both of those launches from here by the way, a real treat for Washington, I think.

Our cargo services will begin in earnest in March, 2012, with deliveries approximately every six months after that. So even though it is a challenging schedule and there are risks to it, we feel very strongly that by the end of 2012, we will have flown four flights.

Orbital was awarded a $170 million COTS Space Act Agreement in February of 2008, in a second-chance competition after one of the first two awardees was dropped by NASA. That is a very important fact. We received significantly less funding and a later start than the predecessors.

Some other pertinent facts that I think are important. The Taurus II development decision and corporate funding preceded the COTS award. This was being done on Orbital money. Spacecraft development began to move forward aggressively after NASA's commitment to invest in our program in February of 2008.

This is a compressed development schedule compared to traditional government programs. It has challenges, but it is using commercial development and production practices with NASA insight. We provide complete transparency to the NASA team. However, 60 percent of the investment in this is from Orbital.

Human rating requirements are met through NASA oversight in specific reviews of the—our ability to meet those requirements. Our COTS development is fixed funding under a Space Act Agreement, the base Space Act plus the augmentation. Our CRS contract is firm fixed price, and there is a difference under a FAR-based services contract. This contract was awarded approximately 10 months after we were awarded COTS in December of 2008.

We do use earned value management tools to control cost and schedule, and currently our internal budgeted costs of work on the Taurus II Program is 95 percent complete.

To briefly review, some of our major accomplishments to date, the decision to use Wallops Flight Facility was made in a very carefully and methodical fashion. It created over 300 new jobs just in the construction alone. The Commonwealth of Virginia and the MARS, Mid-Atlantic Regional Space Port, provided financial backing at the start and are the space port developers.

NASA has completed a horizontal integration facility. The payload processing facility and the launch pad and liquid fueling facility are 90 percent complete with certifications of acceptance to begin in July and static test firing in September. Our three teams are working very closely together. The first two tank sets of our Taurus II have arrived at Wallops. Checkout is continuing. We have tested three of our Aerojet AJ26 engines, and engine four will be tested next week.

Our Cygnus Spacecraft is proceeding quickly and rapidly through our integration and test per our ISO certified processes and will go through a complete standard orbital environmental testing this summer. The first of four cargo modules—the first four cargo modules are complete or in work.

Very briefly, I wish to respond to the three questions provided by the Subcommittee. The first is: what risk reduction milestones were funded by the COTS Augmentation? We have eight milestones addressing the test flight that has been mentioned. They support integration readiness and launch, and then we have two

milestones that support additional simulators to help NASA better understand our control systems.

the second question is: What launch failure contingency planning do we have in place? Mr. Chairman, I can assure you that Orbital is placing maximum emphasis on identifying and controlling risks, as well as insuring that testing and analysis are in place to minimize the chance of failure. This includes taking the position that safety and mission success will never be a lower priority than schedule, which will occasionally result in delays as you have seen. We use every available company resource, every bit of engineering expertise, everyone's operational experience, as well as the advice and insight of both NASA and our team of outside experts to maintain the correct perspective and priorities.

If we do have a failure, the response will depend on what that failure is and what the root cause is. However, we will always have three to five vehicles and launch vehicles in process at any one time so the stand down should be minimal if we are able to quickly resolve the problem.

Our biggest challenges, technical is the launch site development, the cost and schedule, and then meeting the safety review panel requirements which turn out to be a very positive experience. On the business side, design and development effort under a fixed price model is very challenging. Setting prices for services long before development is complete or the NASA mission requirements are well defined is something that is not usually done.

But these are challenges that we accept for the good of the Nation and certainly are worth the risk when you take the long view on human spaceflight. We established a new model for industry and government relationships. We have more flexibility in design and provide a tremendous value for the government over the life of the contract.

In conclusion, we hope that these responses will help to serve the needs of the Subcommittee as you work with NASA to help ensure that more use of the private sector and support of critical space program objectives is successful. We at Orbital are proud that NASA has selected us to participate in COTS and CRS. This partnership has energized our company and our dedicated employees as well as our superb teammates to be fully committed to executing this mission in support of human spaceflight and exploration as safely and efficiently as possible.

The enthusiasm and innovativeness I see around our team are truly contagious. Thank you, again, for this opportunity. I look forward to your questions, and I apologize for running over. I had to use very small font on that thing as you can see.

[The prepared statement of Mr. Culbertson follows:]

PREPARED STATEMENT OF MR. FRANK L. CULBERTSON, JR., SENIOR VICE PRESIDENT AND DEPUTY GENERAL MANAGER, ADVANCED PROGRAMS GROUP, ORBITAL SCIENCES CORPORATION

Good morning Chairman Palazzo, Ranking Member Costello and members of the subcommittee. I appreciate the opportunity to participate in this hearing regarding the status of our commercial cargo delivery capabilities to low earth orbit. Our job on this program is to help maximize our nation's return on investment in the remarkable orbiting facility known as the International Space Station.

It is especially fitting that this hearing is being held one day after the 50th anniversary of President Kennedy's speech to Congress boldly committing our nation to

landing a man on the moon. It's not entirely clear to me, however, exactly what our nation's—or the world's—next audacious goal will be in space, but I know for sure that the next big achievement will not be possible without maximum safe, efficient, and continuous use of the International Space Station as a waypoint on that journey. Just as Mercury, Gemini, X–1, and X–15 paved the way for Apollo and Shuttle, the ISS, with the help of both commercial and government transportation systems, will pave the way for human exploration of the rest of the Solar System. Its potential as a National Research Laboratory, development center, and engineering test bed must be fully realized in order to take the higher risk steps necessary to send crews beyond low-earth orbit for extended periods of time, as well as to justify the extensive investment by the US and all of our partners in this complex and highly capable facility.

Orbital Sciences Corporation is proud to have been selected by NASA in 2008 to be one of the participants in NASA's Commercial Orbital Transportation Services (COTS) and related Commercial Resupply Services (CRS) programs. This partnership between NASA and private industry has energized our company- which next year will mark 30 years of building and operating some of our nation's most advanced and innovative launch vehicle, spacecraft and satellite systems-to develop dependable means of launching cargo and supplies to the ISS, and disposing of unneeded waste, following the retirement of the Space Shuttle. When I left the astronaut corps, I had spent over 20 years of my NASA career, plus my Navy service, working diligently to ensure safety of flight and mission success. When I joined Orbital, I immediately recognized a company team that had a similar focus, and a record of tremendous innovation with such vehicles as the Pegasus air launched rocket and the Minotaur launch vehicle. Our work force is skilled, extremely dedicated to the mission at hand, and individually accountable for meeting our performance and safety requirements. I've had the privilege of working with superb organizations in the Navy and at NASA, and I now consider it a privilege to be a part of an Orbital team that can stand toe-to-toe with any in the government.

Even prior to Orbital's partnership with NASA in the COTS program, we were developing, with our own funding, a new medium-class space launch vehicle, the Taurus II. Taurus II is a two-stage vehicle-with an optional third stage-that will provide low-Earth orbit launch capabilities for payloads weighing over 5,000 kg and access to geosynchronous orbit for smaller spacecraft. This vehicle will provide responsive, low-cost, and reliable access to space not only for CRS missions, but also for national security payloads, NASA science payloads, and certain commercial satellites as well. The Cygnus advanced maneuvering spacecraft is capable of carrying up to 2700 kg of cargo to the ISS, and possesses a multi-use potential as well. It can be used as a maneuvering and hosting spacecraft for a variety of government and private sector customers.

One unique aspect of our involvement in COTS/CRS is that we will initially launch the Taurus II and Cygnus cargo delivery spacecraft from NASA's Flight Facility at Wallops Island, Virginia. While Kennedy Space Center provides outstanding launch service to a wide variety of users, and remains a potential future site for Taurus II operations, Orbital, NASA, and the Commonwealth of Virginia have committed significant financial and technical resources to enable the United States to have a second major east coast launch facility, providing resiliency and flexibility to our nation's space launch capabilities. An added item of interest about Wallops is that members of Congress (and others) can actually view Taurus II launches at this space port from the Capitol Building, so we hope through these launch activities to generate renewed interest in space flight locally and throughout the six-state Mid-Atlantic region.

COTS/CRS provides a new model for U.S. government/private-sector collaboration to develop and operate dual-use space systems. In this collaboration, Orbital has contributed about 60 percent of the development costs for launch vehicle, cargo delivery and disposal systems, and much of the ground-support infrastructure, up front. This high level of investment from a private company recognizes the potential benefits of having a consistent customer in NASA for cargo delivery and disposal in support of the ISS's logistics needs in the near future, and also requires us to work hard to develop new markets for a variety of other users.

The Orbital COTS Program will literally get off the ground with a test of the Taurus II launch system in early fall. Our current target date for the Taurus II test launch from launch pad 0A at the Mid-Atlantic Regional Space Port (MARS) on Wallops Island is mid-October. Our Orbital/MARS/NASA team of over 400 scientists, engineers and technicians, including our teammates from around the industry, is working with great dedication toward this major milestone. Yet as we look forward to the first launch of Taurus II, we are well aware that there are significant risks to the schedule, as there are in any major aerospace development program.

Orbital and our government partners are developing a rocket, a spacecraft, and a launch and control infrastructure simultaneously. This is a significant undertaking, which for the most part has gone extremely well. The Taurus II vehicle planned for the Test Launch is currently undergoing tests at the newly opened Horizontal Integration Facility, or HIF, at Wallops Island. The MARS-developed launch pad and liquid fueling facility are completing construction, and will begin certification testing in early July.

Like most of the aerospace industry, Orbital uses Earned Value Management Systems to track our progress on schedule and cost performance. I can tell you today that based on our internal budgeted costs of work scheduled we are 95 percent complete with Taurus II development and have completed successfully the first 41 months of the 46 month Taurus II schedule. There is also great progress to report at Wallops, where the HIF and Payload Processing Facility are essentially ready to support launches. Development of the launch pad and related support facilities is 90 percent complete.

With respect to development of the Cygnus Advanced Maneuvering Spacecraft, the first flight unit is on track for a December 2011 launch that will demonstrate our capabilities of providing cargo to the ISS. We developed Cygnus on an aggressive 45 month schedule, and are on track to finish the final six months on time.

The Cygnus Service Module for the Demonstration mission is being assembled at our Dulles, VA, facility, and has begun our normal ISO-certified Integration and Test process, which will be followed by thorough environmental testing of the fully assembled spacecraft, tests which we require prior to launch for all of our spacecraft.

The service module for our first CRS mission is in the manufacturing flow as well, following closely behind the Demonstration mission hardware, and hardware for the second CRS mission is arriving at the plant. The hardware acceptance review for our Pressurized Cargo Module (PCM) is occurring this week with our industrial partner, Thales Alenia, with the PCM and its support equipment being essentially complete and ready for shipment to the US. Last December we completed a very successful cargo loading demonstration of the PCM to be used for the first CRS mission, and just this month we conducted a very successful crew equipment interface test with the astronauts and representatives from NASA's mission operations directorate in the actual PCM slated for the COTS Demonstration mission.

The COTS Demonstration mission in December will mark the first use of a dedicated Mission Control Center for Cygnus flight operations. Mission Control Center Dulles, a state of the art facility at Orbital's headquarters five miles north of Dulles airport, was dedicated last November, with the participation of NASA Administrator Charles Bolden, and our operators will work hand in hand with ISS Mission Control at NASA's Johnson Space Center, and other ISS partner nation control centers, to manage the critical rendezvous and berthing of the Cygnus at the ISS. The COTS demonstration mission will be a culmination of all the hard work that has gone into the design, development, and the safety reviews for operations in proximity with the ISS, as well as the many hours of joint testing we are conducting with NASA. Orbital has worked closely with NASA to move further into the ISS Human Spaceflight mode of operation, successfully completing the first two phases of NASA's Safety Review Panel, and are well on the path to completing the requirements of the third and final Safety Review Panel, a prerequisite for approaching the Space Station.

Success on the December COTS demonstration mission will then lead directly to CRS, the actual contract covering the repetitive delivery of cargo to the ISS, with two Orbital CRS missions slated every year from 2012 to 2015. Again, this is a very ambitious schedule, and we will know with greater certainty the exact dates to target for cargo delivery once we have the experience of our first test launch and demonstration flight.

To address our current schedule status versus the original program plan, there are two significant factors that prevented us from achieving the original target dates for the COTS demonstration: First, the change from an unpressurized cargo module to a pressurized cargo module, executed at Orbital expense in response to a desire from NASA to duplicate the requirements of the CRS contract on the Demonstration mission; and secondly, the unexpected challenges encountered in the development of a minimally equipped Pad 0A into the Mid-Atlantic Regional Spaceport's Medium Class Launch Facility at Wallops Island. These challenges have been addressed, and while all activities are not yet complete, the threats to the remaining schedule are small compared to what we have encountered in the past two years.

That in summary is our progress to date. Our Orbital-NASA partnership for the development of a cargo delivery capability to ISS is on track, moving ahead steadily, and, in fact, nearing completion.

The subcommittee has also asked Orbital to respond to three specific questions, which I'm pleased to do. First, you asked about the justification and rationale for each of the risk-reduction milestones funded by the COTS Augmentation that was supported by Congress in the FY 2010 NASA Authorization Bill.

Some history may be useful in this regard. The original NASA COTS competition for $500M resulted in NASA selecting Space X and Kistler Aerospace for the program in August 2006, with Space X receiving the majority of the funding, and Kistler a lesser amount of the $500M. After NASA decided to terminate its funded space act agreement with Kistler, the remaining $170 million was re-competed and awarded to Orbital in February 2008. In determining how best to utilize the reduced funding available for COTS, Orbital was placed in the position of bidding a single demonstration mission along with the development of the Cygnus spacecraft.

Both the Orbital and NASA COTS program offices recognized the elevated risk in the plan for launching the first Cygnus maneuvering spacecraft on the first Taurus II launch vehicle flight. Due to the limited funding remaining in the program, however, this was viewed as a necessity. There is acceptance in the industry that first flight missions of new launch vehicles historically have elevated risk associated with them, largely due to the complexity inherent in launch vehicles, the necessarily small margins of safety in vehicle designs to meet performance-to-orbit goals, and the fact that critical elements of the launch vehicle can never be fully tested in exact flight-like conditions through ground testing.

When the possibility of additional funding for risk reduction was presented, Orbital and NASA mutually agreed that a Test Flight of the Taurus II launch vehicle prior to the COTS demonstration mission was the best use of risk reduction funding. This approach added significant content and value to the program as well as an additional meaningful test of the system. The concept for the Test Flight is to launch a Taurus II vehicle with an instrumented Payload Simulator that mimics the mass properties and other key characteristics of the Cygnus spacecraft. This Test Flight would verify the operation of the launch vehicle and also return valuable launch-environment data from the Payload Simulator. After completing the test flight, the COTS Demonstration mission can be properly focused on the operation of the Cygnus spacecraft and its rendezvous and proximity operations with the ISS.

Therefore, in the context of the above discussion of risk at the programmatic level for the COTS program, Orbital and NASA worked together to develop the 10 COTS Augmentation Milestones that authorized the Test Flight as a top priority, and then added other Cygnus-related risk reduction elements to the program that were deemed beneficial to reducing risk on the spacecraft. Milestones 25 and 26 require the development and installation of additional ground simulators of the Cygnus system to facilitate joint testing and verification between NASA and Orbital prior to acceptance for flight. Milestones 22–24 and 27–31 are associated with deliveries of key components of the test flight and completion of critical readiness reviews. The criteria for success are clearly described for each of the milestones in an amendment to the SAA.

To further discuss the addition of the test flight and the risk that Orbital assumed in adding content to the program, a typical launch service procurement spans 24 months. This span is necessary to authorize subcontracts for long lead suppliers such that all hardware elements can be delivered to the launch site with sufficient time to integrate and test the launch vehicle prior to flight. In the case of Taurus II, the 2nd stage solid rocket motor is the longest lead item requiring 18–21 months lead time. The liquid first stage tanks require 18 months lead time. The plan to incorporate the Test Flight into the program is to utilize the first hardware set previously assigned to the COTS–Demo mission for the Test Flight, and then to re-assign the second hardware set previously assigned to Orb-1 CRS mission to COTS–Demo, and so on. In this way, the earliest opportunity for the Test Flight can be accommodated while minimizing the impact to the COTS–Demo launch date.

To protect for the possibility for the Test Flight, Orbital proceeded at risk in summer 2010 to order a replacement Stage 2 motor assembly from ATK along with other long lead purchases of ordnance and separation joints. This hardware was necessary to backfill the hardware queue to ensure later flights could still be executed on time given the insertion of the Test Flight into the manifest as the first flight of Taurus II. These long lead purchases were made prior to receiving any COTS Augmentation funds and prior to being sure that the COTS Augmentation funds would ultimately be added to the program due to the extended debate on the budget and continuing resolution in Congress. This decision to proceed at risk was based on Orbital's desire to protect for the earliest opportunity for a Test Flight given the uncertain FY11 budget situation for NASA that existed last fall. Two incremental amendments to the COTS Space Act Agreement occurred prior to negotiation of the full suite of milestones authorizing the Test Flight mission.

Your second question was about Orbital's plan to recover in the event of a launch failure or loss of a COTS demonstration flight or a CRS missions. I assure you that Orbital is placing maximum emphasis on identifying and addressing risks, as well as ensuring that testing and analysis are in place to minimize the chance of failure. Based on my experience in this high-risk, high-reward business, the most significant thing an organization can do is to inculcate in its members from top to bottom the strong belief that we will do everything possible to successfully complete our mission, and that each person who has a job to do on the project will be held to the highest level of accountability for their work. This includes taking the approach that safety and mission success will never be a lower priority than schedule, which will occasionally result in delays. And that we are doing, including using every company resource, engineering expertise, and operational experience available, as well as the advice and insight of both NASA and our own outside experts. Yet, if we do suffer a setback, as occasionally happens in this business, what we will do to recover, and our schedule for recovery will very much depend upon the circumstances of the setback, what is learned from a careful review of the available data to determine root cause, and what corrective actions are necessary to be taken. An additional factor to consider is that since we will have three or four Cygnus spacecraft and four or five Taurus II vehicles in production at any one time, we will be able to quickly move to the next mission and provide the needed cargo, providing we are able to identify and correct the cause quickly. This makes a lengthy stand-down in operations unlikely. Having participated in accident investigations in both NASA and the Navy, I know that it is impossible to tell exactly what course will be followed in recovering from an accident, but having the correct program discipline, data retention, and attention to detail prior to an incident will facilitate that recovery. We have instilled those values in our team, which should also minimize the chance of it occurring.

Finally, you have asked Orbital to discuss the biggest challenges confronting us in the development and demonstration of our launch and cargo systems. I will address some of the technical challenges for the launch vehicle first:

The development of a new launch vehicle system is a very complex and expensive task. If the development is done from scratch, meaning that every subsystem and component and software item is brand new, it is an extremely difficult task to complete on schedule and on budget.

In the case of Taurus II and Cygnus, Orbital is able to take advantage of many heritage flight-proven design features. These include:

a. Launch vehicle avionics—Using heritage common hardware for flight control and sequencing, navigation, flight termination, tracking, and telemetry subsystems. These common subsystems are used on Minotaur, Pegasus, Taurus XL, and Ground-Based Midcourse Defense Orbital Boost Vehicle.

b. Launch vehicle software—Using Object-Oriented code base common across Orbital rocket programs.

c. Stage 1 tanks structure—Using 3.9m diameter core based directly on the Zenit Ukranian launch vehicle design, using same pressurization components as Zenit.

d. Stage 1 Propulsion—Using existing AJ26 LOX/RP engines with large stock in inventory at Aerojet.

e. Stage 2 Propulsion—Using Castor 30 motor assembly built by ATK based on Castor 120 heritage design.

f. Cygnus Service Module—Star Bus and Leo Star heritage design for propulsion, command and data handling systems, and software

g. Pressurized Cargo Module—Thales Alenia heritage for the development of pressurized modules for NASA and ESA, to include several ISS pressurized modules.

However, there are other critical program areas where Taurus II was not able to utilize heritage designs and new developments were required:

a. Launch Pad With Liquid Fueling Facility—Despite performing extensive searches early in the program, there was no launch pad available on a US federal range that could accommodate the Taurus II vehicle without significant modification. A new launch pad was therefore required, and a trade study between Florida/Cape Canaveral Air Force Station and Virginia/NASA Wallops Flight Facility was conducted. Wallops was ultimately selected and Pad 0A was razed and completely rebuilt to accommodate a medium class liquid rocket.

b. Stage 1 Propulsion Test Facility—Despite performing a search through the National Rocket Propulsion Test Alliance (NRPTA), no existing stage test facility was available that could accommodate the Taurus II vehicle Stage 1 Static Fire Test without significant upgrade/modification or modernization. It was decided to utilize Launch Pad 0A as the stage test facility and pad systems were designed and built at increased cost to accommodate the increased loads on the pad induced by the Stage 1 Static Test firing.

c. Stage 1 Engine Propulsion Test Facility—After performing a search through the NRPTA for a test stand to use for single engine testing for the AJ26 engine, two were identified as primary candidates—one at the Air Force Research Laboratory/ Edwards AFB, and one at the NASA Stennis Space Center. However, both stands required significant funding to bring to a test ready condition. The Stennis E–1 stand was chosen but had to be significantly modified from horizontal test configuration to vertical test configuration along with other areas of modification.

The above three areas of the program that required significant development resources to be applied constituted the biggest challenges to the development of the Taurus II launch vehicle. The fixed price nature of the COTS program funding meant that cost and schedule overruns experienced during the development of the three facilities listed above were largely the responsibility of Orbital to resolve.

Some may see the challenge of estimating costs for the fixed price Cargo Resupply Contract so soon after our late award of the recompeted COTS SAA, and before development costs or risks were completely understood as a significant risk, and in many ways it is. This issue is somewhat offset by the fact that a contract was indeed awarded, and provided we execute the contract well, this will somewhat justify both the risk and expense of the development effort. It is true, however, that the CRS contract is a financial risk to Orbital, requiring the submittal of fixed delivery mission prices so far in advance of the actual mission execution, with the period of performance spanning a five year period, and before critical development risks were completely identified or addressed.

In summary, the biggest challenge to the company is that a complex program with three major new elements is being developed in essentially a fixed price environment through Space Act Agreements, which provide no company protection for cost overruns or changes in government requirements. And the subsequent business is also fixed price and totally dependent on the success of the work under the SAA. These are challenges that Orbital accepts as good for the nation in the long run, and worth the risk from a long-term business viewpoint. It is important to take a long view on this job. The ISS must be successfully resupplied, possibly for decades. It's true that the technical challenges are also large, but these will be resolved over time by the professionals working the program.

We hope these responses will help serve the needs of the subcommittee as you work with NASA to help ensure that our nation's new path forward to utilize the private sector in support of critical space program objectives is successful. Our company and our team recognize that we have an important role in the ISS mission, and we will take all of the steps necessary with our NASA partner to ensure that our flights are safe and missions successful. Thank you again for the opportunity to testify before this important hearing.

BIOGRAPHY FOR MR. FRANK CULBERTSON, JR., SENIOR VICE PRESIDENT AND DEPUTY GENERAL MANAGER, ADVANCED PROGRAMS GROUP, ORBITAL SCIENCES CORPORATION

Frank Culbertson is Senior Vice President and Deputy General Manager of Orbital's Advanced Programs Group. In this capacity, Mr. Culbertson's responsibilities include the execution and performance of all Orbital programs related to human space flight including the Commercial Orbital Transportation System and Commercial Resupply Services Programs as well as the Launch Abort System Program for the Orion spacecraft. Prior to this position at Orbital, Mr. Culbertson was a Senior Vice President at SAIC, following an eighteen-year career as a NASA Astronaut.

He has flown three space missions and logged over 144 days in space as shuttle commander, pilot, and station crewmember. His last mission launched on the Shuttle Endeavour and lasted for 129 days, from August 10 until December 17, 2001. During that mission, he lived and worked aboard the International Space Station for 125 days and was in command of the Station for 117 days. Mr. Culbertson also held several key management positions within the NASA Shuttle and ISS programs and was Program Manager of the Shuttle-Mir Program.

Mr. Culbertson is a 1971 graduate of the US Naval Academy at Annapolis. He was a naval aviator, a fighter pilot, and a test pilot, and he retired from the Navy as a Captain in 1997. Mr. Culbertson has received numerous honors, including the Legion of Merit, the Navy Flying Cross, the Defense Superior Service Medal, the NAA/FAI Gagarin Gold Medal, and the NASA Distinguished Service Medal.

Chairman PALAZZO. Well, you went over your time budget here, but we don't want you to go over your time budget on the COTS or CRS.

Mr. CULBERTSON. We are working it.

Chairman PALAZZO. All right. I now recognize our final witness, Ms. Gwynne Shotwell, President of Space Exploration Technologies.

STATEMENT OF MS. GWYNNE SHOTWELL, PRESIDENT OF SPACE EXPLORATION TECHNOLOGIES

Ms. SHOTWELL. Chairman Hall, Chairman Palazzo, and Ranking Member Costello and Members of the Subcommittee, thank you for the opportunity to appear before you today and thank you, Congressman Flores, I am honored by your introduction and appreciate the support for the work that we do in the fine town of McGregor, Texas.

SpaceX is an all-American company that was founded in 2002. Our singular goal was to provide safe, reliable, and cost-effective access to space for cargo and eventually crew. In just nine years the company has grown to over 1,300 men and women who embody the best American ideals of intelligence, hard work, ingenuity, and excellence.

In an era of increased outsourcing and off shoring, especially in critical manufacturing technologies, SpaceX maintains an all-American workforce. Every day at SpaceX there are hundreds, nearly a thousand engineers and technicians bending metal, wiring circuits, testing engines, and pushing the boundaries of aerospace engineering and manufacturing.

With the Space Shuttle's imminent retirement I am pleased to testify that in partnership with NASA SpaceX is on track to support the ISS with cargo. Under the support and guidance of NASA's innovative, cost-effective commercial Orbital Transportation Services Agreement, otherwise known as COTS, we have developed and successfully flown a launch vehicle that for the first time since the 1990s has brought launch dominance back to the United States. We are winning launches from French, from the Russians, and from the Chinese.

In addition to this grand achievement and also under the guidance and support of NASA, we have developed, launched, operated on orbit, and reentered the Dragon Capsule. Notably, after the Shuttle retirement in just a few weeks Dragon will be the only capability of carrying cargo back from the International Space Station.

On December 8, 2010—it was a great day—SpaceX became the first commercial company ever in the history to launch, reenter, and recover a spacecraft from earth's orbit. From SpaceX Cape Canaveral launch site Falcon 9 lofted the Dragon spacecraft to where it orbited the earth twice before splashing down in the Pacific Ocean. The mission was truly an American success story. Until late last year only six nations have accomplished what we did, never a private company. These achievements are nothing short of extraordinary, and I am pleased to be able to share this success with you here today as well as our NASA partner.

Including last year's mission SpaceX has completed 25 milestones under the COTS Agreement. Since 2006, NASA has paid us $298 million under the COTS Agreement. SpaceX has matched dollar for dollar NASA's investment to date. It is critically important to understand that we only get paid when we complete milestones according to the success criteria laid out in our Space Act Agreement. We do not get paid merely for expending effort. We have to achieve something.

If we overrun on an effort that we agreed to execute, we must make up for that difference either through investment or capital that comes from our operating expenses. The financial facts are important to digest here. The Falcon 9 launch vehicle and Dragon spacecraft were each developed from a blank sheet to first flight in 4–1/2 years for approximately $300 million each.

SpaceX's next Falcon 9 Dragon flight is on schedule to occur later this year. If all goes as planned, Dragon will berth with the International Space Station, deliver cargo, and return cargo to earth. The final parameters of this flight are under discussion with NASA.

At NASA's request SpaceX has been conducting additional tests, cargo enhancement studies and demonstration, and demonstrations on the spacecraft. These additions to our COTS Agreement are known as the augmentation milestones. They were designed to reduce overall risks, both technical and programmatic. Once COTS is complete SpaceX will begin regular cargo delivery to the International Space Station under our Commercial Resupply Services or CRS contract.

Consequently, SpaceX is preparing for an increase in the number of Falcon 9 and Dragon flights per year by expanding our production capabilities, doubling our structural and production test facilities in Texas, and streamlining our production operations at both the Cape and Hawthorne, California. We are working diligently to ensure that we successfully meet the needs of our government and commercial customers.

I would like to show a video that shows some of the capabilities that we have at our factory, our test site, and our launch site. It is a quick, one-minute video.

[Video]

I am slightly over, but Mr. Chairman, thank you for inviting SpaceX to participate in today's hearing, and I do look forward to continue my cheerleading and answering your questions.

[The prepared statement of Ms. Shotwell follows:]

PREPARED STATEMENT OF MS. GWYNNE SHOTWELL, PRESIDENT, SPACE EXPLORATION TECHNOLOGIES

Mr. Chairman, Congressman Costello and the Members of the Space Subcommittee,

On behalf of Space Exploration Technologies (SpaceX) and our more than 1,300 employees across the United States, I thank you for the opportunity to participate in today's hearing.

With the imminent retirement of the Space Shuttle and the United States' forthcoming reliance on Russia to carry astronauts to the International Space Station (ISS), the readiness of commercial providers to support the ISS is a timely and critical topic. I am pleased to testify that, in partnership with NASA, SpaceX is on track to support the ISS, for cargo and eventually crew carriage.

To date, under the auspices of NASA's innovative and cost-effective Commercial Orbital Transportation Services (COTS) program, the SpaceX Falcon 9 launch vehi-

cle and Dragon capsule have flown successfully and SpaceX has become the first-ever private commercial entity to successfully launch, orbit, reenter and recover a spacecraft. These achievements are unprecedented in terms of their scope, pace, and low level of expenditure. Let me repeat for emphasis here—what SpaceX achieved last year with the support and guidance from our NASA partner is nothing less than extraordinary. Indeed, in the history of space development efforts, we believe that the United States Government has never before received so much output and value relative to dollars spent. The COTS program serves as a model for public-private partnerships, focused on results-oriented, cost-effective, rapid prototyping, design and development.

All praise for COTS aside, there remains work to be done and challenges to overcome as the Nation looks to domestic commercial providers like SpaceX to support the ISS. I will begin my testimony by providing the Subcommittee with a brief overview of SpaceX and our operations. Next, I will address key achievements realized to date, then focus on remaining challenges in development, testing and demonstration. Finally, I will discuss where SpaceX stands with respect to the remaining COTS milestones with a focus on our upcoming mission to the ISS, technical and operational risk reduction efforts and contingency planning as we transition from COTS to our Commercial Resupply Services (CRS) missions.

SpaceX: Innovation Yielding Highly Reliable, Affordable Launch Services

Founded in 2002 by Elon Musk with the singular goal of providing highly reliable, cost-effective access to space to eventually facilitate carrying crew, SpaceX is headquartered in Hawthorne, California. The Company has developed a state-of-the art propulsion and structural testing facility in Texas and maintains offices in Huntsville, AL, Chantilly, VA, Washington, D.C., and shortly, Houston, TX. SpaceX has established launch sites at Cape Canaveral Florida, Vandenberg Air Force Base California, and the Kwajalein Atoll in the Marshall Islands.

Recently ranked as one of the world's fifty most innovative companies by MIT's *Technology Review*, SpaceX is governed by the philosophy that simplicity of design, reliability and affordability go hand-in-hand. We hard-wire that philosophy into our Falcon rockets and Dragon spacecraft by focusing on simple, proven designs, keeping a tight control over quality and ensuring a tight feedback loop between the design and manufacturing teams. To be clear, safety and reliability are paramount for any commercial company; and cost-reduction without safety and reliability is meaningless.

Our workforce, which has grown rapidly from two employees in 2002 to more than 1,300 employees today, embodies the best American ideals of hard work, ingenuity and excellence. Our particular emphasis on developing U.S. engineering and manufacturing capabilities has yielded SpaceX (and, by extension, the Nation) deep domestic, in-house expertise in propulsion, structures, avionics, safety, quality assurance, mission operations, launch, mission management and systems integration.

SpaceX's operational vehicles currently include the Falcon 1 and Falcon 9 launch vehicles and the Dragon spacecraft. Critically, SpaceX's Falcon 9/Dragon system offers an affordable, American-made, end-to-end transportation solution for carrying cargo and potentially crew to the ISS. With respect to development efforts, the Falcon Heavy launch vehicle development (which is not to be confused with NASA's heavy-lift development efforts) is underway, with an expected launch in 2013, and SpaceX is a recent recipient of a CCDev2 award focused on the development of an integrated launch abort system for the Dragon spacecraft.

SpaceX has executed at an unprecedented pace of development and success for an aerospace company, with nearly 40 Falcon 9 missions on manifest, approximately $3 billion in contracts and a customer base that spans the government, commercial and international markets in just nine years. As a result, SpaceX has been profitable every year since 2007, despite dramatic employee growth and major infrastructure and operations investments. Our ability to successfully compete in the domestic and international commercial market demonstrates the long-term viability of our business model and allows us to keep our costs to the U.S. taxpayer low.

To ensure that SpaceX is not dependent upon a single source for any key technology, we have developed the capability to manufacture the majority of our launch vehicle and spacecraft in-house. This provides us with control over quality, schedule and cost, for all key elements from component manufacturing through launch operations. It also allows SpaceX designers to work directly with manufacturing personnel located just steps away, which streamlines the development process.

Total SpaceX expenditures from 2002 through 2010 were less than $800 million, inclusive of all Falcon 1, Falcon 9 and Dragon development costs. That $800 million

includes the cost of building launch sites at Vandenberg, Cape Canaveral and Kwajalein, as well as the SpaceX corporate manufacturing facility. The total also includes the cost of five flights of Falcon 1, two flights of Falcon 9 and one launch and reentry of Dragon. It is fair to say that this level of output versus expenditure is unprecedented in the aerospace community.

Indeed, NASA recently conducted a predicted cost estimate of the Falcon 9 launch vehicle using the NASA–Air Force Cost Model (NAFCOM), its primary cost estimating tool. It was determined that had the Falcon 9 been developed under a traditional NASA approach, the cost would have been approximately $4 billion. The analysis also showed development of the Falcon 9 would have been approximately $1.7 billion based on the traditional commercial models and assumed factors. However, NASA independently verified SpaceX's total development costs of both the Falcon 1 and Falcon 9 at approximately $390 million in the aggregate ($300 million for Falcon 9; $90 million for Falcon 1).

COTS: Key Achievements to Date

The COTS program was the first of its kind for NASA: a ?pay for performance? partnership between the government and private business to rapidly design and prototype critical technologies. NASA structured the COTS program as a collaborative partnership with the commercial space industry, sharing the risks, costs and rewards of developing new space transportation capabilities. Under the program, NASA provides seed money for the development of private spaceflight capabilities, but issues payment only after a company meets technical and financial performance milestones. The participating COTS contractors, likewise, invest in the program and put their own financial "skin in the game."

To date, SpaceX has completed 25 milestones under its COTS Agreement for efforts associated with the development, manufacture and testing demonstration of the Falcon 9 rocket and Dragon spacecraft for cargo carriage to the ISS. (The milestones completed under SpaceX's 2006 COTS Space Act Agreement, prior to amendment for augmentation milestones, are listed in Appendix A, attached.) Critically, SpaceX is well on its way to completing the integration process with the ISS. To date, NASA's Commercial Cargo program has contributed $298 million towards this end. And, in doing so, the United States also has helped facilitate the development of the first internationally competitive launch vehicle in more than a decade and the first-ever operational, private, orbiting and reentry capsule. In terms of "bang for the buck," the United States Government has made a savvy investment.

At present, SpaceX has performed two successful Falcon 9 flights. Each flight carried a Dragon spacecraft—the first mission carried an inert, non-separating Dragon, and the second carried an operational Dragon. The second Falcon 9 launch was the first official launch under the COTS program. It bears noting that the Falcon 9 launch vehicle features nine SpaceX Merlin engines in the first stage, which allows the Merlin engine to rapidly attain heritage by means of each flight.

The Merlin is the first new all-American hydrocarbon engine for an orbital booster to be flown in forty years and Falcon 9 is the first U.S. launch vehicle with engine-out capability after liftoff since Saturn V.

On December 8, 2010, SpaceX became the first commercial company in history to launch, reenter, and successfully recover a spacecraft from Earth orbit. SpaceX's COTS demonstration mission blasted off at 10:43 AM EST from Launch Complex 40 at Cape Canaveral. Falcon 9 lofted the Dragon to orbit where it twice circled the Earth at speeds greater than 7,600 meters per second (17,000 miles per hour). Dragon reentered the Earth's atmosphere and splashed down just after 2:00 PM EST in the Pacific Ocean. The mission was nothing short of a complete success.

Until late last year, launching, orbiting, reentering and recovering a spacecraft was a feat previously performed by only six nations or government agencies: the United States, Russia, China, Japan, India, and the European Space Agency. NASA's expert advice and mentorship throughout the development process helped SpaceX build upon 50 years of U.S. space achievements to reach this goal.

Once again, the financial facts are import to digest here: the Falcon 9 launch vehicle was developed from a blank sheet to first launch in four-and-a-half years for approximately $300 million. The Falcon 9 is an EELV-class vehicle that generates roughly one million pounds of thrust (four times the maximum thrust of a Boeing 747) and carries more payload to orbit than a Delta IV Medium. Likewise, the Dragon spacecraft was developed from a blank sheet to the first demonstration flight in just over four years for about $300 million. The Dragon is a free-flying, reusable spacecraft capable of delivering pressurized and unpressurized cargo to the ISS and safely returning cargo to Earth.

COTS Augmentation Milestones

At NASA's request, prior to Dragon's successful orbital flight, SpaceX began conducting additional tests on the launch vehicle and spacecraft and performed additional Dragon component system capability demonstrations. Those tests and demonstrations contribute to the eighteen new COTS milestones, known internally as 'augmentation milestones,' that have presently been added to our COTS Agreement. The uncertainty in Fiscal Year 2011 funding profiles led NASA to divide COTS funding among multiple amendments to its COTS agreements.

The COTS augmentation milestones exceed the tests and demonstrations originally agreed to by SpaceX and NASA for COTS when the parties first signed their Space Act Agreement. Specifically, certain milestones augment pre-planned ground and flight testing, and others accelerate the development of enhanced cargo capabilities with the remaining focusing on infrastructure improvements. The additional milestones further develop the ground infrastructure needed for cargo carriage operations and help improve the launch and recovery operations, test site and production facility infrastructure. In short, COTS augmentation milestones are meant to further reduce risk and enhance the execution of the cargo demonstration and operational missions to be performed under the COTS and CRS programs. The COTS augmentation milestones that have been completed to date total $40 million. NASA recently added eleven augmentation milestones as an additional amendment to the COTS agreement. Those tests, reviews, demonstrations and infrastructure enhancements are planned to be completed prior to the next COTS mission. (The augmentation milestones and associated rationale for each are listed in Appendix B, attached.)

Fulfilling the COTS Objectives: Next Steps and Remaining Challenges

SpaceX's next flight of Falcon 9 with the Dragon spacecraft is scheduled to occur later this year. The final parameters of that flight are under discussion with NASA; however, SpaceX's goal is to have that COTS flight culminate in Dragon delivering cargo to the ISS and returning cargo safely to Earth. The mission will require SpaceX to accomplish all of the criteria for Demonstration Flight 2 prior to beginning the Demonstration Flight 3 criteria, which include berthing with the ISS. In effect, SpaceX will have fully achieved the development and demonstration goals of the COTS program and be prepared to undertake its CRS missions. Importantly, if SpaceX does not meet the mission success criteria for Demonstration Flight 2, then we would be prepared to fly once more under the COTS agreement if necessary. Here, it bears noting as a point of comparison that the European ATV and Japanese HTV conducted ISS operations on their maiden voyages. Orbital's current plan likewise calls for berthing on their first flight to the ISS.

A number of modifications have been made to Dragon to ensure a successful next flight and ISS berthing. To reduce the risk involved with Dragon approaching the ISS, redundancy has been added to the safety-critical systems. As an example, the initial mission flew one flight computer and one inertial measurement unit (IMU), while the ISS-missions fly multiple flight computers and IMU's to meet the ISS required fault tolerance.

To facilitate safe ISS berthing, the Dragon will be flying a proximity operations suite, including space-to-space communication systems and proximity navigation sensors. These are complex systems that present challenges. Additionally, Dragon will be flying a grapple fixture and a Passive Common Berthing Mechanism (PCBM), which are the physical attachment mechanisms for the ISS. As the next mission will be longer in duration than the first, a new power generation system, including solar arrays and new batteries, are in development. Star trackers and an active thermal control system have been added to sustain Dragon on orbit.

Ensuring Safe, Highly Reliable Access to Space

Given the purpose for our founding, SpaceX is first and foremost devoted to safety and reliability. By the nature of the business, commercial spaceflight providers cannot afford to take unnecessary risks that would endanger cargo or crew. As is true with respect to commercial aviation, businesses will fail unless safety and reliability come first, regardless of price. The need for a laser-like focus on safety and reliability becomes even more acute when commercial space companies have their own financial skin in the game, offer services on a firm, fixed price basis, and only get paid in full if they perform.

Per the Subcommittee's inquiry, SpaceX has plans in place to investigate, understand and take action, if necessary, for any anomaly that occurs during a mission. SpaceX has worked with the FAA, NASA, Air Force and National Transportation

Safety Board in this respect. The time required to complete the process would, of course, depend on the actual nature of the situation being addressed.

SpaceX has demonstrated the capability to react rapidly in the event of test or flight anomalies. As an example, during the Falcon 1 flight 3, which was a demonstration mission of our smaller launch vehicle in mid-2008, a failure occurred in flight. SpaceX arrived at the root cause of the failure within a day, quickly implemented the fix, and less than seven weeks later, successfully launched Falcon 1 flight 4.

In the case of a COTS or CRS mission, SpaceX maintains an active Falcon 9 and Dragon production line. The subsequent Falcon 9 and Dragon spacecraft are always in production and able to be readied for launch quickly after making any modifications that might be indicated by an anomaly. Notably, due to our unique capabilities whereby we design, develop, build and test the majority of our hardware, we can achieve far faster turnaround on anomaly and failure investigations more quickly than anyone else in the industry. Instead of getting bogged down with an army of lawyers and subcontractors after a failure, our engineering and test team can rapidly determine root cause and resolution.

Commercial Resupply Services

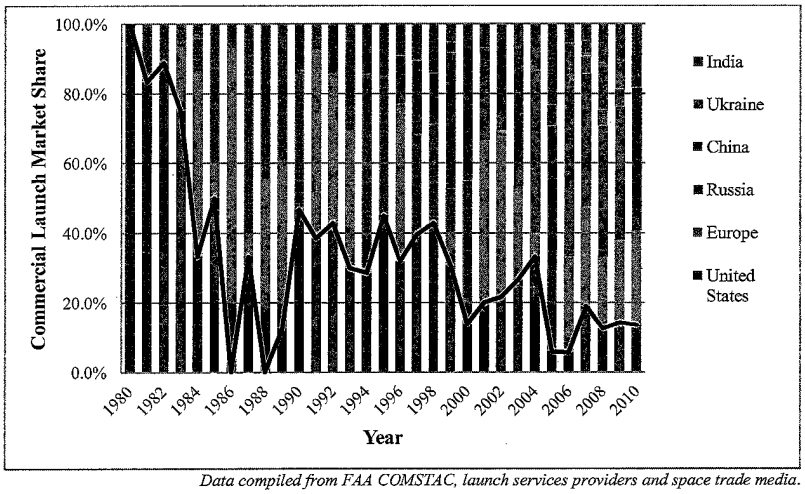
In 2008, SpaceX competed for and was awarded a Commercial Resupply Services (CRS) contract to deliver cargo to the ISS. Over the term of the CRS contract, SpaceX will deliver pressurized and unpressurized cargo to the ISS, including plants and animals, as well as return cargo to Earth. The $1.6 billion contract represents a minimum of 12 flights with an option to order additional missions.

It bears noting that the average price of a full-up NASA Dragon cargo mission to the International Space Station is $133 million including inflation, or roughly $115 million in today's dollars. That price includes the costs of the Falcon 9 launch, the Dragon spacecraft, all operations, maintenance and overhead and all of the work required to integrate with the ISS. Under SpaceX's firm, fixed price contract with NASA, if there are cost overruns, SpaceX will cover the difference, not the taxpayers.

SpaceX is preparing for an increase in the number of Falcon 9 and Dragon flights per year by expanding our production capabilities. Currently, SpaceX's near-term production capacity supports five to six Falcon 9 vehicles per year. The expansion plans will increase production capacity to produce ten to twelve Falcon 9 launch vehicles by 2013, and then twenty by 2015. This is roughly a 50% increase annually. In preparation for increased production, SpaceX has more than doubled the footprint of its structural and propulsion test facility in Texas. We have also reorganized the production teams into a more efficient, streamlined organization. SpaceX is working diligently to ensure that we successfully service our government and commercial customers.

Recapturing Commercial Launch Services Market Share

For the first time in more than three decades, an America company has begun to recapture international market-share in the commercial satellite launch sector—a sector in which the U.S. has seen steady erosion relative to Chinese, Russian and French competitors. SpaceX has begun successfully competing for and winning commercial satellite launch contracts. Whereas in 1980, 100 percent of commercial launches took place from within the United States; today, it is less than 12 percent.



Data compiled from FAA COMSTAC, launch services providers and space trade media.

Bringing back commercial launches to the United States is just one example of the benefits of NASA's targeted investment in SpaceX. By leveraging private funding with federal investment, controlling our costs and developing a diverse customer base, we are able to offer competitive pricing to our commercial and government customers. Likewise, safe, reliable and affordable transportation of cargo and astronauts to low Earth orbit by an American company will keep jobs in the United States, eliminate reliance on Russia to support the ISS, and save U.S. taxpayers significant money that instead can be invested in what NASA does best, pursuing the next frontier.

Mr. Chairman, thank you for your support and for the opportunity to participate in today's hearing. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

Appendix A:

Completed COTS Milestones (2006 Space Act Agreement baseline)

- ✓ Project Management Plan Review
- ✓ Demo 1 System Requirements Review
- ✓ Demo 1 Preliminary Design Review (PDR)
- ✓ Financing Round 1
- ✓ Demo 2 System Requirements Review
- ✓ Demo 1 System Critical Design Review
- ✓ Demo 3 System Requirements Review
- ✓ Demo 2 Preliminary Design Review
- ✓ Draco Initial Hot-Fire
- ✓ Financing Round 2
- ✓ Demo 3 Preliminary Design Review
- ✓ Multi-engine Test
- ✓ Demo 2/3 System Critical Design Review
- ✓ Financing 3
- ✓ Demo 1 Readiness Review (DRR)
- ✓ CUCU Flight Unit Design, Acceptance, and Delivery
- ✓ Demo 1 Mission
- ✓ Cargo Integration Demonstration

Appendix B:

Augmentation Milestones to COTS Space Act Agreement

Description	Purpose	Completed or Open	Amendment #
Pressurized Cargo Environment Modal Test Plan Setup and Pressurized Cargo Environment Modal Test	These two milestones provided early high fidelity data on the environments expected for Dragon cargo.	Completed	Amendment #5
LIDAR Sensors 6 Degree of Freedom Testing (open loop)	This milestone reduced the risk for the COTS flight to ISS by providing higher fidelity data to characterize the proximity sensor performance. The test was performed at the Marshall Space Flight Center Flight Robotics Laboratory whose capabilities allowed rapid testing for a large number of test scenarios. The data also helped to speed algorithm development.	Completed	Amendment #5
Solar Array Deployment & Component Thermal Vacuum Tests and Thermal Vacuum System Test Plan and Procurement	These two milestones included thermal vacuum testing of key Dragon and trunk subsystems to reduce risk on early flights to the ISS—with more cycles than would have been allowed in flight. An Aerospace Corporation study found that thermal vacuum tests uncovered an additional 43% of latent defects compared to only thermal cycle and unit testing.	Completed	Amendment #5
LIDAR Sensors 6 Degree of Freedom ("DOF") Testing Plan (closed loop)	This plan defines the detail of the 6 DOF tests that will provide true "test-like-you-fly" fidelity of the entire Dragon proximity Guidance, Navigation and Control (GNC) system. Also, by incorporating the sensors into the GNC bay of the Dragon drop test vehicle, near field obstructions will be introduced thus making this test the highest fidelity possible without approaching the actual ISS. Successfully flying the approach trajectory while discriminating the near field obstructions of the Dragon GNC Bay will greatly increase confidence that the software qualification testing, nominally done only via simulation, is adequate to fly the mission.	Completed	Amendment #6
Overall Infrastructure Plan and Long Lead Procurement	This milestone identifies high-value, high payoff modifications, upgrades and additional capabilities to the existing production, test and Launch Complex 40 facilities that will enhance and streamline cargo and	Completed	Amendment #6

	vehicle flows to benefit NASA's ongoing and long-term cargo transportation needs.		
Thermal Vacuum Tests (System Level)	Full up Thermal vacuum testing of the Dragon spacecraft and trunk system. This test reduces risk on all flights to ISS as simulated environments are generally wider than those experienced on orbit. This testing provides much confidence in component behavior in vacuum. This additional system level test will reduce the risk of anomalies on-orbit that could cause program delays.	Open	Amendment #7
Test Site Infrastructure Implementation, Launch Site Infrastructure Implementation and Production Infrastructure Implementation	To meet the criteria for these milestones, SpaceX will implement enhancements developed under a prior milestone, including high-value modifications, upgrades and capability additions to SpaceX's testing facility, Launch Complex 40 and production infrastructure. Improvements to the test facilities in McGregor, TX, will improve engine acceptance rates and structural testing times. The launch complex and production enhancements will improve and streamline cargo and vehicle production flows to benefit NASA's ongoing and long-term cargo transportation needs.	Open	Amendment #7
Dragon Trunk Acoustic Test	The acoustic test will provide systems-level workmanship verification for the Dragon solar array assemblies and integrated trunk assembly, by exposing it to the acoustic and vibration environment prior to actual flight. Extensive component testing is already done—this test represents a robust system level verification.	Open	Amendment #7
LIDAR Sensors 6 Degree of Freedom Test (closed loop)	This 6 DOF test which will provide true "test-like-you-fly" fidelity of the entire Dragon proximity Guidance, Navigation and Control (GNC) system. Also, with the sensors located in the GNC bay of the Dragon drop test vehicle, near field obstructions will be introduced thus making this test the highest fidelity possible without approaching the actual ISS.	Open	Amendment #7
Design Review of Enhanced Powered Cargo Accommodations and Demonstration of Enhanced Powered Cargo (ground)	In addition to various Life Science samples from NASA, which are currently accommodated in the Dragon capsule, there are numerous other now-funded science activities that will take advantage of powered mid-deck storage locations. This milestone will	Open	Amendment #7

	provide NASA design options to increase power, data and critical operations for a critical cargo capability		
Design Review of Pressurized Cargo Volume Increase	The cargo manifest with the COTS baseline Dragon is volume-limited on ISS flights, which results in excess mass capability on all missions. This design effort which culminates in a review will analyze high-value modifications to the Dragon to increase the cargo capacity beyond that proposed for COTS, possibly resulting in lower recurring cost (and cost per kilogram) for NASA. It is critically important to maintain the viability of the powered cargo locations and the early and late access capability.	Open	Amendment #7
Full Dragon EMI/EMC Test, Second Flight-Like HITL (Dragon Force)	A full-scale EMI/EMC test is final verification that the vehicle's electrical components will not interfere with either each other or external electrical components such as the ISS. This test will verify both radiated emissions and susceptibility. SpaceX will also develop another complete Hardware in the loop simulator called Dragon Force to ensure that multiple hardware and software test scenarios can run in parallel.	Open	Amendment #7
Dragon Cargo Racks and Hatch Simulator	This simulator will be developed and delivered to NASA to train crew and other flight team members in the cargo handling processes and procedures. In addition to training, the capability allows for the development of new cargo handling concepts and process improvement as well as the ability to develop crew aids as required.	Open	Amendment #7

Chairman PALAZZO. Thank you, Ms. Shotwell. I thank the panel for their testimony and remind the Members that Committee rules limit questioning to five minutes. The chair will at this point open the round of questions. The chair recognizes himself for five minutes.

As was originally presented to Congress for an investment of $500 million, the COTS Program would allow NASA to enter into Space Act Agreements, excuse me, with two potential launch service companies to enable them to develop the capability of delivering cargo to the International Space Station, provided they could meet all milestones and were competitively selected for the follow-on delivery contract.

Congress was supportive and provided the money beginning in fiscal year 2005, but as Chairman Hall noted, what began as a reasonable step-by-step approach to develop and improve capabilities first to be followed by a competitive acquisition did not happen. NASA simply ran out of time and is now gambling the future of Space Station and the success of two very new launch systems—on two very new launch systems. Excuse me.

The original cost estimates to be borne by the Federal Government for COTS have escalated dramatically. What started as a demonstration program for $500 million has not been completed, and yet to date NASA has spent or obligated over $1.25 billion under COTS, COTS Augmentation and Cargo Resupply Services Contract.

So my first question to Mr. Gerstenmaier, why did NASA originally sell COTS to Congress as a $500 million effort only to later seek additional sums by asserting that further risk reduction efforts were necessary?

Mr. GERSTENMAIER. Again, as originally envisioned we went into the COTS Program with the idea that we would do the development activity for the $500 million that you recognized, and then later as time progressed and we now are in the situation where we no longer have the Constellation Program as a backup, it became important to us that the delivery service to keep Space Station viable and to provide a reasonable backup capability we needed to look at a way that we could augment that additional funding with some additional milestones to lower the overall risk and help us ensure that we deliver cargo to station.

And it is kind of a fine point but is that augmentation absolutely required, or is it just prudent management, and I think where we are in this situation with the requirement to deliver this cargo in a timely manner to Space Station we needed to invest in activities that lowered the overall risk. You could say they are not absolutely required. The thermal vacuum test that we have added. You could learn that in space, but if that didn't work in space, you would be questioning why you didn't do that testing on the ground ahead of time to help you pull back in schedule.

So when we looked at it overall, we developed these activities, these $300 million of other activities we thought would help lower the risk to help us ensure that we keep Space Station viable. So the reason for the change was we recognized the criticality of the situation we were in, and we needed an adequate backup plan to be prepared for the oncoming cargo delivery of the cargo to Station.

Chairman PALAZZO. And so you initiated that decision in 2008, even before the announcement of the cancellation of the Constellation Program?

Mr. GERSTENMAIER. Yes, and again, I think it is driven by the overall requirement. We knew the criticality of this, we saw the Shuttle Program coming to an end, we knew our spares and our supplies, and we thought it was prudent at this point to add some additional margin, some additional risk mitigation to the program by recommending that we added these augmentation milestones.

Chairman PALAZZO. So NASA basically underestimated the cost of meeting the COTS Program as originally laid out to Congress.

Mr. GERSTENMAIER. And I would say that the environment when we initiated the COTS Program was one environment, and then later as we went through time that environment and the criticality of the cargo delivery became more important to us, and as prudent managers we saw that, and we recommended an augmentation approach, which we provided to you to go ahead and help us augment to provide some additional assurance that we could provide the cargo when it was needed.

Chairman PALAZZO. When does NASA realistically expect the commercial partners will have these systems ready to fly CRS flights?

Mr. GERSTENMAIER. We expect the COTS demonstrations to be late this year, and we expect the actual services to occur next year in 2012.

Chairman PALAZZO. Does NASA anticipate asking for additional money to buy down further risks before these systems become operational?

Mr. GERSTENMAIER. No.

Chairman PALAZZO. Mrs. Shotwell, Mr. Culbertson, how much confidence do you have in your company's ability to meet the latest schedule using available COTS and augmentation funds?

Mr. CULBERTSON. Go ahead.

Ms. SHOTWELL. We are only months away from the completion of the development of the Dragon spacecraft that will berth with the International Space Station. Once development is complete schedules are much easier to predict. It is a production environment, not a development environment. So we are very confident.

Mr. CULBERTSON. We are in a similar position. We are in production on the first two of the Cygnus spacecraft that will deliver cargo already. The demo spacecraft is going through I&T on the Taurus II side, and once we complete the test flight, we will have increased confidence in the launch vehicle itself and should be able to move rapidly through the missions as we are scheduled.

The remaining challenges that we have are relatively small compared to the ones that have been behind us that have affected our schedule. So we don't see a lot of risk to the upcoming schedule.

Chairman PALAZZO. Thank you. I have consumed my time.

I now recognize the Ranking Member, Mr. Costello.

Mr. COSTELLO. Thank you, Mr. Chairman.

To follow up on the Chairman's last question, Ms. Shotwell, you are confident, I mean, under the contract you are doing a final demonstration launch the last quarter of this year and then you

have four that you will be doing next year. Is that correct? So a total of five in a one-year period.

Ms. SHOTWELL. That is correct.

Mr. COSTELLO. And you are confident that—are you building the necessary components fast enough to meet these missions and the schedule over the next three years of the contract?

Ms. SHOTWELL. We have produced six first stages for Falcon 9 and we are in the fourth—second stage for Falcon 9, and I believe we are in production on the fourth Dragon spacecraft. So we do understand the timeframes associated with building these capabilities. As I said earlier, it is much easier to predict how long it takes to build something rather than develop something.

Mr. COSTELLO. Mr. Culbertson.

Mr. CULBERTSON. Yes, sir. We, as I said, we are in production on the follow on to the demo missions. We have a great deal of confidence that we will be able to continue that, and so I believe we will be able to deliver, as I said, the four launches that we intend to do by the end of 2012, including the two demonstration flights and the two CRS missions.

Mr. COSTELLO. Associate Administrator Gerstenmaier, let me ask you, has NASA independently verified, I mean, not only your opinion but have you independently verified what they have just testified to? Do you believe that they are building the necessary components not only to meet the short term but the three-year contract schedule for instance that SpaceX has with NASA?

Mr. GERSTENMAIER. We have insight, and they have produced the hardware that they have described, and they have plans and schedules to go deliver to the schedules that they just described. But then as kind of a prudent buyer, we have made sure that there is margin in our systems, and we can accept some delays in processes that occur or start-up problems occur or we discover something in flight that doesn't work right, we have overall margin that will not affect the operation of Space Station.

So we understand their schedules, they are very reasonable, they are good schedules the way we see them, but then we have gone above and beyond to protect on the Space Station side to make sure that we are not absolutely 100 percent dependent upon those schedules that they have to be on there at exactly those times. We have some margin in the overall system that will allow us to continue to effectively utilize Space Station.

Mr. COSTELLO. Ms. Chaplain, would you like to comment?

Ms. CHAPLAIN. Just in our general experience things happen even at the last minute and in the late stages of development, and it is well that they could happen here. If we are conducting vacuum tests, they typically reveal problems, and we don't know how difficult they would be to fix in late stages. So I would agree with what Mr. Gerstenmaier was saying. There is still the risk that there will be delays. It is typical with a lot of spacecraft development.

Mr. COSTELLO. Just—I think it would be helpful for the Members of the Subcommittee, Associate Administrator Gerstenmaier, if you would explain to us NASA's oversight in the interaction that you have, that NASA employees have with both companies here. On a

day-to-day basis do you have employees from NASA in the facilities, both SpaceX and Orbital?

Mr. GERSTENMAIER. Yeah. We have minimum insight into their activities. I think we have one employee basically at both contractors that kind of just oversee what is happening in a general sense. They are not involved in any of the processing, any of the details. They are more of a facilitator, understanding schedules, passing data back and forth.

We do numerous technical interchanges and meetings with the teams. They are in the process of going through some safety review functions for the Space Station. They have been involved in the activities to approach Space Station. We spend a lot of time in meetings understanding technical requirements, working back and forth in that sense.

Mr. COSTELLO. So you have one employee that physically is there, assigned on a day-to-day basis?

Mr. GERSTENMAIER. Yes.

Mr. COSTELLO. Switching to another issue, let me ask you, Russia has expressed publicly some unease about commercial providers docking at the International Space Station, and these reports come just months before SpaceX plans to dock at the ISS during its final demonstration flight.

Can you explain the concerns of Russia to the Subcommittee and how NASA intends to address their unease?

Mr. GERSTENMAIER. Their concerns are fairly typical that we have seen as a vehicle comes to station. We have pretty stringent visiting vehicle requirements of what it takes to approach Space Station, and we need to make sure that the vehicle not only gets there safely but if it has to abort or stop the motion coming in, that it won't do any damage to Space Station. You know, we need to make sure that there is not a collision potentially. We have very stringent requirements. We are in the process of reviewing the way the individual spacecraft meet those requirements. We are doing that activity right now. We are working through some technical problems that we need to understand, and we are working with SpaceX and with Orbital on both of those.

When we complete those safety reviews probably in the June timeframe, we will do a bunch of simulations to make sure we have a high probability of doing this activity. Then we will schedule the appropriate reviews with our international partners, not only the Russians but the Europeans, and we will go through the process of ensuring to them and showing to them why we think it is safe and prudent for us to allow these vehicles to come up and stop and be picked up by the SSRMS on the Space Station and ultimately berth to the station.

So we are working through the same methodical process that we used to bring the Automated Transfer Vehicle to orbit. That is the European cargo transfer vehicle, and we did the same process with the Japanese transfer vehicle that delivers cargo. We are following exactly the same process with them. Both of those spacecraft on their maiden flights, in the case of the Japanese it was the first launch of their rocket, and it was the first actual berthing of their spacecraft to the ISS. So this isn't unprecedented territory for us. We are following the same processes we did with the international

partners with our commercial providers, and once we understand to our level of satisfaction and we are ready for that approach to Space Station, we will then bring it up with the partners, and I think we will get acceptance from the partners at that point.

Chairman PALAZZO. The chair now recognizes the gentleman from Texas, Chairman Hall.

Mr. HALL. Mr. Chairman, I thank you and thank you for your questions, and I subscribe to your questions and Mr. Costello's sincere approach to it.

Mr. Culbertson, you and I are probably the few that remember some of these things because of our age but——

Mr. CULBERTSON. Thanks, Mr. Chairman.

Mr. HALL. I call you back to June 25, 1997. Mr. Gerstenmaier just mentioned something there that accidents do happen and things can happen that are unforeseen and not predicted, but I think you remember the day the Russian progress vessel collided with Space Station Mir. I call you back to that time, and I say that because there can be occasions like that.

I think, Frank, you were the manager of the Shuttle Mir at that time, and Mr. Gerstenmaier was, operations manager, I think, but at any rate, you both remember that. You remember that the Space Station lost pressure, and it was a very dangerous situation we thought, and you thought, all of us thought. Luckily with your good work nothing happened, and no one was hurt.

But those things make me wonder about whether the cargo delivery providers, whether they are commercial providers or one of our own international partners, bear any liability if they cause an accident to the Space Station.

I am sure you have thought about that, and we go back to that, even we have had the Discovery, those that have just returned from up there that had some immediate problems we thought. So those things can happen.

How are we assured that we can be compensated or made whole by mistakes made by those that we contract with? More than that. Let me ask this. How much non-NASA business are you going to have to have to survive? You are going to enter into contracts and Frank, I have every ability, belief in you that a person can have. I have been told that Mrs. Shotwell is very capable and her boss, Elon Musk, is a can-do person that has succeeded, been successful, and I am very hopeful that all that is true, but you are signing a contract. It is just a paper contract, and we are going to have to know that they can—that you can produce that that you are saying that you are going to produce, and you have a chance to demonstrate that, and I think you have a time set to do that in, and we will wait and see when that time comes.

But to sustain your business model under the Cargo Resupply Services Contract I guess I would like to know what percent of the businesses have to come from customers other than NASA in order to meet your internal rate of return projections to where you can keep our contract.

Can your companies continue to be a reliable contractor to NASA if a few or say no other contracts are secured from commercial customers?

Mr. CULBERTSON. Mr. Chairman, as far as Orbital goes, right now we are focused on the CRS contract, and we have set our business model up so that we can support it from a business standpoint and from a rate of return. It is pretty tight in the beginning because of all the development, but we think that by the end of the—this phase of the contract we will at least not be under water.

We are hoping for additional business from NASA since the Station will be extended and——

Mr. HALL. And it is logical that you will have.

Mr. CULBERTSON. Yeah, and it is something that we are thinking about now, but right now we are really focused on the immediate.

As far as additional customers for cargo, that really depends on how other things develop both in the commercial world and in the government. We are prepared to address those markets, and our Taurus II vehicle as well as our Cygnus spacecraft are available for other customers for other uses. But right now we are not counting on that for the success of the program.

Orbital has about $1.25 billion worth of annual revenue, and we have lots of other lines of business that the company continues to thrive on, and this is an area that is very special to us, and we hope to continue to grow. But we do it because we are committed to the success of the Station and not because we have to try to make a pile of money on it.

Mr. HALL. Ms. Shotwell, you are here in the place of Mr. Musk, and we are probably going to ask him to come before us sometime in the future, and we wish you well, and if you have any comments you want to add to Mr. Culbertson's comment, I probably have maybe five seconds left.

Ms. SHOTWELL. I speak fast. SpaceX, even given the tremendous amount of development activities that we have had over the past few years, we have been profitable since 2007, NASA represents less than half of the missions that we currently have under full contract for Falcon 9. We have 38 missions contracted for Falcon 9, and, as I said, less than half of those are for NASA.

So we can sustain a business without NASA. We like NASA's business. We like the activity that we are executing both under COTS and CRS. We are actually proud to be NASA's partner, but we can survive without that activity.

Mr. HALL. And Frank, I will write you a letter to ask for a question on whether or not you bear any—the liability of any accident that is caused at the Space Station. I will write a letter to both of you for that, and the chairman will ask you to answer it. Thank you.

I yield back what time I don't have.

Chairman PALAZZO. Thank you, Mr. Chairman.

I now recognize the gentleman from Oregon, Mr. Wu.

Mr. WU. Thank you very much, Mr. Chairman.

Mr. Gerstenmaier, I would like to start with you and ask for your assessment of what could cause further schedule delays in the COTS demonstrations and as they say in biochemistry, what are the rate-limiting steps which remain to be taken?

Mr. GERSTENMAIER. Again, I think it as both Gwynne and Frank have talked about, they have got a lot of development behind them and things are very good from a hardware standpoint. I think the

next phase will be the operational phase, and it is the approach to Space Station and how we actually close the loop with the rendezvous, proximity operations sensors that provide the information to the spacecraft as it comes and docks.

So it is those kind of activities that I think will be the next challenge, is how you actually take the vehicle and not only get it to orbit but now you bring it into close proximity where it can essentially stop and then be picked up by the Space Station arm and then berth to the station.

So I think there is some challenges in that area. I think we will see some surprises in the hardware as it gets on orbit and operates. We try to mitigate those problems as much as we can on the ground and through ground testing, but I think we will see some potential surprises there that we will have to deal with to make sure that we can accommodate those and have a safe berthing to station.

So the concern there is you don't want to put yourself in a situation like we did before with Progress where we were essentially pushing so hard to get to station that we cut some safety corners and then we had the accident and the collisions with Mir. So we need to make sure that we have got the right measures in place so we do this in a measured, straightforward fashion, and we have enough margin in the overall system if there is some little delays associated with that they can recover so we can still meet what we need to.

Mr. WU. So, Mr. Gerstenmaier, these are of an operational nature. How would you test for that without actually endangering the Space Station? I also would like the rest of the panel to comment on that.

Mr. GERSTENMAIER. We have a very methodical approach. We do an activity called a collision avoidance maneuver. So we allow the spacecraft to get to a distance where it cannot hit the Space Station, and then we ask the spacecraft to do a collision avoidance maneuver. It does that maneuver, we actually monitor the performance of that maneuver on the ground, we compare the performance that we observe in space with the performance that we predicted on the ground pre-flight, and we certify that that vehicle is now ready to move into a closer point to Space Station.

We then allow them to move into a closer distance, we do a similar verification and test maneuver, we go back and validate that possibly even over an evening, and then we let them move in.

So we have a series of steps or gates as we approach Space Station where we learn more and more about the capabilities of the vehicle, is it operating the way it was designed, and that lowers the overall risk as we approach. That is exactly the same approach we used with both of the international cargo carriers we took to station.

Mr. WU. Well, I would like the rest of the panel to comment on that and also the additional question of if there is a delay or a failure, who bears the financial risk and who has the reserves? Is it the private company, or is it NASA, or both?

Ms. SHOTWELL. We have a very methodical approach to addressing this exact concern. The first part is to ensure that you have a fundamentally-reliable design. We do that by architecting to reduce

failure modes, and then we also make sure that we have redundant hardware. Our Dragon spacecraft is two-fault tolerant to issues.

So once you believe you have a good design or you have put in place a good design, then you do extensive testing on the ground. I agree with Mr. Gerstenmaier that one of the riskiest subsystems is this proximity operations piece. We do still have some activity left before we are ready to fly that, of course, and so we do extensive ground testing. We have done ground testing at Marshall. It is pretty extensive ground testing at the Marshall Spaceflight Center. They have a great prox-ops test capability there. We will be doing some additional ground testing in our factory as well.

So you have a fundamentally reliable design, you do as much ground testing as you possibly can, you do extensive software work in coordination with NASA, and then you have to fly, and then you get into this spaceflight test program and getting through those gates on orbit, you do a little bit, you test it, you look at your data, you fly a little bit closer, you again review the data before you continue on.

Mr. WU. Who is going to bear the risk of delay or technical difficulties?

Ms. SHOTWELL. As far as the financial risk goes, SpaceX bears that burden. We have signed a contract to do activities, and it is our responsibility to execute.

Mr. WU. Mr. Culbertson.

Mr. CULBERTSON. As to that part it is the same for us. I mean, this is—there is no additional funding, so if we are delayed, it costs us money, so we keep schedule in mind, but as I said before, it doesn't reach a higher priority than mission success or safety.

In terms of the safety of the Space Station, we take a similar approach to SpaceX. In addition, just like them, we have hired people with experience in this area. We use the NASA expertise as advisors and insight into what we are doing, and then in the critical approach phase there is actually NASA oversight through the Safety Review Panel of what we are doing. The simulations we go through are very realistic, they are very mature, and very thorough. We have the same fault tolerance, and our rendezvous design is such that if we have a problem at some point and we lose control of the spacecraft, it will just sail past the ISS because we don't get on the final approach until the last few—couple of hundred meters.

At that point we do have to demonstrate the avoidance maneuver. We have to show that we can back out, that we can clear the Station, and that we have sufficient redundancy in the system to do that.

So this is an area that we have paid a lot of attention to. It is the most critical phase of the flight, and we have to protect the Station. This is more important than delivering the cargo.

Mr. WU. Thank you very much, Mr. Chairman.

Chairman PALAZZO. I now recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman, and that last description of your company's ability to complete that part of the mission was very impressive considering the fact that you personally have gone through this and so I think of anybody in the

room, we have got some fellow that actually went through the procedures that we are talking about. Well, I say at the desk there.

So let me ask a couple questions. Mr. Chairman, with all due respect to the concept of gambling on two companies, if we are, indeed, gambling on two companies, I think it is a good bet, a much better bet than gambling on patching up the Shuttle. We have spent a little over $1 billion now on trying to achieve a commercial and competitive approach. It is fascinating to see we have two competitors sitting right next to one another here today offering us their services and continuing to want to win this competition.

We have spent in order to achieve this a little over $1 billion. Let us just note one flight of the Shuttle is a little over $1 billion without the payload, and that is a system that we know does not have the reliability that we need to have in order to rest assured that the Space Station can be resupplied and that we can meet other, our other goals in space.

So that billion dollars that has been spent rather than spending it on another Shuttle flight I think has been a very good decision.

With that let me also note, and let me see if I can get this right, both SpaceX, you have received about $300 million in government money so far, in NASA money in the development of Falcon 9?

Ms. SHOTWELL. We have received $298 million under the COTS Program for Falcon 9 and Dragon development.

Mr. ROHRABACHER. Orbital has received how much?

Mr. CULBERTSON. A little bit less than that.

Mr. ROHRABACHER. Okay. So we have had—and is Orbital like the SpaceX match dollar for dollar?

Mr. CULBERTSON. It is not really a dollar for dollar. It is whatever it takes to complete the program once you have spent the Space Act funds.

Mr. ROHRABACHER. All right.

Mr. CULBERTSON. And so the onus is on the company to complete the project no matter what the government is funding.

Mr. ROHRABACHER. But how much have you spent so far in the project non-government money?

Mr. CULBERTSON. Probably a little more than the government has.

Mr. ROHRABACHER. Okay. So what we have if we really look at this, the government . . .

Mr. CULBERTSON. Actually quite a bit more than that when you count Taurus II.

Mr. ROHRABACHER. Okay. Well, America, if we are not saying that the Space Program belongs to the government but instead belongs to the people, America has received for $300 million each, let's say, we have received at least $600 million in benefit to the Space Program, unless, of course, we think the Space Program is a government program and is owned by the people who work for the government and not the people who are of this country who are paying for, out of their pockets for whatever is achieved into space.

So I would suggest that gambling on these two new systems, as I say, and the price that we are talking about is—was a very good bet indeed. I take it that both of you, the Orbital and SpaceX, are operating on a fixed price contract, and you have—now, we know that the cost has gone up a little bit as has been noted as this com-

mercial space endeavor has moved forward, but the costs that have gone up have been basically going up because new milestones were set for your companies by NASA. Is that correct?

Mr. CULBERTSON. Additional content was added to the development program under the Space Act Agreement that we agreed to add to the program, and NASA agreed to invest in that partially.

Mr. ROHRABACHER. So but no, there has been no additions of cost to the taxpayers that was generated by something that you didn't foresee but were not required to do. In other words, you have done what you were required to do for the price that you agreed to do it at as compared to, I might add, the development of other programs for NASA that are not fixed price that seem to always go over and need more money, not based on meeting NASA milestones but just because they underestimated what their costs would be. Is that correct? Go right ahead.

Mr. CULBERTSON. It is probably better for Bill to answer that.

Mr. ROHRABACHER. What do you think, Bill?

Mr. GERSTENMAIER. Again, in this case we added these augmentation milestones to help assure where we needed to be.

Mr. ROHRABACHER. Right.

Mr. GERSTENMAIER. They weren't absolutely required, and this is a better way from a cost risk to the government for us to go enter into these activities.

Mr. ROHRABACHER. Right, but let's just note this was not that this program cost more money because as we have seen in so many other NASA programs because the people who had contracted were being unrealistic about what they could achieve or what they were willing to put in. What we have here is, again, examples of when we deal with the private sector, we make things a private endeavor rather than just a totally government endeavor, it costs the American people less, we end up getting more for the dollars that are being put in rather than less and more risky.

And, again, when we talk about the risk factor, I, when I look at the Shuttle, the risk compared to what we are talking about is overwhelming, and it always has been, and the Shuttle went from being—I was—I happened to be a young reporter when that, when the decision was made to move forward with the Shuttle and covered some of the earlier press conferences, and the Shuttle was going way, way over everything, whatever anybody believed it would cost. And there was no reliability on the people who were building the Shuttle to keep those costs down.

In fact, they were operating on cost plus, which gave them free reign. I think that now we are dealing in a very responsible commercial way. So I appreciate this hearing, Mr. Chairman, and I think we have learned a lot. Thank you very much.

Chairman PALAZZO. I now recognize the gentlelady from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to our witnesses today.

Mr. Gerstenmaier, you commented to Committee staff that your decisions frequently involve consideration of different risks, the source of the risks, and the mitigating measures, and I know this hearing is focused on commercial cargo but I think some of the les-

sons that are learned for commercial crew, if any, are too valuable not to be highlighted right now.

And so I wonder if you could tell us whether the risk and mitigating measures involved in testing the industry's ability to bring crew to the Space Station is likely to be similar to those in developing commercial cargo transportation?

Mr. GERSTENMAIER. I like to think our experience in this cargo activity will help inform us on how we move forward into the crew activity so we can take what we have learned through this process through cargo and dealing with the commercial providers in a kind of a non-traditional government manner with both the space act and also with the fixed price contracts, and we can see what works well, what doesn't work well from an overall product standpoint, and that can inform the approach that we take as we move forward into the cargo or into the crew activity.

So I think we can learn the lessons of working with these guys from a cargo standpoint. We can understand some of the risks, some of the things we understand, we don't understand, and understand how to move forward as we move into crew with the proper safeguards in place for the criticality of transporting crew to orbit.

Ms. EDWARDS. Are there factors that you would anticipate make it more challenging to develop commercial transportation of crew than cargo?

Mr. GERSTENMAIER. I think crew is more—is less fault tolerant from an overall standpoint. We have a very high regard for life and so we want to make sure that the crew is protected in all aspects, whereas the cargo, if it is lost, it is an impact to us, but it is recoverable. We can manufacture more hardware on the ground and fly again.

So crew carries a higher burden for perfection in order to make sure that the activity is performed in the best manner possible. So I think we need to factor that into our thinking, into our logic, into our acquisition approach for those activities to make sure we have got those proper safeguards that are proportional to the criticality of the cargo that we are carrying.

Ms. EDWARDS. And how important are the mitigating measures that are available under CRS such as pre-positioning by the STS–135 and availability of partner spacecraft and giving you the needed margin to ensure the continued Space Station viability?

Mr. GERSTENMAIER. Those are extremely important to us from a Space Station standpoint. Our philosophy of putting all the necessary cargo to keep Station viable for roughly about a year period on orbit is tremendously valuable to us. That allows some schedule slips to occur, that allows some of these flights to move around, and it is not an immediate impact to us. We had the critical items to make sure we can effectively utilize Space Station with minimal resupply for about a year.

So it has been really important for us to take these remaining Shuttle flights to get the cargo up to Space Station. It has also been very important for us during this phase to have the ability to return cargo from Space Station so we can understand what failures are occurring on orbit so we can make repairs in the next generation of hardware that we deliver to Station.

So I think we have utilized the Shuttle in the most effective manner for this lead-up period, and we have postured ourselves with the proper margin to allow us to bring these new providers online in a safe and reasonable timeframe.

Ms. EDWARDS. And how are you going to ensure that the margin will be available during the industry's attempt to demonstrate the ability to provide commercial crew transportation safely and reliably?

Mr. GERSTENMAIER. Again, this overall margin sits there throughout that period of time. It doesn't go away instantaneously on one particular date. We also assumed pretty conservative failure rates for our components on orbit, and we are in a pretty good period with Space Station where there is not a lot of failures occurring. Typically when you launch a spacecraft the first period on orbit there is a lot of failures as new systems come online. Then you reach a period where there is not many failures. Then towards the end of life as components start aging you start seeing more failures. We are in that low part of the curve, but we have assumed in our estimates that we would be in the higher part where more components are failing, so we have margin in the overall systems design on Station.

So I think we have a very reasonable margin to move forward. We need them to keep moving forward as fast as they reasonably can. We will encourage them to stay on the schedules they described to you, but we recognize that we won't push those schedules so far that we take risks to Space Station or we take risks to overall goal that we end up with a major failure on our hands.

So we will balance that risk of delivering on time as much as we can versus the margin we have on orbit, and we will balance those two as we do all along in all of our activities in space.

Ms. EDWARDS. Thank you very much. I just want to get in really quickly with Ms. Shotwell and Mr. Culbertson, I wonder if you can tell me as you talked about absorbing the potential for delay or for catastrophic failure, are you holding reserves in place of—in order to be able to, you know, to pay for those risks should they happen? I mean, how do we know that your company isn't just going to go belly up and then the taxpayers are left holding the bag?

Ms. SHOTWELL. Under our cost agreement with NASA we meet quarterly with their program management and show them our financials and show them what we have on our books. We do have some reserve right now.

Ms. EDWARDS. How much?

Ms. SHOTWELL. In our bank account?

Ms. EDWARDS. How much do you have in reserve that you are holding in case there is a delay or failure?

Ms. SHOTWELL. Currently we have about $30 million worth of reserve, and that grows monthly.

Ms. EDWARDS. And that is going to pay for a delay or a failure?

Ms. SHOTWELL. Not quite yet. No.

Ms. EDWARDS. Thank you.

Ms. SHOTWELL. It will build up by the time we reach the Station.

Ms. EDWARDS. Thank you.

Chairman PALAZZO. I now recognize the gentleman from Oklahoma, Mr. Lucas.

Mr. LUCAS. Thank you, Mr. Chairman.

Ms. Shotwell, in your testimony you say that NASA independently verified SpaceX's total development costs for Falcon 1 and Falcon 9 at $390 million. Does that include the cost of development for the Dragon Capsule?

Ms. SHOTWELL. No, sir. That was just for the Falcon 9 and the Falcon 1 Program.

Mr. LUCAS. So how much more was spent to develop the Dragon Capsule?

Ms. SHOTWELL. As of December last year another $300 million.

Mr. LUCAS. As of December last year. Okay. So what is the total development cost then for the entire Falcon and Dragon system?

Ms. SHOTWELL. We are not quite done with the Dragon development. I anticipate the entire development to be——

Mr. LUCAS. I have been led to believe maybe $690 million. Is that a fair number?

Ms. SHOTWELL. No. It will be $50 or $60 million more than that, sir.

Mr. LUCAS. So $700 million then.

Ms. SHOTWELL. That is correct.

Mr. LUCAS. Did NASA independently verify SpaceX's total development cost for the entire Dragon 9 and—Falcon 9 and Dragon Systems?

Ms. SHOTWELL. They had access to our financial data for that. I don't know the extent of the analysis they did on the data.

Mr. LUCAS. And maybe this is a question for the director as well as yourself then. Who exactly performed that kind of verification? An entity from within NASA or——

Mr. GERSTENMAIER. I will need to take that question for the record. I don't know the specifics of how that detailed cost accounting was done.

Ms. LUCAS. Well, as you can well expect just looking at this from the perspective of the taxpayer, we are curious about the money and the details and the verification.

You told our staff, Ms. Shotwell, that SpaceX does not assign engineering costs to individual vehicles. Is that correct?

Ms. SHOTWELL. Our engineers do not sign timecards. On the other hand, we can estimate the numbers of engineers that are working individual projects, but it is just estimates.

Mr. LUCAS. So I guess my question then doesn't that make it kind of hard for SpaceX or NASA to know what the true development cost is?

Ms. SHOTWELL. It makes it difficult to understand the exact cost. On the other hand, the overall cost for the total program is not. It is the money that we have expended.

Mr. LUCAS. So then I would ask thinking about that and looking at what the real costs are involved to both yourself and the associate administrator, so do either one of you keep track of the value of the technical services received from NASA since you mentioned using various facilities and testing equipment? Has that just been a freebie so to speak, or is that accounted for by either entity?

Ms. SHOTWELL. We pay for the facilities that we use from NASA, for example, the Marshall Spaceflight Center facility. We have le-

veraged the Arc Jet facility testing out of Ames, and we pay for that.

Mr. LUCAS. So that is all tracked, that is all verified, that is all of public record then?

Mr. GERSTENMAIER. Yes.

Mr. LUCAS. To you, Associate Administrator, NASA has told us that the average cost to deliver a kilogram of cargo to the International Space Station by the RS—CRS contract is $59,000 per kilogram. I believe CRS providers are expected to deliver 40 metric tons, 40,000 kilograms times $59,000 per kilogram. By my math that is about $2.36 billion, and the CRS contract total is $3.5 billion, totals on the contracts.

So what is the remaining trillion—billion, sorry, we are into too many trillions in this town anymore, billion, $140 million paying for?

Mr. GERSTENMAIER. The way we—the numbers we talk about in cargo, we talk about the 40 metric tons of cargo, 20 to each contractor. That is what we consider usable cargo. So for that, for us that is the actual cargo that is delivered to space. That is the thing that we can actually use, but you can't just deliver it. You actually have to pack it, it has to go into flight support equipment in the spacecraft, and there is other things that hold it in place or allow it to be delivered, and that is the difference in price.

So we are paying for a price per rocket and then we have been asked to provide the price per kilogram, so then we just divide those out, and whether we include that other support equipment or not, you can get two different prices for the price for kilogram. And we can show you all the accounting and all the math and all the details behind that if you would like to go review that in detail.

Mr. LUCAS. I suspect we will look at all the numbers because it on the surface appears to be about a $1 billion prize here for successfully prevailing in this contract.

With that, Mr. Chairman, I yield back the balance of my time.

Chairman PALAZZO. Thank you. I recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

I am looking at what the Committee staff has prepared for us, and there are some things that kind of stood out, and I would like any of the witness's response to it, and this is on page five of 12 of our handouts.

The following chart lists approximate cost to deliver one pound of cargo to the International Space Station under various programs. Development costs are not included in these calculations and are considered proprietary information by the COTS partners. We have got for the Space Shuttle $21,268 per pound, $21,268. We have got for the Russian Progress $18,149 per pound, and then we have the Commercial Resupply Services, CRS, of $26,770 per pound.

So if this information is accurate, CRS costs 26 percent more to deliver a pound to the International Space Station than does the Space Shuttle and 47 percent more per pound than if we used the Russian Progress. And then there are some further notes. Costs for the Russian Progress and the Commercial Resupply Program are NASA estimates. The CRS estimate would be higher at around

$39,700 per pound if derived using a method similar to that used for the Space Shuttle.

Now, if that ends up being the correct number, $39,700 per pound using the CRS Systems, well, that is 118 percent higher cost to American taxpayers than the Russian Progress and 21,000—excuse me. Eighty-seven percent higher cost to American taxpayers than the cost of using the Space Shuttle.

My first question is are these numbers accurate or inaccurate, and if they are inaccurate, where did the Committee staff make their mistakes, and second, just your general thoughts concerning this information.

Mr. GERSTENMAIER. I think I would like to go ahead and we can take that for the record. We need to understand exactly what went into those calculations and then compare them with what we have got for estimates. It is difficult on how you assume what costs are where, whether we have—we look at new obligation authority, we look at actual costs during the year, you know. How many Shuttle flights occur per year drives that clearly right. If we only fly one or two Shuttle flights, that dramatically changes that number in that table.

Mr. BROOKS. Well, this is assuming four missions per year.

Mr. GERSTENMAIER. Okay.

Mr. BROOKS. According to another one of the footnotes. Again, I don't know if this information is accurate or inaccurate, but I do find it startling that at least according to what the staff has handed me that the Commercial Resupply Service approach is so much higher for American taxpayers than is either the Russian Progress or the NASA Space Shuttle.

Mr. GERSTENMAIER. Again, we also have to look at how we—those are calculated, the development costs for the Shuttle Program are not in those numbers. There is lots of things that we need to talk about specifically, so it is not as simple as the table implies. I would like to take the question for the record, and we can provide you much more detail behind those numbers, and we can understand better what is in the table, and we can do much more of a fair comparison between the two and show you the range of how you can look at these numbers, and it is not—there is not a single number as you described. There will be a range of numbers for each one of those columns that you described in the table, and we can show you those ranges and how they fit across all three providers.

Mr. BROOKS. Well, please, if you could have some of your staff get with the Committee staff and consult about this, would that be satisfactory?

Mr. GERSTENMAIER. We will do that.

Mr. BROOKS. Thank you.

[The information can be found in Appendix II.]

Ms. SHOTWELL. Could I respond?

Mr. BROOKS. Certainly.

Ms. SHOTWELL. I appreciate that. One of the assumptions used to calculate at least our dollars per pound here in the charter was—it is an erroneous assumption. It was purely taking the $1.6 billion under the CRS contract and dividing that by 20 metric tons. The fact is that NASA has bought 12 flights from SpaceX. We could

take much more than 20 metric tons to orbit on those flights. We don't charge NASA extra for anything above the 20 metric tons as long as we are still doing the 12 flights.

Depending largely on the density of the cargo that we take and we haven't packed the Dragon yet with actual cargo, but in the best case from a taxpayer perspective, if we can take the full Falcon 9 performance capability to the ISS, the cost per pound of cargo is under $10,000 a pound using our system. It is not $26,000 a pound.

Mr. BROOKS. Thank you, and would you please get with the Committee staff at some point, either you or someone else, and try to ascertain what the true numbers are in as much as that is critical I am sure to the decision making process that the Congress will make.

Ms. SHOTWELL. Yeah. I would be happy to.

Mr. BROOKS. Thank you.

Chairman PALAZZO. I now recognize the gentlelady from Florida, Mrs. Adams.

Mrs. ADAMS. Thank you, Mr. Chairman, and I appreciate you holding this hearing.

We are working through an incredible time in the history of the American Space Program. I would be shocked if you would find anyone on this panel who didn't understand this. You know, yesterday was the 50th anniversary of those famous words from our 35th President, John F. Kennedy, who said, you know, we are going to go to the moon, and he inspired all of us to believe we could beat the Russians, and we could make it to the moon, and American ingenuity was limitless in the face of seemingly insurmountable odds.

Mr. Chairman, in my district people are hurting. Their families are hurting, they are fighting tooth and nail to scrape together to pay their mortgage, they are looking for change to pay for their gas, and now here comes the layoffs, lots of layoffs. And I understand sometimes layoffs happen, but what is most troubling is this one was unnecessary. It was unnecessary because we didn't have to get to this point. It was poor planning, poor management, and a lack of vision that led us here. And as I see it we must continue to invest in our exploration capabilities, we must continue to invest in our cargo transport capabilities, and we must continue to invest in job creation.

This all starts by NASA following the directives of Congress. We cannot lose sight of the fact that an Authorization Bill exists, and if we don't like the direction of the Authorization Bill, if we think that as a Nation we need to move in a different direction or change something in that Authorization Bill, then we should have that conversation rather than trying to start a different direction through budget requests.

Ms. Shotwell and Mr. Culbertson, I hope you both fully understand the awesome, awesome responsibility being laid on your respective companies. This is not some meaningless investment or some contract that your country—company can just simply hope to fulfill. The future of our international commitments, the bond and the promise of the United States is on the line, and you signed up for the responsibility to ensure those promises have been met.

History has trusted the United States of America to lead the way in space technology and exploration. I hope you and your companies understand what is being asked of you by the American people and the trust that the American people have put in you because it is not something I take lightly, and I will not be able to let you forget that either.

With that said, I would like to start with Mr. Gerstenmaier. This country has spent over $1.25 billion on the commercial cargo effort to date. When is our first cargo mission going to supply Station?

Mr. GERSTENMAIER. The demonstration flights will be later this fall, and the first cargo resupply mission will be in 2012.

Mrs. ADAMS. How much more money do you expect NASA will request for this effort before the commercial companies will be able to resupply on a regular basis?

Mr. GERSTENMAIER. We will request no more funds than what are there. These are fixed price activities as we described earlier, and the cost that we have laid and we brought forward are the costs we expect, and so we—there will be not any more increase to deliver the cargo that we have purchased through these service contracts.

Mrs. ADAMS. How many people does NASA expect to hire to manage our Commercial Cargo Program as the flight manifest starts to fill up?

Mr. GERSTENMAIER. We will not hire any NASA civil servants beyond what we currently have monitoring the Cargo Program as the flights ramp up.

Mrs. ADAMS. What confidence level does NASA have in each contractor meeting the latest revised schedules for their first cargo resupply missions?

Mr. GERSTENMAIER. I think the schedules they have laid out are optimistic but realistic schedules. I think I would also as we have discussed here earlier, I would also say that I would be remiss if I didn't expect to see some schedule delays and delays in those schedules, and we will be prepared for those delays. They will not have financial penalties to us for those delays, but we have to make sure we had the right margin on Space Station that we don't impact the operations of Space Station when those inevitable delays occur.

Mrs. ADAMS. Now, when asked about the article in the paper about possible problems with docking, SpaceX docking and doing the test docking, you said there were technical problems that needed to be understood. What type of technical problems? I mean, are they such problems that could delay any kind of test docking for a length of time, a longer length of time?

Mr. GERSTENMAIER. No. They are understandable problems that we have seen before. There are some hardware differences. As Gwynne described earlier, there is a lot of software activity that needs to be done. We are very closely monitoring that software activity to make sure that it gets done correctly.

I don't see anything there that is an extraordinary problem, but they are not easy technical problems to solve. We will work through the contractors as we have before. We will apply our best folks to help where we can, and the companies have been doing a great job of responding and helping and working with us in those

areas. The activities they are doing at Marshall to actually verify software and hardware functionality is a tremendous testimony that SpaceX has stood up, to recognizing this as an area that needed extra help. They went and procured some extra help from NASA in that area.

Mrs. ADAMS. So you don't believe it will be delayed?

Mr. GERSTENMAIER. There will be some delays, but they will be manageable within the overall margin we have onboard.

Mrs. ADAMS. Ms. Shotwell, I know but SpaceX has received $250 million of the American tax dollars so far for Region 18 of your 22 COTS. Are you going to be ready to deliver on your promise to supply the Station when this country needs it?

Ms. SHOTWELL. Yes, we are.

Mrs. ADAMS. Thank you.

Chairman PALAZZO. All right. Thank you.

I now recognize the gentleman from Texas, Mr. Olson.

Mr. OLSON. Well, thank you, Chairman Palazzo and Ranking Member Costello, for your courtesy and the opportunity to come back to Science and Aeronautics Subcommittee. While I am no longer on the Subcommittee, I still represent the heart of human spaceflight, the Johnson Space Center in Space City, USA. I am grateful to our witnesses for being here today, excuse me, to give us your insights and perspectives.

The commercial industry has been part of the human spaceflight program since its inception. The only thing that has changed is the means in which we contract with the commercial sector for the critical services and support they provide to NASA with change, prudent management, and forthright accountability by all parties, Congress, NASA, and industry is imperative.

Adherence to the goals, objectives, safety requirements, and budgets and milestones are critical to the agency's success. If we falter in any one of these areas, we risk failure, and in our business failure can cost lives, waste precious funding, result in irreversible damage to the industry, and in some cases result in the failure of an entire program.

In this business failure is not an option. We must avoid failure at all costs, and in doing so it is imperative that we provide candid and factual updates of the program accomplishments and issues so they can be mitigated before failure. This is the essence of why we are here today, to assess where we are in the NASA COTS Program that began in 2005, six years ago.

My first question is for you, Mr. Gerstenmaier. First of all, I want to tell you you were missed at the Art at NASA Gala in Houston a couple weeks ago, and I understand the COTS Program is behind schedule relative to the pronouncements over the past year by the COTS providers. In your view where do we stand today relative to both program investment and schedule now that we are five years and $1.2 billion into the program?

Mr. GERSTENMAIER. Again, I think as we have discussed earlier, the development activity is a very tough time for these, for the contractors to do development, and we see that. We wanted to make sure we got the development right, and we didn't rush that, so we had some schedule delays in the development activity. I think that is appropriate and reasonable for where we are, and we have re-

tired some of those development activities. We now entered into the operational phase, and we need to continue to monitor that moving forward.

So I think I see the scheduled delays that have occurred. I think they are reasonable with what we have seen. I have seen these companies rise to the challenges that they have encountered during these development delays, and they both have done a very good job of working through those problems. I think there will be problems in the future. They need to address those in a very straightforward manner as you described, and we need to make sure we get to the right technical solution and don't shortchange things or cut things to move forward because it is absolutely important we get this service to Station as soon as we can and make sure we get it there safely.

Mr. OLSON. Yes, sir. I agree completely. We do have to minimize that gap, but just following up with that question, is it your view that the COTS providers had the capacity and resources in place to successfully execute this manifest, their manifest on this timeline?

Mr. GERSTENMAIER. I think they have the appropriate resources to do that, but I think we, again, need to be prepared that if they run into problems, we have some ability to absorb some delays, and we don't force them into a situation where they have to take undue risks.

Mr. OLSON. Appreciate that.

Ms. Shotwell, Mr. Culbertson, would you like to comment on that question?

Mr. CULBERTSON. Well, as far as how we are executing here, I want to, first of all, I want to apologize to Bill for tossing my customer a grenade a few minutes ago and without taking it back, and I will take it back right now. What we are doing is a combination of Space Act Agreements with, as I said, fixed funding and fixed price contracts under the FAR, which are to protect both parties from—on a contractual basis. But they are fixed price, and if we have to go redo a test, we absorb the cost of that test. If we have to figure out a different way to ship our first stage to Wallops, we have to absorb the cost of doing that. We don't transfer that cost to the government. This is not a cost-plus contract.

So there is not going to be a growth in cost on the CRS to the government, but there may be cost to us, and so that affects our ability to continue on the program in the future, and we will have to evaluate as we go forward whether it is profitable and worth the risk or not. Right now it is worth the risk because we see it as very important to the Nation that we provide this cargo delivery. But we see it important to the industrial, the space industry that commercial companies step up to this responsibility and figure out a way to accomplish this.

This is a precedent for what is coming in the future, I believe, and the amount of money that has been paid to us on the CRS contract has been mentioned several times as extra money that has been sent to the contractors. That is not the case. When you do business in a commercial world, you are given milestone payments. You are given progress payments in order to make sure that you can buy your long-lead items, you can pay your staff, you can pay

your engineering development and keep the program moving until you reach that final goal, and we have 20 to 30 percent at stake on every mission if we don't execute it. So we are not going to get paid ahead of time. We have to execute it, and so we are committed to making it happen, but it is a commercial endeavor and not a traditional government cost plus development, and that is a really big difference from what people are used to, and I think some folks in the community might be having trouble understanding that.

We are very sympathetic to the impact of layoffs and what is going on. If I could hire all the people that are being laid off in the Shuttle Program, I would do it, but then I couldn't control my costs in order to provide you the service you need.

Mr. OLSON. Ms. Shotwell.

Ms. SHOTWELL. Yes. Just to be clear, we have built enough hardware and we are far enough along in our development, we are very confident of our costs and thus our prices. We will execute, we will complete the COTS demonstration, and we will execute the CRS missions to Station for what we have proposed.

Mr. OLSON. Thank you, ma'am, and since I have crossed into the realm here where the clock is actually increased, I have a red light, I yield back the balance of my time.

Chairman PALAZZO. Thank you, Mr. Olson.

That is it for our questions today. I do want to thank our witnesses for their testimony.

Mr. OLSON. Mr. Chairman, one question. I would like to ask unanimous consent that I enter—I have a statement to enter into the record about my concerns, some of my concerns elaborated on my concerns with the course our country is following. I apologize.

[The prepared statement of Mr. Olson appears in Appendix II:]

Chairman PALAZZO. Without objection, so approved.

Several things seem clear from today's testimony, namely that there is still tremendous challenges both companies need to address, and time is growing short. NASA has obligated 1.25 billion over the last five years, and it is my firm hope that before the year is out we will have real proof that this investment has been worthwhile.

Congress has been very supportive and has provided significant additional funding, but the burden of proof is now on NASA and its commercial partners to accomplish what they have signed up to do.

I thank the witnesses for their valuable testimony and the members for their questions. The members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments from members.

The witnesses are excused, and this hearing is adjourned.

[Whereupon, at 11:41 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. William H. Gerstenmaier, Associate Administrator, Space Operations Mission Directorate, National Aeronautics and Space Administration

Questions submitted by Chairman Steven Palazzo

Q1. If a reduction of ISS crew size were implemented because of delays in CRS, how would the reductions be apportioned among the ISS member nations? Would a NASA astronaut continue to serve on board even if it was the U.S. who failed to maintain a reliable cargo delivery system?

A1. Any impacts caused by Commercial Resupply Services (CRS) contract delays would need to be jointly worked with the International Space Station (ISS) International Partners. NASA has kept the Partners apprised of the progress of these vehicles. Any impacts to overall ISS crew complement planning will be negotiated with the Partners along with the other impacts to science and cargo.

Q2. Do the cargo delivery providers, whether they are commercial providers or one of the international partners, bear any liability if they cause an accident to the space station?

A2. The Intergovernmental Agreement (IOA) for the International Space Station (ISS) contains a broad cross-waiver of liability clause to encourage participation in the exploration, exploitation and use of outer space through the ISS. The United States and its international partners waive claims against each other, and against each other's contractors, for damages caused during space operations, except for damages caused by willful misconduct. The IGA requires NASA to flow down this cross-waiver to its contractors. The CRS contract also includes this cross-waiver of liability. Neither the CRS contractor nor NASA is liable for damage to the other's property that occurs during space operations, including damage to the ISS, except for damage caused by willful misconduct. If the contractor damages the ISS, the mission is deemed a failure and the contractor forfeits the final milestone payment for that mission.

Q3. If a commercial cargo provider loses a mission, do they have to replace the cargo?

A3. In the event of a failed mission, the contractor forfeits the final milestone payment (20 percent of the mission price). The contractor is not required to replace the cargo.

Q4. If they lose a mission do they owe NASA a replacement flight? If no, why not?

A4. In the event of a failed mission, the contractor forfeits the final milestone payment (20 percent of the mission price). The contractor is not required to re-perform the flight.

Q5. NASA is investing considerable sums to stand-up two new launch providers. What were the factors that led NASA to take this path instead of using existing capabilities of the EELV program? Current Delta and Atlas launch systems have proven to be highly reliable, but they're also under-utilized. How and why did NASA come to the conclusion that using a clean-sheet approach with new launch systems was more cost-effective?

A5. The Commercial Resupply Services (CRS) contracts were awarded through a full and open competition for the delivery of a minimum of 40 metric tons of cargo from 2011 through 2015. None of the proposals that were received by NASA in the competition proposed the use of an Evolved Expendable Launch Vehicle (EELV). The successful bidders—Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (OSC)—were selected on the basis of the responsiveness of their proposals to the requirements of the announcement. These proposals involved the use of the new Falcon-9 and Taurus-2 launch vehicles.

Q6. Have NASA and FAA clearly worked out roles and responsibilities regarding the safe launch and reentry of cargo payloads?
Q6a. Are there any unresolved issues between the two agencies relative to the licensing of NASA-contracted cargo payloads to ISS?

A6a. Launches under the CRS contract are commercial launches, not Government launches. The contractor is required to obtain a FAA license for launches and reentries.

Q6b. Is FAA treating the resupply flights in the same manner as any other commercial launch?

A6b: NASA cannot speak for the FAA with regard to how it treats other commercial launches. Launches under NASA's CRS contract are commercial launches, not Government launches. The contractor is required to obtain a FAA license for launches and re-entries.

Q7. It's my understanding that fixed-price contracts are generally used to buy commodities or other services that have relatively low risk. Since CRS is not a low risk venture why did NASA choose to use a fixed-price contract for the cargo resupply services program?

A7: The CRS acquisition was conducted under Part 12 of the Federal Acquisition Regulation (FAR), Acquisition of Commercial Items. The contract complies with the Federal Acquisition Streamlining Act (FASA), which requires that acquisitions of commercial services must be fixed-price contracts. Cost-type contracts are prohibited for commercial services.

Q8. Why was FAR Part 12 chosen over FAR Part 15 for Cargo Resupply Services acquisition?

A8. The Commercial Space Act of 1998 states that space transportation services are considered to be commercial items for acquisition purposes. NASA complied with this requirement by using Part 12 of the FAR, Acquisition of Commercial Items, to acquire ISS cargo resupply services under the CRS contract.

Q9. Given the degree of risk using newly developed launch systems to deliver critical cargo to the ISS, do one or two demo flights equate to a mature system?

A9. NASA recognizes that one or two missions do not equate to a mature system. The commercial cargo contractors and NASA will be learning new things about these cargo vehicles as they fly their test launches, demonstrations, and the CRS missions. Even after the Space Shuttle had flown for several years, NASA was learning new things about the operation of the vehicle. NASA recognizes that there is risk in these new systems that will only be reduced through continued safe and reliable performance. One of the reasons NASA invested in two cargo providers was to mitigate the normal start -up issues that may occur with these new cargo launch systems.

Q10. Your testimony said, "NASA sees no reason to doubt either company's objectives," yet there have been no demonstrations flights to the ISS so their capabilities are unknown.
a. If the demonstration flights are unsuccessful, what is NASA's plan?

A10a. The COTS partners are strongly incentivized to successfully complete their demonstration flights. The companies do not get paid for their milestones unless they are successful. In addition, both companies have over a billion dollars at stake for the services missions under the CRS contracts. If either company has an unsuccessful demonstration flight, NASA expects them to keep trying until they are successful. However, in the event that one of the CRS contractors cannot meet its obligations under CRS, then NASA could rely on the remaining CRS contractor to fly additional cargo flights. Both companies have indicated that they can increase their flight rate for CRS missions if required by NASA. In addition, NASA could contract for additional HTV, ATV, and/or Progress flights for more cargo delivery.

Q10b. Does NASA have any recourse, monetarily or otherwise, if the providers fail to meet NASA's requirements?

A10b. Under the terms of the SAA, the partners are only paid for milestones that are successfully completed. If milestones are missed, NASA may unilaterally terminate the agreement if it is determined that sufficient progress is not being made and it is in the best interest of the Government. See the response to Question 10 for a non-monetary recourse. The CRS contracts include termination for cause provisions. They also contain clauses regarding recovery of interim milestone payments and require the contractor to forfeit the final milestone payment in the event of a failed mission.

Q10c. Do the CRS contracts contain any "look back" provisions which would allow NASA to recover damages if the providers fail to fulfill their obligations?

A10c. In the event of a failed mission the contractor forfeits the final milestone payment. Once the contractor reaches the final milestone event, prior milestone payments for that mission are not recoverable.

Q11. In briefings by senior NASA officials leading up to this hearing, committee staff was told, "NASA did not get the level of detail with Space Act Agreements that they expected."
Q11a. What was missing and what were the weaknesses NASA found in dealing with a complicated development activity under a Space Act Agreement?

A11a: There has been no information missing from the data provided to NASA. Under the COTS SAAs, the partner proposes its own milestones and provides NASA with the data needed to verify that the milestone was successfully accomplished. To date, this has been done for every performed milestone under the COTS SAAs. It should be noted that after the SAA partners chose to use the ISS as their on-orbit test bed, the provision of key development data related to meeting safety requirements for conducting proximity operations and berthings to the ISS was made a requirement of their SAA agreements. To date, the information required by NASA to determine that the SAA partners are meeting those safety requirements has been provided.

Q11b. What lessons were learned from this?

A11b. NASA believes that it is important to have the option of using different mechanisms to work with its partners. In this case, use of SAAs for the COTS demonstration flights and contracts for CRS operational missions was appropriate. The former approach maximized flexibility for the COTS providers in preparing for a demonstration of their commercial capabilities, while the latter obtained cargo delivery services specifically for NASA including the insight required for an operational system.

Questions submitted by Acting Ranking Member Jerry Costello

Q1. What types of in-kind or non-reimbursable services allowed by Space Act Agreements are being provided to COTS companies? Has NASA analyzed and estimated the value of those in-kind services? If so, what are the results of the analysis and estimated values?

A1: NASA provides limited technical assistance to the COTS partners from the Commercial Advisory Team (CAT). The CAT is made up of technical experts throughout the Agency who assist NASA and the COTS companies in the disposition of technical milestones. NASA has not estimated the value of these services, as the Agency does not track the time providing assistance only and specifically to the COTS partners. Their function supports both the COTS partners and NASA management. Other than the CAT, NASA has offered use of the Tracking and Data Relay Satellite Services (TDRSS) for space communications with the ISS and has provided some equipment to facilitate ISS ground testing and integration. The estimated value of these equipment and services has not been calculated.

Q2. What insight and oversight mechanisms is NASA using to ensure that CRS contractors are on track to meet their production goals and scheduled flight milestones? Are they the same mechanisms for either COTS or CRS?

A2. NASA has weekly schedule meetings with the CRS providers, SpaceX and Orbital, and so has considerable insight into the progress that the contractors are making. In addition, under the contract, each provider delivers monthly detailed schedule updates on not only the CRS missions but also their demo activities. The schedules show progress on major vehicle hardware, software and integration activities including insight into their schedule slips. In addition, the ISS Program has key design, test, and analysis deliverables that are required from the providers to verify safety and interface requirements are met, and to perform integrated analysis and verification that ensures that the final vehicle can be successfully integrated with the on orbit ISS vehicle. The ISS Program also has insight into the conditions that drive these deliveries. And finally, the program performs independent analysis of the schedules and deliverables that SpaceX and Orbital provide and assesses their performance.

Q3. What is the nature of your insight into COTS contractors and what specific areas do you have exposure to?

A3. NASA has significant insight into the COTS partners' technical and schedule status. The COTS program office has frequent and thorough communications with the partners ranging from daily telecons for technical integration issues to formal quarterly management reviews with the NASA program manager and company executives. NASA also has limited insight into company financial status to assess the

company's financial viability and verify that both the company and NASA contributions are consistent with the terms of the agreements.

Q3a. Why have the COTS launch dates slipped, and how much advance insight did you have that the slips would occur?

A3a. The COTS partners have experienced delays due to development challenges as their program transitions from design to integration and testing. Both partners continue to make technical progress toward their development and demonstration milestones. Schedule status is formally reported by NASA, using its own judgment regarding estimated dates at the quarterly management reviews.

Q3b. Will NASA's level of insight be any different under the CRS contracts?

A3b. NASA's level of insight is different under the CRS contract than under the COTS SAAs. Under a contract, NASA has the ability to levy specific contractual requirements and the responsibility to verify them. Under the CRS contract, the contractors have to demonstrate that they meet specific cargo configuration requirements and environmental constraints (and provide the relevant data to NASA). In addition, NASA is performing a risk assessment on the launch system design for the contracted missions that are not being performed for the demonstration missions.

Q3c. What indicators from CRS provider activities, for which NASA currently has no insight into, might enhance the accuracy of projected mission launch dates?

A3c. NASA receives detailed schedules from the contractors, and believes that it currently has sufficient, continuing insight into CRS provider activities to be able to make reasonable projections of mission launch dates. This is an important consideration, as it impacts the cargo complement to be flown on a given CRS mission.

Q4. If cargo delivery flights fall behind schedule, how will NASA prioritize what cargo is carried on those flights? What priority is given to utilization payloads in CRS mission manifesting and scheduling?

A4. If CRS cargo delivery flights fall behind schedule, NASA will prioritize the cargo carried on those flights on the basis of payload criticality to the maintenance and operation of the International Space Station (ISS). Beyond meeting these requirements, NASA will first satisfy additional requirements associated with NASA utilization missions involving the Human Research Program and Technology Development and Demonstration projects necessary to NASA's exploration mission. Finally, NASA would work together with the Non-Profit Organization managing the National Laboratory aspects of the ISS to determine the priority of utilization-related cargo, including equipment and samples supporting research objectives by organizations other than NASA. The success of the CRS cargo delivery flights and use of the ISS as a National Laboratory have always been directly linked.

Q5. How will NASA respond if a commercial provider experiences a failure and indicates to NASA that the cost of recovering puts the financial viability of its company at risk?

A5. NASA would assess the specific situation before determining an appropriate course of action. The Government may terminate the CRS contract if the contractor fails to perform or fails to provide, upon request, adequate assurances of future performance.

Q6. How do the CRS contracts deal with last minute payload additions on CRS flights? For instance, if NASA determines that there is a need for a critical life support component to be shipped up to the Station, is there flexibility to allow NASA to add that payload to a CRS flight at the last minute? Would there be a financial implication for such a late addition to the payload?

A6. The CRS contract allows flexibility in the specific manifest as long as the cargo bag complement and overall weights of the bags remain within the negotiated limitations of the mission. NASA specifically designed the contract this way to allow late-load items and the ability to fly critical life support spares at the last minute.

Q7. Does NASA plan to include National Laboratory payloads on the scheduled 2012 commercial cargo flights? If not, why not? What will be the impact on that research if commercial providers are not ready to deliver cargo to the ISS next year? How can researchers plan for ISS utilization under these circumstances?

A7. NASA does plan to include National Laboratory payloads on 2012 CRS cargo flights. Should the CRS capabilities be delayed, delivery of material in support of National Laboratory research would be delayed, as well. While NASA and its CRS

providers are working to establish a routine cargo delivery capability to the ISS to enable maximum use of the Station for research in a wide variety of science disciplines, it is important that researchers build a degree of flexibility into their schedules to accommodate possible slips in the availability of these new services.

Q8. What do any CRS delays mean for the number of scientific experiments that can utilize the ISS, the nature of science that can be conducted, and the duration of potential experiments on ISS?

A8. The specific impacts of a potential delay in the availability of CRS capabilities would depend on the length of the delay, the planned duration of a given experiment, and whether such a delay involved resupplying an experiment already in progress aboard the ISS. In most cases, a delay in the operational availability of cargo services would mean a delay in the commencement of a particular experiment. NASA and its CRS providers are working to ensure that cargo resupply will be available in a timely manner, both to support scientific research and utilization and to maintain Station operations.

Questions submitted by Congresswoman Donna Edwards

Q1. As with any space mission, commercial cargo providers are at risk of suffering a launch failure.a. How will NASA respond if a commercial provider experiences a failure and indicates to NASA that the cost of recovering puts the financial viability of its company at risk?

A1a. With regard to COTS, NASA's response to a commercial partner's failure and resultant financial uncertainty would depend on the nature of the failure, the financial risk posture of the company, and its plan for recovery after the failure. However, in general, if a company is unable to complete the milestones listed in the SAA, NASA may terminate the agreement and is under no obligation to make any further payments.

With regard to CRS, NASA's response would be dependent on the particular circumstances of the failure and the company's performance. The Government may terminate the CRS contract if the contractor fails to perform or fails to provide, upon request, adequate assurances of future performance. One of the NASA mitigations for this risk was the award of two CRS contracts.

Q1b. Who is responsible for funding any technical work needed to address the failure to meet technical objectives?

A1b. With regard to COTS, NASA pays for a milestone only if the milestone is successfully completed. The COTS partners are responsible for funding any work needed to address the failures of any technical objectives in order to retry and successfully complete the objective for payment in a subsequent milestone.

With regard to CRS, the CRS contractor is responsible for ensuring that its launch system and spacecraft provide the required service and meet the technical requirements of the services contract. NASA makes fixed-price payments for the services, regardless of the actual costs the contractor incurs to ensure its system meets the requirements or to address failures to meet the requirements. NASA does perform insight activities of the contractor and pays for those activities.

Q1c. Are there any reserves being held at NASA should a major failure to meet COTS [or CRS] objectives occur?

A1c. With regard to COTS, there are no reserves held in the COTS program for additional payments to the COTS partners since NASA is not financially responsible for additional costs associated with failures. NASA is responsible only for the investments included in the Space Act Agreements and those payments are only made upon successful completion of milestones in the Space Act Agreements.

With regard to CRS, NASA does not hold specific reserves to address a major failure. Program reserves or other Agency reserves would need to be used if additional flights were required.

Questions submitted by Congressman David Wu

Q1. Is NASA assuming any liability risk or providing any indemnification for the CRS missions?

A1. Launches and re-entries under the CRS contract are licensed by the FAA, and are covered by the FAA's statutory provision for Government payment of third-party liability claims exceeding the contractor's required insurance. NASA does not have

authority to indemnify the CRS contractors, and contractually has not assumed the risk of third-party liability for the CRS contractors.

Q2. Do the.CRS contracts protect NASA's assurance of cargo delivery in the event that a commercial provider experiences a launch failure?

A2. In the event of a failed mission, the contractor is not required to re-perform the mission. One of the mitigations for this risk was the award of two CRS contracts.

Q3. Do the COTS Space Act Agreements and CRS contracts allow for non-NASA payloads to be flown on the same NASA mission?

A3. With regard to CRS, the contractor is performing a service specifically for NASA. In the case of a shared CRS cargo flight to ISS, NASA and non-NASA payloads would have to meet the same requirements. Payloads are prohibited from interfering with each other, with the function of the cargo delivery vehicle, or with ISS systems and functions.

With regard to COTS, the partner is conducting its own demonstration of its capability and may choose to fly other payloads on the demonstration flights. However, other payloads cannot interfere with ISS systems and functions.

3a. Can NASA veto such a shared mission?

A3a. With regard to COTS, yes, NASA can disapprove any payload for missions to the ISS that does not meet ISS safety requirements. Under the CRS contract, NASA has the ability to disapprove a shared mission that has an impact to the CRS mission, does not meet ISS safety requirements, or causes NASA to perform additional work for which NASA has not received consideration.

3b. What precautions must NASA take if it shares the same mission and what is required of NASA?

A3b. With regard to COTS, all payloads proposed to be flown to or near the ISS must be approved by the ISS Safety Review Panel.

With regard to CRS, in the case of a shared CRS cargo flight to ISS, NASA and non-NASA payloads would have to meet the same requirements. Payloads are prohibited from interfering with each other, with the function of the cargo delivery vehicle, or with ISS systems and functions.

3c. Does NASA get any cost-reduction from the CRS contractors if it allows them to fly non-NASA commercial payloads on a CRS mission?
3d. If not, why not?

A3c&d: NASA purchases CRS services in terms of kilograms of up mass, not flights; the NASA cargo upmass on a particular CRS flight might or might not take up the total upmass capacity of that flight. Therefore, NASA does not receive a cost reduction from the CRS providers if a given flight is able to take up some non-NASA cargo in addition to that upmass procured by NASA.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Cristina Chaplain, Director, Acquisition and Sourcing Management, U.S. Government Accountability Office

Questions submitted by Chairman Steven Palazzo

Q1. What were the weaknesses that were found with the government's use of Space Act Agreement for complicated development activities like CRS?

A1. Space Act Agreements were not used in the procurement of Commercial Resupply Services(CRS). In June 2009, we reported that the International Space Station program office awarded, under a separately competed procurement from COTS, two commercial resupply services contracts in December 2008 to SpaceX and Orbital. In prior reports we have noted weaknesses on DOD development activities that were conducted through the use of the other transaction authority including the Evolved Expendable Launch Vehicle (EELV) and Future Combat Systems (FCS). For more information on these weaknesses in these programs, please see question 2 below.

Q2. In your testimony you state, "Going forward, it will be important for both NASA and the commercial sector to avoid hinging strategies on assumptions that we know have negatively impacted previous efforts to adopt commerciallike approaches in space." Would you please elaborate on some of these erroneous assumptions and explain by providing examples from other government procurements that you think are applicable?

A2. We have previously reported that DOD's EELV program was begun under the assumption that there would be a large national and international marketplace for commercial satellites and therefore, for launch vehicles. However, this commercialmarketplace never materialized. As a result, the government became the lonepurchaser, increasing costs above the original baseline. Additionally, because thisprogram was begun under an "other transaction authority" (DOD's authority similarto NASA's Space Act agreement authority), DOD has been unable to fullyunderstand the costs associated with the program. This lack of knowledge canimpact the government's ability to negotiate costs when awarding a contract.

In 2003, the Army and Boeing entered into an "other transaction" agreement for the system development and demonstration phase of the FCS program. The Army's rationale for using such an agreement was to encourage innovation and to use itswide latitude in tailoring business, organizational, and technical relationships to achieve the program goals. The FCS program faced significant challenges in setting requirements, developing systems, financing development, and managing the effort. Congress raised concerns over the use of the agreement for the development of a program as large and risky as FCS, and the Secretary of the Army directed that the other transaction agreement be converted to a FAR-based contract.

In addition, the X-33 and X-34 programs were developed as an effort to significantly reduce the cost of access to space by partnering with private industry to develop and demonstrate technologies needed for future reusable launch vehicles reaching orbit in one stage. Both programs experienced difficulties achieving their goals primarily because NASA did not develop realistic cost estimates, timely acquisition and risk management plans, and adequate and realistic performance goals. In particular, neither program fully assessed the costs associated with developing new, unproven technologies; provided for the financial reserves needed to deal with technical risks and accommodate normal development delays; developed plans to quantify and mitigate the risks to NASA; or established performance targets showing a clear path leading to an operational reusable launch vehicle. Underlying these difficulties were problems with the agreements and contracts that established the relationship between NASA and its industry partners and eventual erosion of commercial prospects for the development of new reusable launch vehicles. As a result, both programs were cancelled.

Questions submitted by Acting Ranking Member Jerry Costello

Q1. How timely has the response been to delays in SpaceX's second COTS demonstration flight due to the need to redesign components for the propulsion system, producing the launch vehicle tank, and in testing of the Dragon spacecraft's navigation sensor?

A1. As of June 2011, no new delays have been reported and SpaceX has completed two additional milestones as part of its risk reduction efforts.

Q1a. Should we expect that SpaceX will need to address other technical issues following the second and third COTS demonstrations, and even after the initial CRS flights, given that the launch vehicle is so early in its flight history?

A1a. We reported last November that NASA certifies rockets based on payload risk classifications, which require anywhere from 3 to 14 successful launches for the highest classification category (lowest risk tolerance), depending on various certification alternatives.

Officials at the Aerospace Corporation told us that while the causes of a given system's failures can change over time (i.e. from the first three to seven flights, or even later in the design-life of the system), early failures are heavily weighted toward engineering design or process errors, especially in the first three launches. Once these errors are caught and "driven out" of a system, workmanship errors are the next most frequent cause of failures. After about the seventh launch, the frequency/severity of workmanship errors exhibits a steady state throughout the flight history of a system. Aerospace officials said this basic trend is the same for both expendable and reusable launch vehicles, as well as for both government and commercial systems, although the failure rate is much higher for the latter.

As such, there is a reasonable expectation that SpaceX will need to address additional technical issues following future demonstration missions; however, the incidence or duration of any delays resulting from such issues is a matter of speculation.

Q1b. If so, has time been added to the schedule to accommodate these types of changes?

A1b. This question would best be addressed by SpaceX and NASA. Nevertheless, as of June 2011, there have not been any apparent changes to the company's COTS schedule from what we testified on May 26th. It has been reported in the media that NASA has given tentative approval for SpaceX to combine its second and third demonstration missions into one mission to be completed near the end of 2011.

Q2. What do any CRS delays mean for the number of scientific experiments that can utilize the ISS, the nature of science that can be conducted, and the duration of potential experiments on ISS?

A2. We reported in November 2009 that if these vehicles are delayed, NASA officials said they would pursue a course of "graceful degradation" of the space station until conditions improve. Under such conditions, the space station would only conduct minimal science experiments. International Space Station program officials told us in May 2011 they have taken steps to mitigate the short-term impact of CRS flight delays through prepositioning of cargo on the last space shuttle flights. Officials added that these flights and the planned European Space Agency's Automated Transfer Vehicle and Japan's H-II Transfer Vehicle flights in 2012 will carry enough cargo to meet science-related cargo needs through most of 2012. Despite these steps, NASA officials said they would still need one flight each from SpaceX's and Orbital's vehicles in order to meet science-related cargo needs in 2012. Beyond 2012, NASA is highly dependent on SpaceX's and Orbital's vehicles in order to fully utilize the space station.

Questions submitted by Congresswoman Donna Edwards

Q1. You say in your statement that GAO's work looking at other government acquisitions has shown that the government is required to make additional investments to mitigate risks and that the amount of investment can be lessened by securing, early on, accurate knowledge of costs, schedule, and risks. You also say that NASA has limited influence over the approaches taken by cargo providers. What does this say about the appropriateness of using the NASA cargo model to acquire crew transportation services?

A1. NASA has performed extensive analysis to determine if Space Act agreements are appropriate for remaining phases of its commercial crew effort and has tentatively concluded that such agreements would not be appropriate. Specifically, NASA's entire commercial crew certification process is based on partners' compliance with NASA safety requirements for human spaceflight, but according to NASA, such requirements cannot be levied in a Space Act agreement.

Q2. Mr. Culbertson stated that for Taurus II and Cygnus, Orbital was able to take advantage of heritage flight-proven design features although new developments were required for other program areas. In the partnership between NASA and the commer-

cial cargo providers, who is credited with the invention of the capabilities according to the Space Act agreements?

A2. The Space Act agreements between NASA and Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital) state that ″NASA has determined that to stimulate and support the capability of a United States commercial provider to provide space and orbital transportation services to the public and the Federal Government, the interest of the United States would be served″ by waiving the government's rights to inventions[1] made[2] by the partners in the performance of work under these agreements. The Space Act agreements include a provision that provides a means for NASA to waive rights to any or all inventions that may be made under the agreements. We contacted NASA about whether the waivers were granted, but have not yet received a response. Because GAO has not specifically analyzed issues related to intellectual property rights and the commercial cargo Space Act agreements, we do not know whether or not the partners petitioned for such a waiver or if NASA granted it. Ultimately, the determination of whether or not a certain invention falls within the parameters of these provisions will be made on a case by case basis.

Questions submitted by Congressman David Wu

Q1. Your prepared statement notes that "additional resources have been allocated to development of the launch complex in Wallops Island to mitigate further slips."

Q1a. Who is supposed to be responsible for developing the launch complex—NASA or Orbital?

A1a. To support its COTS demonstration mission, Orbital and the Mid-Atlantic Regional Spaceport are responsible for funding the construction of several new facilities, including a horizontal integration facility (to integrate the Taurus II with the Cygnus spacecraft); a launch pad, mount, and ramp; and separate fueling facilities for the Taurus II and the Cygnus spacecraft. As required by its Space Act agreement with NASA, Orbital completed an initial review in September 2008 of the launch site facilities to be developed and prepared a concept of operations for its launch activities. NASA provided Orbital with $10 million for completing this milestone.

Q1b. What is the extent of additional funding that has been provided to develop the launch complex and what is the source of that funding?

A1b. We have not conducted audit work to determine the extent and source of the additional funding. This question would best be addressed by Orbital and NASA.

Q1c. In your view, is the plan and schedule to complete the launch complex viable?

A1c. We previously reported that Orbital's development schedule was aggressive and the company continues to experience delays in developing its launch complex at Wallops Island. In June 2009, we reported that Orbital's construction schedule indicated that its launch pad, mount, and ramp would be completed by the end of 2009, its horizontal integration facility was planned for completion in May 2010, and the Cygnus space vehicle fueling facility was planned to be completed by October 2010. In May 2011, we testified that the completion of the company's launch facilities remained the key program risk to meeting its COTS demonstration mission schedule. Orbital officials told us that an around-the-clock schedule would be initiated later in the summer to expedite the completion of verification testing of the liquid fueling facility, which is the primary risk factor in completing the launch facility. Orbital officials indicated in July 2011 that its COTS demonstration mission would slip from December 2011 to February 2012 to allow for the completion and certification of its rocket propellant and pressurization facilities at Wallops Island.

[1] "Invention" is defined by both SpaceX's and Orbital's Space Act agreements as "any innovation or discovery that is or may be patentable or otherwise protectable under title 35 of the U.S.C." Title 35 relates to patents.

[2] "Made" is defined by both SpaceX's and Orbital's Space Act agreements, in relation to any invention, as "the conception or first actual reduction to practice of such invention."

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Frank Culbertson, Jr., Senior Vice President and Deputy General Manager, Advanced Programs Group, Orbital Sciences Corporation

Questions submitted by Chairman Steven Palazzo

Q1. Under the COTS agreement your company has to meet milestones in order to receive progress payments:

Q1a. How would you describe NASA's responsiveness to data submissions made by your company when seeking to prove compliance with a milestone?

A1a. NASA has been very responsive to our data submissions. Our approach has been to pre-coordinate with NASA the type of data they expect as part of the milestone completion criteria, which has helped to avoid confusion when milestone completion letters are submitted. Further, when submissions are made, NASA has been very responsive in reviewing the data and responding with questions, allowing us to satisfy their concerns in a timely fashion and meet our milestone plans.

Q1b. How responsive has NASA been with requests for technical assistance?

We have generally worked any requests for technical assistance through NASA's Commercial Cargo and Crew Program Office and in all cases, they have been very responsive to our requests. They have coordinated the support on the NASA side and the resulting support has been very good.

Q2. In your testimony you state, ". . .this is a compressed development schedule compared to traditional government programs, it has challenges, but it is using commercial development and production practices with NASA insight." NASA has always used commercial suppliers to build and operate launch vehicles and spacecraft, so please explain exactly what these "commercial development and production practices" are and how they differ from any other NASA development and production.

A2. While NASA has certainly purchased goods and services from privately owned companies throughout its history, the federal acquisition regulations impose restraints on NASA's purchases which are quite different from commercial practices. Orbital Sciences' continuing analysis over several decades indicates that the spacecraft we build for private companies cost between one-third and one-half of the cost of U.S. government spacecraft. That difference is largely accounted for by the additional oversight required by the government at all levels (e.g. technical, managerial and financial).

Q3. Orbital is planning its first demonstration flights in October; when do you expect the launch pad at Wallops Island, Virginia will be ready?

A3. Orbital has relatively little influence on the readiness date of the launch pad that is owned by MARS. It is our understanding that MARS plans a dedication ceremony for the launch pad in October. The first demonstration flight cannot occur any sooner than three months after the pad becomes available.

Q4. When does Orbital plan to fly its first non-NASA commercial mission with the Taurus 2 launch vehicle?

A4. Orbital continues to discuss non-NASA Taurus II flights with potential customers. Since no contract has been signed, it is not yet appropriate to announce a mission.

Question submitted by Ranking Member Jerry Costello

Q1. To what extent does Orbital purchase insurance for the launch and payload associated with a CRS cargo launch? What, if any, other steps does Orbital take to mitigate against the potential failure of a CRS cargo launch?

A1. Orbital plans on procuring insurance against the final payment of our milestone based contract with NASA which is approximately 20% of the total mission cost.

Orbital has performed satellite launches dating from 1990 and has developed a solid performance record over two decades of missions for commercial and government customers. The keys to Orbital's success include well documented design, verification, and operations processes that are certified to AS 9100/ISO 9001 industry standards. These documented processes allow Orbital to incorporate lessons learned from earlier launches into the mission cycle for the CRS cargo launches. An-

other key attribute is Orbital's use of hardware and software that is common across multiple programs within Orbital, meaning that teach rocket component benefits from an active production line and extensive testing performed on several different products. In addition, Orbital takes several active steps to mitigate against the potential failure of a CRS cargo launch, including:

1) Independent Peer Review: One of Orbital's ingrained internal processes is an Independent Design review performed by peers within each engineering department but outside of the program to ensure the vehicle is ready to fly.

2) Independent 'Gray Beard' Review: Orbital has retained an Independent Readiness Review Team (IRRT) comprised of experts with long careers with NASA, the Air Force and industry leading technical organizations. The IRRT has attended each of the Taurus II design reviews dating to the start of development to actively apply technical expertise and industry lessons learned.

3) Independent Safety and Mission Assurance Organization: Orbital has created an independent S&MA reporting chain that is outside of the program and which reports directly to the General Manager of the Launch Systems Group. Patterned after NASA lessons learned from the Challenger disaster, the S&MA group places quality inspectors and safety engineers in positions of active oversight on the Taurus II program while maintaining independence from the program.

4) Component Qualification Program: Orbital has developed an internal process for verifying the design of flight hardware prior to flight that is based on MIL–STD–1540, which is a recognized aerospace industry standard. This process ensures that each hardware component is tested to environmental levels exceeding the flight environments to demonstrate design margin (called Qualification Testing). In addition, each flight component is tested to flight environment levels to screen out workmanship defects (called Acceptance Testing). The combination of Qualification and Acceptance Testing provides confidence that the rocket components will function properly during flight. Flight software goes through a disciplined Functional Qualification Test that similarly verifies that he software meets all design requirements and that it functions in a reliable manner.

5) Test Like You Fly: Orbital has created the simulation tools necessary to rigorously test the software and hardware together in realistic 'hardware in the loop' environments that exercise the integrated system throughout multiple mission sequences prior to flight. Off nominal logic and redundant functions are also tested as part of the rigorous ground test program. Statistical methods such as Monte Carlo analysis are utilized in simulation environments to ensure mission success is still achieved even while varying critical subsystem parameters to worst case deviations.

Questions submitted by Congresswoman Donna Edwards

Q1. Are there any reserves being held at Orbital should a major failure to meet COTS objectives occur? How much reserve is being held?

A1. Orbital's contract for the Commercial Orbital Transportation System (COTS) and Commercial Resupply Services (CRS) with NASA is a fixed price contract with Orbital responsible for additional costs for tasks above and beyond what NASA requires us to do to fulfill our obligations under the contract. Orbital has an extremely healthy balance sheet including hundreds of millions of dollars of cash on hand, and thus is in no risk of not meeting its obligations.

Q2. In the partnership between NASA and Orbital, who is credited with the invention of the capabilities according to the Space Act Agreements?

A2. Orbital owns the intellectual property associated with our launch vehicle, the Taurus II, which is being entirely developed by Orbital with its own money. The development of the Cygnus is partially funded by NASA-the COTS Space Act agreement signed in 2008 gives intellectual property rights associated with the development of Cygnus to Orbital.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Gwynne Shotwell, President, Space Exploration Technologies

Questions submitted by Chairman Steven Palazzo

Q1. Under the CQTS agreement, your company has to meet milestones in order to receive progress payments:
a. How would you describe NASA's responsiveness to data submissions made by your company when seeking to prove compliance with a milestone?

A1. NASA has created an efficient and effective process for receiving and responding to data submissions. NASA has been prompt in providing comments or additional data requests with respect to milestone reviews, notices of successful milestone completion, and timely payments.

b. How responsive has NASA been with requests for technical assistance?

To date, NASA has been highly responsive in providing SpaceX with technical assistance as requested in the context of COTS. Here, NASA and SpaceX technical teams have worked as partners towards achieving the objectives of the COTS agreement. Separate from the COTS Space Act Agreement, SpaceX also has executed Reimbursable Space Act Agreements (by which SpaceX pays NASA for the use of the agency's time and facilities) with other NASA centers. For example, SpaceX has executed Reimbursable SAAs with NASA AMES Research Center and the Jet Propulsion Lab for technical assistance and use of facilities.

Q2. When does SpaceX plan to fly its first non-NASA commercial mission on the Falcon 9 launch vehicle?

A2. SpaceX has already flown a non-NASA Falcon 9 mission. The first Falcon 9 flight, launched successfully on June 4, 2010 under an FAA commercial launch license, was a nonNASA demonstration mission. At present, SpaceX's next flight of the Falcon 9 for a commercial customer is scheduled for the third quarter of 2012.

Q3. In your testimony you said, "SpaceX, even given the tremendous amount of development activities that we have had over the past few years, we have been profitable since 2007." Is this based on GAAP reported earnings? Has SpaceX had positive free cash flow each year since 2007?

A3. We consider the most important financial metric related to profitability to be positive cash flow. SpaceX has experienced a stronger ending cash balance through positive cash flow each year since 2007.

Q4. In your testimony you said that NASA represented less than half of SpaceX's 38 contracted Falcon 9 missions. Who are the non-NASA customers, and how many missions are scheduled for each customer?

A4. Per the attached, SpaceX's current NASA, commercial and international missions under contract include 33 full Falcon 9 missions plus 5 optional flights to total 38. Of those flights, thirty-seven percent are NASA resupply missions to the International Space Station (ISS). The list of customers and the number of missions are indicated on the attached manifest; please see Attachment 1—SpaceX Manifest.

Question submitted by Acting Ranking Member Jerry Costello:

Q1. Please explain to what extent SpaceX purchases insurance for the launch and payload associated with a CRS cargo launch. What, if any, other steps does SpaceX take to mitigate against the potential failure of a CRS cargo launch?

A1. SpaceX will comply with all contractual and regulatory requirements for each launch mission it performs. In accordance with the terms of its CRS contract and the applicable FAA regulations, SpaceX will purchase insurance at least in the amount prescribed by the FAA to cover the potential claims of third parties for bodily injury or property damage arising out of any particular licensed activity. Third-party launch liability insurance, however, does not cover any loss or damage to the payload on a CRS mission. The FAA's regulatory regime requires NASA (or any other purchaser of launch services) to bear the risk of loss to the payload during a licensed activity.

Specifically, the FAA's regulatory regIme requires (and the CRS contract reflects) the implementation of a reciprocal waiver of claims for each licensed activity, under which each party waives and releases claims against all the other parties to the waiver and agrees to assume financial responsibility for property damage it sustains

and for bodily injury or property damage sustained by its own employees, and to hold harmless and indemnify each other from bodily injury or property damage sustained by its employees, resulting from a licensed or permitted activity, regardless of fault.

The risk of loss is minimized, however, as SpaceX performs extensive testing and analyses to ensure the success of each mission. In addition, NASA maintains extensive insight and approval rights under the CRS contract in order to allow NASA to assess the risk to the cargo itself and to its safe and timely delivery. Finally, NASA reserves the right to utilize Government-performed technical assessments of launch and cargo vehicles/configurations to evaluate the readiness of the Contractor to deliver NASA cargo to the ISS. The combined efforts of the SpaceX–NASA team effectively mitigate the risk of potential failure of a CRS cargo launch.

Questions submitted by Representative Donna Edwards:

Q1. I take from your testimony that SpaceX will be able to sell its designs, vehicles, and capabilities to partners other than NASA. Can you estimate the market value of this transfer? How much could SpaceX stand to gain from selling its capabilities in the private market?

A1. As described by NASA in its initial COTS solicitation of January 2006, the COTS program was established to: (a) implement U.S. Space Exploration policy with an investment to stimulate commercial enterprises in space, (b) facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving reliable, cost effective access to low-Earth orbit, and (c) create a market environment in which commercial space transportation services are available to Government and private sector customers. As the product of joint public-private funding, there is no "transfer" and the work performed under COTS is meant to be commercialized. SpaceX, like all U.S. entities, is bound by export control laws and other restrictions from selling designs, vehicles or capabilities to non-U.S. entities, absent State Department approvals. SpaceX may sell services, for which some of the underlying technologies were developed under the COTS program, into the commercial and governmental space transportation markets. Demand in the private commercial market varies from year-to-year and market share potential depends on a wide range of factors; however, as noted in hearing testimony, whereas in 1980, 100 percent of commercial launches took place from within the United States; today, it is less than 12 percent. For the first time in more than three decades, via SpaceX, an America company has begun to recapture international market-share in the commercial satellite launch sector—a sector in which the U.S. has seen steady erosion relative to Chinese, Russian and French competitors over the three previous decades.

Q2. In the partnership between NASA and SpaceX, who is credited with the invention of the capabilities according to the Space Act Agreements?

A2. Under the standard Invention and Patent Rights Clause included by NASA in Space Act Agreements under which the nongovernmental partner performs work of an inventive type for NASA, the partner may obtain title to inventions it makes under the SAA through an advance or individual waiver, and NASA benefits through retention of a government purpose license in the invention, as well as from the available commercial source of a needed technology. In this case of the partnership between NASA and SpaceX, NASA has determined that in order to stimulate and support the capability of a United States commercial provider to provide space and orbital transportation services to the public and the Federal Government, the interest of the United States would be served by waiving to SpaceX the rights to any inventions made by SpaceX in the performance of work under the COTS SAA. With respect to each SpaceX invention for which a waiver of rights is applicable, however, NASA reserves (a) an irrevocable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government in accordance with any treaty or agreement with the United States; and (b) march-in rights.

Attachment 1 - SpaceX Manifest

Customer	Date†	Vehicle	Launch Site
NASA COTS – *remaining*	2011	Falcon 9 / Dragon	Cape Canaveral
ORBCOMM – *multiple flights*	2011-2014	Multiple	Cape Canaveral
NASA Resupply to ISS – *Flights 1 thru 12*	2011-2015	Falcon 9 / Dragon	Cape Canaveral
Falcon Heavy Demo Flight	2012	Falcon Heavy	Vandenberg
MDA Corporation (Canada)	2012	Falcon 9	Cape Canaveral
SES (Europe) – *two flights*	2013, 2015	Falcon 9	Cape Canaveral
Thaicom (Thailand)	2013	Falcon 9	Cape Canaveral
DragonLab	2013	Falcon 9 / Dragon	Cape Canaveral
NSPO (Taiwan)	2013	Falcon 9	Vandenberg
Spacecom (Israel)	2014	Falcon 9	Cape Canaveral
Space Systems/Loral	2014	Falcon 9	Cape Canaveral
Astrium (Europe)	2014	Falcon 1e	Kwajalein
Bigelow Aerospace	2014	Falcon 9	Cape Canaveral
CONAE (Argentina) – *two flights*	2014, 2015	Falcon 9	Cape Canaveral
Iridium – *multiple flights*	2015-2017	Falcon 9	Vandenberg

† Hardware arrival at launch site.

Appendix II

Statement Submitted for the Record

STATEMENT SUBMITTED FOR THE RECORD

PREPARED STATEMENT OF REPRESENTATIVE PETE OLSON

Since I have been a Member of Congress, I have been a strong advocate of NASA, its mission, and the significant importance that space has had around the world and to our country. NASA's programs profoundly impact almost all aspects of the U.S. economy and our daily lives through technology development and influence in national security, medical science, aeronautics, planetary science, research, education and many other areas.

However, what is no longer clear to me and many of my colleagues is . . . NASA's current mission. The U.S. space industry needs a path forward that sets a clear direction with attainable goals and an appropriate balance of human space flight, exploration, technology, science, and aeronautics programs that can assure U.S. competitiveness and a strong future for our country and the industry.

Collectively, the agency and programs have been studied and evaluated extensively in the past decade by Presidential Commissions, independent commissions, The Government Accountability Office, NASA's Office of the Inspector General, professional organizations and NASA, resulting in complete instability due to too many changes in direction, policy, budget and programs, to safely, affordably, and successfully move forward in any U.S. space endeavor. This trend must stop—NASA is wasting billions of tax payer dollars as a result of ineffective management, and imprudent decisions. The agency, a proud symbol of U.S. exceptionalism and regarded as one of the most technically capable, worthy of our national investment, has now deteriorated to an agency whose future and purpose is in question and programs under constant scrutiny.

Right now we face a gap with an unknown end . . . a gap in U.S. space capability that was unnecessary, risking our future and global leadership in space, and creating a detrimental and irreversible impact to our industrial capability for years to come. The position we find ourselves in was entirely avoidable and must now be corrected with explicit direction, clearly articulated goals, and the commensurate funding. Performance and accountability to these goals—safety, cost, program milestones, and succeeding or failing—is our collective responsibility. The viability of NASA's future and our nation's future in space depends on our success, right now.

The civil space program needed to evolve in order to move beyond Low Earth Orbit where our expertise and resources have been the focus for more than 30 years. There is challenge in this necessary evolution but methodical, strategic planning could have preserved the critical capabilities required for the next step. Instead, the Administration opened up a revolution in February of 2010 that has led to our fragmented industry. By evidence of actions on the part of NASA and the Administration, we are operating under two government policies—the NASA Authorization of 2010 enacted last October and the President's National Space Policy released last June. Now, as Congress has stepped in, in partnership with the Agency and industry to bring stability back into the agencies programs, we must understand where our programs are in accomplishing the goals and objectives of their programs. In order to equitably manage our precious government resources, we must hold all segments of the industry—The Administration, NASA, and contractors—accountable for their actions and performance.

There is only one policy that should be directing NASA and the civil space industry . . . the Authorization Act of 2010, funded through the Continuing Resolution. NASA must move forward, without hesitation, in implementing the actions detailed in the NASA Authorization of 2010, enacted by the President and Congress, last October.

The Authorization directs NASA to continue the development of a commercial cargo and crew capability to support the International Space Station and accelerate the development of the Space Launch System (SLS) and Multipurpose Crew Vehicle (MPCV) that will take the U.S. beyond low earth orbit (LEO) order to develop capabilities to take humans to Mars. The Authorization is the most prudent action at this point, well thought out in the context of the budget environment, current capabilities, and industry development to assure a strong future in space for the U.S.

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD BY MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, SPACE OPERATIONS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ISS Program Planning and Control

ISS Independent Government Estimate for Commercial Resupply Services (CRS)

Program Planning & Control Office (PP&C)

June 21, 2011

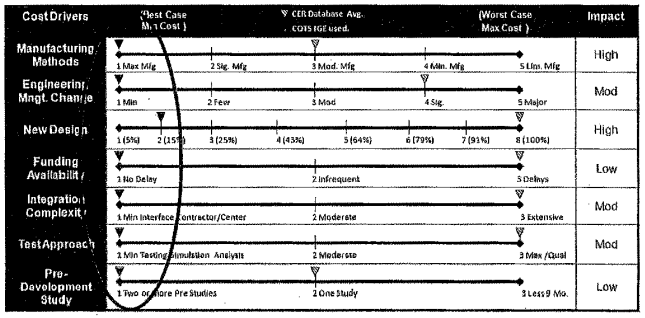
ISS Cost Estimate for Commercial Resupply Service (CRS)
Ground Rules and Assumptions

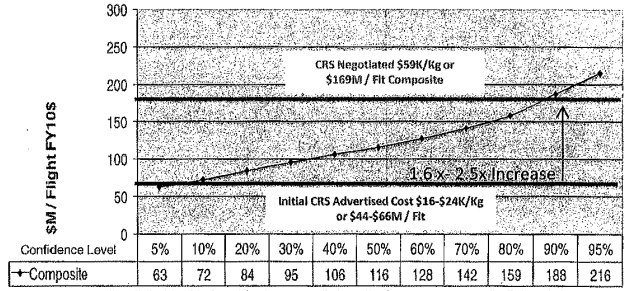
- In April 2007, the ISS Program Planning & Control Office developed an Independent Government Estimate (IGE) of potential cargo providers - - IGE utilized technical data available at that time for the following vehicles: HTV, ATV, Space X, and RpK
- In March 2008, the IGE was updated to incorporate additional information gained during the Commercial Orbital Transportation System (COTS) re-compete and 1 year of additional COTS knowledge
  - IGE updated to include Orbital technical data and removed RpK, ATV, and HTV
- Utilized NASA/Air Force Cost Model (NAFCOM) as primary estimating tool
- NASA historical cost drivers were adjusted to model the uniqueness of each developer's system at a subsystem level
  - Major input drivers include 85% learning curve, low percentage of new design, low Systems Engineering & Integration (SE&I), and high manufacturing capability
- IGE estimated cost per flight
- Vehicle payload capabilities were estimated at 2.5Mt for Space X (PDR) and 2.3Mt for Orbital (Proposal)
- Assumed (for estimating purposes only) CRS Up mass requirement split ~50%/50% between 2 providers at 2 to 3 Flight/Yr.
- Based on up mass requirements, the IGE assumed a total of 20 to 25 CRS vehicles would be needed (spread across two providers)
- April 2007 study did not include DDT&E amortization or launch vehicle operations and support impacts
- April 2008 study added 50% DDT&E amortization (less COTS investment), launch vehicle operations, and support impacts
- Both IGEs ($/Kg) do not include launch insurance, third party indemnification, analytical integration cost for ORU certification, and Flight Support Equipment (FSE) cost
- Contract Award was completed in December 2008 at an average of $59K/Kg (CRS composite FY11-FY16 services)

ISS Cost Estimate for Commercial Resupply Service (CRS)
April 2007 IGE Summary

- ISS completed IGEs for the CRS effort in April 2007
  - IGEs were developed with following GR&As
  - Utilized NASA/Air Force Cost Model (NAFCOM) as primary estimating tool
  - NASA historical cost drivers were adjusted to model the uniqueness of each developer system at a subsystem level
    - Major input drivers include 85% Learning Curve, Low % New Design, Nominal SE&I, High Manufacturing Capability
    - IGE ($/Kg) did not include launch insurance, operations, third party indemnification, no analytical integration cost for ORU certification, and no FSE cost
  - Results
    - $52K/Kg or $142M / Flight (46%/54% SpX/RpK.)
    - DDT&E – $1.2B @ 70th %

      Not Included in the Per Mission or Per Kg Price



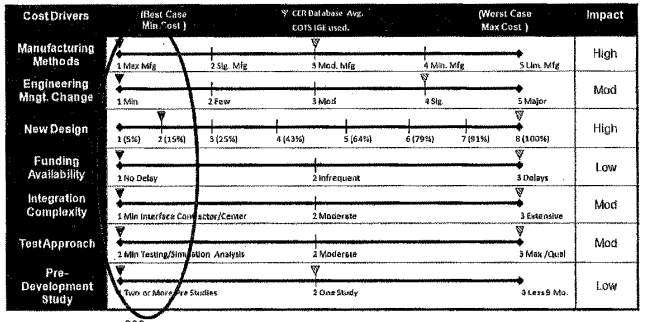


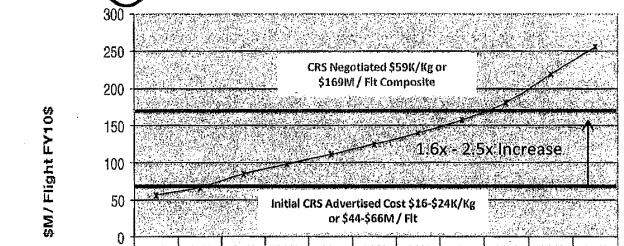
Confidence Level	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Composite	63	72	84	95	106	116	128	142	159	188	216

Initial IGE for CRS indicated providers' early advertised costs were overly optimistic by a factor of 1.6 to 2.5 compared to final negotiations

ISS Cost Estimate for Commercial Resupply Service (CRS)
April 2008 IGE Summary

- ISS completed updated CRS IGEs in April 2008
  - IGEs were developed with following GR&As
  - Utilized NASA/Air Force Cost Model (NAFCOM) as primary estimating tool
  - NASA historical cost drivers were adjusted to model the uniqueness of each developer system at a subsystem level
    - Major input drivers include 85% Learning Curve, Low % New Design, Low SE&I, High Manufacturing Capability
    - IGE ($/Kg) did not include launch insurance, third party indemnification, no analytical integration cost for ORU certification, and no FSE cost
- Update to the April 2008 IGE included
  - April 08 increased Flight Quantities from 20 to 25
  - April 08 included Space X and Orbital and removed RpK, ATV, and HTV
  - April 08 included Operations Support
  - April 08 included amortization of 50% of the DDT&E less COTS investment
- Results
  - $57K/Kg or $157M / Flight (46%/54% SpX/Orb.)
  - DDT&E – $860M @ 70th %





Confidence Level	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Composite	56	67	85	98	111	125	140	157	181	219	256

April 08 IGE update for quantity changes, operations and amortization of DDT&E continued to indicate optimistic provider estimates.

Acronyms

- ATV – Automated Transfer Vehicle (European Space Agency (ESA) Cargo Vehicle)
- CER – Cost Estimating Relationship
- COTS – Commercial Orbital Transportation Services
- CRS – Commercial Resupply Services
- DDT&E – Design, Development, Test & Evaluation
- FSE – Flight Support Equipment
- GR&A – Ground Rule and Assumption
- HTV – HII Transfer Vehicle (Japan Aerospace Exploration Agency (JAXA) Cargo Vehicle)
- IGE – Independent Government Cost Estimate
- ISS – International Space Station
- Kg - Kilogram
- Mt – Metric Ton
- NAFCOM – Nasa / Airforce Cost Model
- Orb – Orbital
- ORU – Orbital Replacement Unit
- PDR – Preliminary Design Review
- RpK – Rocketplane-Kistler
- SE&I – Systems Engineering & Integration
- SpX – Space X