

**STATEMENT OF
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**BEFORE THE
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES**

February 27, 2015

Chairman Palazzo, Ranking Member Edwards, and Members of the Subcommittee,

Thank you for the opportunity to participate in this important hearing. I also want to thank the Science, Space, and Technology Committee for its continued support for NASA's Commercial Crew Program. This innovative program will soon yield a critical outcome: the return of U.S. human spaceflight capability. To state the obvious, our current dependence on Russia to carry U.S. astronauts into space is unacceptable for numerous geopolitical, competitive, and financial reasons. Critically, American companies stand poised to fly American astronauts safely and reliably by 2017. Today, I am pleased to provide you with information regarding the status of SpaceX's efforts, technologies, schedule and remaining challenges as we move towards our first crewed mission to the International Space Station (ISS) under NASA's Commercial Crew Transportation Capabilities (CCtCap) program.

SpaceX is honored to have been selected by NASA as one of the two CCtCap awardees. Human spaceflight is the primary reason that SpaceX was founded in 2002; the safety and reliability technologies that we have designed and built into SpaceX launch vehicles and spacecraft reflect this long-standing intent. While there remain technological hurdles to overcome, we are working steadily, thoughtfully, and efficiently with NASA to yield the safest and most reliable astronaut transport system that the world has ever known.

1. SpaceX Background

Thirteen years after SpaceX's founding, we are the fastest growing launch services company in the world with nearly 50 missions on manifest. Today, SpaceX is serving the Nation's space program in multiple respects, including cargo resupply missions to and from the ISS with the



Falcon 9 launch vehicle and Dragon spacecraft under NASA's Commercial Resupply Services (CRS) program. We have now successfully launched the Falcon 9 fifteen consecutive times, conducting missions for NASA, the Department of Defense, and the world's leading commercial satellite telecommunications companies. To date, the Dragon spacecraft has berthed with the ISS six times, carrying cargo and science payloads – including plants and live animals – and successfully returned critical science experiments and other cargo to Earth. Earlier this month we brought cargo back from the Space Station on a Dragon spacecraft and the very next day Falcon 9 launched a deep-space science payload for NASA, NOAA, and the Air Force.

As a commercial space transportation company, SpaceX is restoring America's competitive position in the global space launch market. We are recapturing market share that the U.S. long ago surrendered to our French, Russian, and Chinese competitors. This translates directly into jobs for Americans. With each Falcon 9 launch, for any of our customers, SpaceX demonstrates safety and reliability, which is critical for our NASA and national security customers. Each launch also demonstrates the best in U.S. high-tech engineering and manufacturing capabilities - all of SpaceX's design, development, engineering and manufacturing occur here in the United States. Every Falcon 9 launch vehicle (including engines and tanks) and Dragon spacecraft are made in America. We do not rely upon Russia for any element of the launch vehicle or spacecraft.

At SpaceX, we believe strongly in the value of competition. NASA has narrowed its crew transportation services providers to two companies that will compete for future astronaut launch opportunities. A competitive environment for the provision of launch services generally, and for astronaut carriage in particular, benefits of NASA and the country. Competition improves safety and provides the best outcome for the consumer – in this case, NASA and the American taxpayer. Indeed, the Aerospace Safety Advisory Panel's (ASAP) Annual Report for 2014 noted that it, “strongly supports NASA's decision to select two companies for the CCtCap contract” because “NASA will benefit from competition.” Further, the ASAP correctly observed that, “the inherent dissimilar redundancy of these two systems means that a technical issue with one system will not preclude continued U.S. access to the ISS.”

2. Crew Dragon and Falcon 9 System Overview

SpaceX provides fully integrated, domestic human spaceflight capability for astronaut transport with all four major elements imbedded and integrated within the company – the Dragon spacecraft, Falcon 9 launch vehicle and their associated ground systems and mission operations.

America's astronauts will ride in Crew Dragon atop the Falcon 9 launch vehicle from the historic LC-39A launch pad at NASA's Kennedy Space Center. SpaceX is upgrading LC-39A to support several launches per year, including the Falcon Heavy launch vehicle. SpaceX will manage all crew launch and mission operations using an approach similar to the one that has resulted in 15 consecutive successful missions, including 6 Dragon cargo missions in partnership with NASA. Precision and rapid recovery operations will be executed in the water and on land, built on SpaceX's lessons learned from the ISS cargo program.

SpaceX's Crew Dragon and Falcon 9 integrated crew transportation system is designed to reduce complexity, enhance safety and increase reliability. For example, our system eliminates a separate launch abort tower that requires a critical jettison event on every mission. Crew Dragon is providing fault tolerance above and beyond NASA requirements in many instances. For example, the SuperDraco launch abort system (LAS), which is fully integrated into the spacecraft and includes an increased fault tolerance level to ultimately support a safe propulsive land-landing concept of operations. Additionally, the Cargo Dragon's deployable solar arrays have been eliminated to reduce the number of mechanisms on the vehicle and further increase reliability.

By developing, testing, manufacturing and integrating all elements of the commercial crew transportation system, SpaceX is able control all elements of the system to improve reliability, enhance safety and control schedule. To further improve safety and reliability, SpaceX places a very high value on our ability to 'test like you fly.'

3. Crew Dragon

Crew Dragon is a free-flying, reusable spacecraft that will safely and efficiently carry the next generation of American astronauts to space. It is designed to fly up to seven astronauts to and from space beginning in 2017.



Crew Dragon was designed and is built and tested at SpaceX's facilities in partnership with NASA and thousands of American suppliers. It builds upon the success of Cargo Dragon, which has been carrying cargo to and from the ISS since 2012. While it employs key common elements with Cargo Dragon, the crew system has been designed to be more robust with key safety and reliability features that are described below.

Crew Dragon represents a significant step forward in space access. Leveraging the most advanced 21st century technologies, the Crew Dragon system also takes advantage of lessons learned over the history of human spaceflight. Crew Dragon is comprised of three main structural elements: the nosecone, which protects the vessel and the docking adaptor during ascent and reentry; the spacecraft, which houses the crew and pressurized cargo, as well as the service section (containing avionics, directional thrusters, parachutes, and other infrastructure); and the trunk, which will support Crew Dragon's solar arrays and radiators, as well as providing aerodynamic stability during aborts.

3.1 Crew Dragon Advanced Safety Systems

For the first time ever in human spaceflight, astronauts will have a dedicated system for escape in the event of a launch anomaly all the way through launch ascent to orbit. The spacecraft employs the SuperDraco launch abort system, which is capable of safely moving the Crew Dragon away from the launch vehicle at any point during ascent. In the past, astronauts could be pulled rapidly away to safety in the event of a launch vehicle anomaly only in the earliest stages of ascent. The Space Shuttle had no such safety system.



Crew Dragon's LAS relies on the 8 SuperDraco engines built into the spacecraft's sidewalls. Those engines produce up to 120,000 pounds of axial thrust. The LAS includes significant redundancy - it is a fault tolerant system that exceeds NASA requirements. While NASA does not mandate fault tolerance during an abort, Crew Dragon can suffer a failure within its system and still operate safely during the majority of the ascent. To demonstrate the capability and resiliency of this 21st century safety system, SpaceX will test Crew Dragon's escape capabilities during a unique pad abort test this spring and an in-flight abort test later this year.

Crew Dragon's systems were designed with a critical focus on safety and reliability and provide a precision controlled reentry from space. Dragon's passively stable shape generates lift as it reenters the Earth's atmosphere supersonically. In addition to the 8 SuperDraco engines onboard Crew Dragon, its 16 Draco thrusters provide 2-fault tolerant roll control during reentry for precision guidance on course for a soft touchdown on land. Additionally, a movable ballast sled allows the angle of attack to be actively controlled during entry to further provide precision landing control. The Crew Dragon's SuperDraco engines are divided into four quads, each with



two SuperDracos and 4 Draco engines. The SuperDracos will activate to provide precision land landing capability. Nominally, only two quads are used for on-orbit propellant with the Dracos and two quads are reserved for propulsive landing using the SuperDracos. For aborts or on-orbit faults, all four quads are available for Draco or SuperDraco operations, increasing flexibility, robustness, and performance in these critical situations. In the event of any anomalies with the propulsion system, Dragon retains its parachute capability for a soft water landing, a technology that has been demonstrated repeatedly via cargo missions.

Designed in partnership with NASA and fabricated by SpaceX, Crew Dragon's heat shield is made of PICA-X, a high-performance improvement on NASA's original phenolic impregnated carbon ablator (PICA). PICA-X is designed to withstand heat rates from a lunar return mission, which far exceed the requirements for a low-Earth orbit mission. It has been featured successfully on all of the Cargo Dragon missions. Crew Dragon incorporates an improved version of PICA-X, which better protects the spacecraft from the searing temperatures of reentry.

3.2 Crew Dragon Accommodations

Crew Dragon has many innovative systems and features that complete the evolution of our currently operational cargo vehicle into a safe and reliable vehicle for human transport. These systems include seats, spacesuits, an environmental control and life support system, and crew displays and controls.



Crew Dragon will be capable of carrying seven crewmembers seated in two rows, a capability in excess of the NASA requirement to transport four crewmembers. Crew Dragon carries sufficient breathable gas stores to allow for a safe return to Earth in the event of a leak of up to an equivalent orifice of 0.25 inches in diameter. As an extra level of protection, the crew will wear SpaceX-designed spacesuits to protect them from a rapid cabin depressurization emergency event of even greater severity. The suits and the vehicle itself will be rated for operation at vacuum.

Crew Dragon features 21st century controls, including a modern touchscreen control panel to provide the crew with situational awareness and insight to the health and status of their vehicle as well as the ability to send critical commands to further guarantee crew safety in the event of contingencies. Using this interface, the crew will also have the ability to manually pilot Dragon even after two faults. Its environmental control and life support systems will provide the crew with fresh air ventilation, remove carbon dioxide, and control humidity and cabin pressure. Fire detection and suppression systems will protect the crew in the event of an emergency. Crew Dragon's seats are being designed with advanced occupant protections that draw on lessons learned from the Space Shuttle Columbia accident investigation reports, as well as the latest in automotive occupant protection technologies. Accommodations will also be provided for required food preparation and waste disposal.

3.3 Crew Dragon builds on ISS Cargo Services

Falcon 9 and Dragon were conceived and architected with human spaceflight in mind. SpaceX undertook designs from inception to meet human certification requirements, including increased structural factors of safety, triple-string avionics, trajectories with acceleration limits within human safety limits, and many others. In fact, Dragon was originally designed to meet NASA's human engineering safety requirements in SSP 50808 because the Cargo Dragon flies in close proximity to the ISS and berths with the ISS. It also supports on-orbit crew habitation during cargo transfer operations. The commonality between the cargo and crew versions of Dragon allows for significant end-to-end flight heritage and operational experience to be gained on critical functions – including launch, navigation and control, thermal protection, thermal control, power generation and distribution, avionics, software, entry guidance and recovery – well before the first crew flight.



SpaceX's crew transportation development efforts build on the successful flight history of the Falcon 9 and Cargo Dragon currently operational under our CRS contract with NASA. SpaceX is collecting significant data and experience on the Falcon 9 and Dragon system through our CRS and other launch missions. Notably, the Cargo Dragon and Falcon 9 are scheduled to fly together at least 9 more times before the first Crew Dragon manned test flight in 2017. The Falcon 9 itself is scheduled to launch more than 50 times prior to the first Dragon crew mission. To date, 100 SpaceX Merlin 1D engines have been flown successfully on operational missions.

4. Falcon 9

Falcon 9 is an all-American rocket with a heritage of 15 consecutive successful flights. Falcon 9 features a simple two-stage design to minimize the number of stage separations. With 9 engines on the first stage, Falcon 9 has engine-out reliability during ascent. All of Falcon 9's structures, engines, separation systems, ground systems, and most of its avionics were designed, manufactured, and tested in the United States by SpaceX.



4.1 Falcon 9 First Stage

Falcon 9's first stage incorporates 9 Merlin engines. Merlin's thrust-to-weight ratio exceeds 150, making the Merlin the most efficient booster engine ever built, while still maintaining the structural and thermal safety margins needed to carry astronauts. The Merlin engines that power the first stage were developed and are manufactured in-house by SpaceX. SpaceX also produces Falcon 9's tanks, avionics and software in-house. The use of multiple clustered engines provides propulsion redundancy such that the first stage could suffer engine loss without causing a mission failure. This feature has not been present on any U.S. launch vehicle since the Saturn V moon rocket.

The 9 Merlin 1D engines are housed in Falcon 9's Octaweb thrust structure in a circular pattern with a single center engine. The layout provides individual protection for each engine, and further protects other engines in case of an engine failure. This design also allows the first stage to survive reentry and return to Earth post-launch, with the eventual goal of refurbishing and re-flying the stage. Though this capability may appear to be tangential to the crew program, since our CCtCap contract calls for brand-new vehicles for every crew mission, in order to survive the harsher environments of reentry, the first stage has been designed to be far more structurally robust than an ascent-only stage for the primary and critical ascent portion of the mission. This results in a safer and more robust launch vehicle for astronaut carriage.



After ignition, a hold-before-release system ensures that all engines are verified for full-thrust performance before the rocket is released for flight. That is, the rocket runs at full thrust and all systems are verified as green for launch before a mission proceeds. Only then, with thrust greater than five 747s at full power, the Merlin engines launch the rocket and its passengers to space.

4.2 Falcon 9 Second Stage

A single Merlin vacuum engine powers Falcon 9's second stage. The second stage engine ignites a few seconds after stage separation and can be restarted multiple times to place multiple payloads into different orbits. The second stage is made using most of the same tooling, materials, and manufacturing techniques as the first stage. This commonality yields significant design and manufacturing efficiencies. The



commonality of the vacuum rated Merlin with its first stage variant is key to our high confidence in second stage reliability. Redundancy of critical components is included in the second stage engine design that exceeds even those present on the first stage engines. The helium spin start, pyrophoric igniter based engine architecture provides a very reliable means of ensuring engine start. Since the engine is designed to perform a number of restarts, for crew missions there is significant margin for the fluids required to perform a single start. Every Falcon 9 flight involves 10 similar engines that are acceptance-tested and operated in flight; therefore, Falcon 9 engines accrue flight heritage at a rapid clip that further distinguishes the Falcon 9 from its competitors.

4.3 Falcon 9 Safety & Reliability

An analysis of launch failure history between 1980 and 1999 by the Aerospace Corporation showed that the majority of known launch failures can be attributed to three causes: engine failure; stage-separation failure; and, to a much lesser degree, avionics failure. Accordingly, these three failure modes have been the focus of unrelenting attention at SpaceX. Falcon 9 is designed to have reliability in excess of NASA requirements and also achieve the stringent reliability requirements of other customers such as the U.S. Air Force's Evolved Expendable Launch Vehicle (EELV) program. With 9 Merlin engines clustered together to power Falcon 9's first stage, the vehicle is capable of sustaining engine failures and still completing its mission. From inception, Falcon 9's structure was designed with factors of safety required to human-rate the vehicle. Falcon 9 is an improved version of the architecture employed by the Saturn I and Saturn V rockets of the Apollo program.

To further improve safety and reliability, SpaceX places a very high value on the ability to 'test like you fly.' Every engine and every rocket stage is put through acceptance static fire testing at SpaceX's Rocket Development and Test facility in McGregor, Texas. Those tests use the actual avionics and software that will be used for flight, which allows system level assessments of a majority of the key flight systems in an integrated fashion. Prior to launch, a static fire test is performed with the fully integrated launch vehicle at the launch site. Static fire allows a complete

test of the vehicle, ground systems, and the interactions between the two. During static fire, SpaceX runs a launch countdown that fully tracks with launch day operations, cumulating with the launch vehicle achieving the level of thrust necessary to begin flight. At that point, SpaceX terminates thrust and safes the vehicle before reviewing the test data in preparation for launch.

With only 2 stages, Falcon 9 limits problems associated with separation events. The stage separation system features fault tolerant mechanisms that use pneumatics; this allows us to test the mechanics before we fly them, unlike traditional pyrotechnic systems.

SpaceX maximizes design and in-house production of much of Falcon 9's avionics, helping ensure compatibility among the rocket engines, propellant tanks, and electronics. Falcon 9's avionics and power architecture feature triple-string redundancy that is robust to failures during ascent. All critical control functions are designed to meet the high standards of reliability required to fly astronauts.

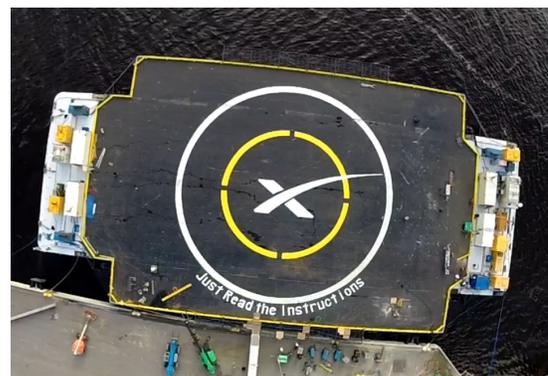
SpaceX utilizes an extensive instrumentation suite to gather data on all critical systems and validate prelaunch predictions on every flight. The combination of robust avionics, flight software, and extensive instrumentation allows us to implement crew ascent abort algorithms using demonstrated detection systems that have already been in use on every flight of Falcon 9. That capability is critical to astronaut safety.

Our Hawthorne, California, factory has a complete hardware simulator for avionics. By utilizing electronics identical to those on the rocket, the simulator allows SpaceX to check nominal and off-nominal flight sequences and validate the data that will be used to guide the rocket. The flight software is run on the actual launch vehicle to perform the same type of checks at the launch site prior to flight.

As mentioned above, SpaceX uses a hold-before-release system – a capability required by commercial airplanes, but not implemented on many launch vehicles. After the first stage engines ignite, Falcon 9 is held down and not released for flight until all propulsion and vehicle systems are confirmed to be operating normally. An automatic safe shutdown occurs and propellant is unloaded if any issues are detected.

4.4 Falcon 9 Reusability Benefits Safety and Reliability

SpaceX believes a fully and rapidly reusable rocket is the pivotal breakthrough needed to substantially reduce the cost of space access. While most rockets are designed to burn up on reentry, SpaceX rockets are designed not only to withstand reentry, but also to return to the launch pad for a vertical landing. Through reusability testing on the ground in McGregor, Texas, and in-flight testing, SpaceX is making great strides toward this goal. Although not required for crew missions, certain upgrades to the Falcon 9 first stage for return flight benefit the



primary mission because a recoverable stage requires inherently higher levels of reliability. For example, Falcon 9 carries extra propellant to perform stage recovery and landing burns, which provides margin in excess of what a vehicle designed just for ascent can provide and can be used for the ascent portion of flight. SpaceX is also gaining key insights from our first stage recovery attempts regarding the reentry phase of spaceflight; those insights will inform our efforts to develop the safest possible systems.

5. Crew Transportation Development Overview

SpaceX has partnered with NASA on crew transportation development efforts since 2011. By leveraging our existing vehicle designs and infrastructure, SpaceX has made significant progress on hardware development and testing under NASA's Commercial Crew Development II (CCDev2) and Commercial Crew Integrated Capability (CCiCap) programs. Through those programs, SpaceX accomplished development testing of our regeneratively-cooled, throttleable SuperDraco launch abort engines; composite overwrapped propellant and pressurant tanks to support the high thrust SuperDracos; structural qualification of the capsule primary structure; and fully integrated parachute system. The execution of the Pad Abort and In-flight Abort validation tests represent major milestones on the road to human spaceflight in the Crew Dragon spacecraft.

Since submitting the CCiCap proposal in January 2014, SpaceX has continued to enhance the Crew Dragon design to improve safety, operational flexibility, and reliability. These improvements include: the ability to perform precision propulsive land landing with full fault tolerance; increased propellant tank capacity for improved mission performance and to support propulsive landing; a movable ballast system to allow for high precision landings; life support system components moved from the trunk into the capsule service section to increase reliability; and consolidated avionics components to decrease complexity. The near doubling of the propellant tank capacity significantly increases the available impulse of the LAS allowing the capsule to travel further away from a failing launch vehicle. Additionally, the migration of life support consumables into the capsule allows the capsule to maintain pressure during the entire descent phase assuming a worst-case leak. Active center of gravity control allows for lift vector modulation for precise landings that ultimately enable fast access to the returning crew either on land or in the water.



Precision propulsive land landing will be certified in parallel with parachute to water landing for Crew Dragon. This will allow the teams to stay on schedule and ensure U.S. crew transportation safely and reliably in 2017. Land landing will become the baseline for the early post-certification missions; in the meantime, precision water landing under parachutes has been proposed as the baseline return and recovery approach for the first few flights of Crew Dragon. Parachute to water landing leverages SpaceX's excellent water recovery heritage, providing safe, fast, and reliable access to the crew. Per contract requirements, access to the crew will be provided within one hour of landing in the water and access to cargo within two hours of landing. Contingency plans involving multiple recovery vessels and locations will be fully implemented.

With each flight, the Falcon 9 launch vehicle also continues to undergo improvements to safety, reliability, and performance. The Falcon 9 will launch approximately 50 times before the first crew flight. As with the rest of the crew transportation system, SpaceX and NASA have been working closely throughout the commercial crew design, development and test programs to certify all launch vehicle designs and operations for astronaut safety and system reliability.

5.1 CCtCap Schedule and Challenges

Subsequent to SpaceX’s CCtCap award late last year, a program initiation meeting was held in October 2014, setting forth expectations, processes and deliverables. All targets were met leading up to the first major program milestone, the Certification Baseline Review (CBR), which was held in December 2014. The first Quarterly Program Review (QPR) was held in January 2015. Engineer-to-engineer engagement is now fully underway, with daily contact and various Technical Interchange Meetings (TIMs) already completed or planned. CCtCap contractual milestones appear immediately below. The majority of the CCtCap milestones shown below are hardware (versus paperwork) milestones; as such, the completion of each milestone represents significant forward progress.

Milestone	CLIN	Current Date
Certification Baseline Review (CBR) Complete	001	COMPLETE
Avionics Test Bed Activation	001	2015
Docking System Qualification Complete	001	2015
Launch Site Operational Readiness Review (LSORR)	001	2015
Initial Propulsion Module Testing Complete	001	2015
Delta Critical Design Review (dCDR)	001	2015
Propulsive Land Landing Test Complete	001	2015
Launch Site Operational Readiness Review (LSORR) for Crew	001	2016
ECLSS Integrated System Test	001	2016
Space Suit Qualification Testing Complete	001	2016
DM-1 Post Qualification Review (PQR) Complete	001	2016
Flight Test Without Crew Certification Review (FTCR)	001	2016
Demo Mission 1 Flight to ISS Without Crew	001	2016
Parachute Qualification Complete	001	2017
Design Certification Review (DCR)	001	2017
Flight Test Readiness Review (FTRR)	001	2017
Demo Mission 2 Flight to ISS With Crew	001	2017
Operations Readiness Review (ORR)	001	2017
Certification Review (CR)	001	2017

Over the next 10 months, our key focus is on the delta Critical Design Review (CDR) in December 2015. CDR represents a locked down baseline design after which there are no planned changes to the crew transportation architecture. All architecture trades will be closed at that time

with supporting development testing, and several components will already have proceeded through qualification testing, further reducing the risk of late breaking design changes. NASA and SpaceX are working closely in the time before CDR to ensure the smooth completion of the milestone and resolve any challenges early. The major items underway for the CDR are: aerodynamics database development, detailed loads analysis, development and qualification testing of avionics, propulsion and structures components, and crew training definition.



As we work toward the delta CDR, SpaceX will continue development testing of the SuperDraco LAS using a quarter section flight module at the SpaceX Rocket Development and Test facility in McGregor, Texas, to demonstrate full software and hardware-in-the-loop testing of the abort and landing system. Additionally, the flight capsule weldment design will be released and fabrication will begin this summer to support the first CCtCap demonstration mission in 2016. Another capsule weldment will be manufactured in short succession and populated with an entire environmental control and life support system to enable ground testing including various hardware and software failures and to ensure reliable crew life support system function during anomalies. Those tests will provide critical input for crew certification. Docking system qualification hardware is already in process to support full qualification testing utilizing two test units. One docking adapter will undergo complete environmental testing including vibration, thermal, and shock testing, while a second unit will be utilized for extensive docking simulations including a test at NASA's Johnson Space Center with a 6-degree of freedom simulator to minimize a docking issue with the ISS.

A key interim milestone is the Avionics Test Bed Activation in June 2015. The test bed will be comprised of a complete Crew Dragon avionics system and will be set up in SpaceX's state-of-the-art hardware-in-the-loop test facility. This important facility will be used to fully test all of Crew Dragon's computer systems to make sure that the spacecraft hardware and software is designed properly and is extremely robust and reliable. The tests will prove out communication between all major avionics components, including the flight computer, power unit, and vehicle device control unit. Our facility has a long heritage providing critical support to the development, test, and operations of all SpaceX flight systems.

To provide significantly increased NASA insight appropriate for a human spaceflight program, SpaceX and NASA have paired key program and technical leads as counterparts ensuring transparency, communication, fast problem solving, and early agreement on strategies and plans. Dozens of recurring forums and meetings have been established and are jointly led to keep the broader NASA and SpaceX community aware of progress and agreements as well as resolve questions and concerns. Program management leads from both NASA and SpaceX regularly evaluate the progress of insight and interaction to ensure program success.

One of the expected challenges in any program of this magnitude is aligning the schedule with the work ahead while providing sufficient NASA insight and interaction to certify a safe and reliable system. To this end, and in support of the reliability upgrades discussed, some milestones have been moved to ensure sufficient time is provided to develop and certify key systems.

Another challenge to the project's success is whether the program receives consistent and robust Congressional support and funding. The United States has been reliant on Russia for too long, and underfunding the Commercial Crew Program in fiscal year 2016 could further prolong that dependency. NASA is on course to achieve domestic astronaut carriage to the Space Station by 2017. Fully funding the commercial crew program to support the two awards is critical to maintaining that schedule, which will lead to an eventual reduction in spending as Soyuz flights are no longer needed by NASA. Underfunding of the Commercial Crew Program would effectively result in more taxpayer money being spent on Russia Soyuz services and delay the full utilization of the ISS.

5.2 Risk Management

Key risk management and safety deliverables were provided early in the program and recently updated per NASA input. SpaceX and NASA held a hazard and safety planning meeting earlier this year to ensure that all hazard reports to the Safety Technical Review Board will be delivered prior to the system delta Critical Design Review. Safety and risk are closely tracked and managed at SpaceX through a well-established process leveraging our risk database, vigilance at all levels of the company, and a culture encouraging open discussion and risk mitigation. SpaceX provides NASA in-depth insight into this process.

The following focal areas have been identified: ensuring crew transportation capability certification in 2017; ensuring the timely development of all systems in advance of the delta Critical Design Review; and ensuring that NASA and SpaceX are in agreement on the interpretation and approach to meeting all technical and safety requirements. SpaceX acknowledges that certification of precision propulsive land landing is expected to take additional time; therefore, it will be done in parallel with precision water landing thus preventing this capability from delaying NASA's goal of completing certification in 2017. Remaining design trades are being closed by mid-2015; NASA and SpaceX are engaged in regular interaction and insight. In order to ensure agreement on requirements, the teams are leveraging the partnership to clarify requirement intent and, if needed, propose variances, jointly assess requirement change requests from NASA, and drive open issues to closure.

5.3 LC-39A Construction for Commercial Crew Launch

SpaceX's crew transportation system will launch from the historic Apollo and Shuttle launch location, LC-39A on NASA's Kennedy Space Center. We have made excellent progress renovating the complex over the last year; construction will be completed by mid-2015. SpaceX is investing over \$60 million in LC-39A to modernize the complex for Crew Dragon, Falcon 9 and Falcon Heavy. Construction on the hangar has begun and will be completed later this year. Taking advantage of the existing launch tower, SpaceX will add a crew gantry access arm and

white room to allow for crew and cargo ingress to the vehicle. The existing Space Shuttle evacuation slide-wire basket system will also be re-purposed to provide a safe emergency egress for the Dragon crew in the event of an emergency on the pad that does not necessitate using the Crew Dragon's launch abort system.



6. Conclusion

Thank you again for the opportunity to provide an overview of SpaceX's efforts to provide American astronauts with safe and reliable transportation to space. It is our honor to work with NASA to end America's dependence on Russia for Space Station access and, most importantly, replace it with the safest and most reliable crewed transportation capability possible.