IAC-08-D2.1.03

The SpaceX Falcon 1 Launch Vehicle Flight 3 Results, Future Developments, and Falcon 9 Evolution

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ABSTRACT

Falcon 1, the entry vehicle in the Space Exploration Technologies launch vehicle family, is designed to provide the world's lowest cost access to orbit. The vehicle is designed above all for high reliability, followed by low cost and a benign flight environment. It is a two-stage, liquid oxygen and rocket grade kerosene (RP-1) powered launch vehicle capable of placing a 420 kg satellite into a 185km circular orbit, inclined 9.1 degrees. Falcon 1 combines a re-usable, turbo-pump fed first stage powered by a single SpaceX Merlin engine with a pressure fed second stage powered by our Kestrel engine and capable of multiple re-starts.

SpaceX has conducted two demonstration flights each sponsored by the Defense Advanced Research Projects Agency (DARPA). The first operational launch of Falcon 1 carrying a U.S Department of Defense's Operationally Responsive Space (ORS) Office satellite took flight on August 3, 2008 from the SpaceX launch complex in the Central Pacific Marshall Islands' Kwajalein Atoll. During the integration of this mission, SpaceX demonstrated its ability to perform responsive mission integration for three separate candidate ORS payloads. The actual flight payload was determined by the ORS Office only a few weeks before the actual launch. In addition to the ORS primary payload, Flight 003 also carried a rideshare adapter experiment for ATSB of Malaysia (the primary customer for the following Falcon 1 launch), and two NASA CubeSat payloads. Results from this mission are presented.

Consistent with SpaceX's corporate philosophy of rapid and continuous improvement, Falcon 1 has a planned evolution path which will include significant upgrades based upon experience from previous missions and our design work on its sister vehicle, the Falcon 9. Beginning in the second quarter of 2010, the enhanced 'Falcon 1e' will become SpaceX's standard small launch vehicle with upgraded performance capable of placing 1000kg into LEO. An overview of the Falcon 1e upgrades and description on how they will positively impact the satellite community are discussed.

The Falcon 9 launch vehicle builds on the technologies and expertise developed during the design, assembly and commercial deployment of the Falcon 1. A Falcon 9 vehicle overview is presented along with a hardware status and flight manifest.

INTRODUCTION

SpaceX was founded in 2002 by Elon Musk with the goal of reducing the cost and increasing the reliability of access to space by a factor of ten. To accomplish these goals, SpaceX is developing a family of launch vehicles which includes the Falcon 1, Falcon 9 and Falcon 9 Heavy to offer a full spectrum of light, medium and heavy lift capabilities. Additionally, SpaceX is developing the Dragon capsule for transport of cargo and crew to and from the International Space Station.

The Falcon family of launch vehicles has been developed from "clean sheet" designs in order to reduce dependency on legacy components and implement technology improvements wherever feasible. To reduce cost and increase reliability, SpaceX combines significant in-house manufacturing capabilities, rigorous flight-representative testing and streamlined launch operations.

SpaceX is organized with a flat hierarchy and high engineer-to-manager ratio to facilitate decision-making, rapid prototype iteration and innovation. The Falcon 1 was designed, developed and qualified in less than four years. It has since launched three times; reaching space on the second and third launches. A fourth launch is scheduled during the third quarter of 2008. The first flight of the Falcon 9 is scheduled for early 2009. Figure 1 provides an overview of the various Falcon 1 and Falcon 9 configurations.

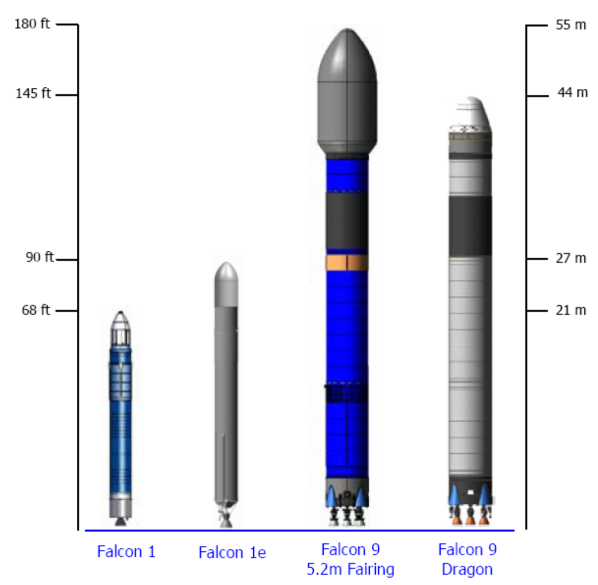

Figure 1: The SpaceX Falcon launch vehicle family.

SpaceX has over 540 employees and is headquartered in a >500,000 sq.ft. facility in Southern California with a 300 acre test site in Texas and launch complexes at the Kwajalein Atoll in the Republic of Marshall Islands, Vandenberg Air Force Base in California, and Cape Canaveral Air Force Station in Florida.

FALCON 1 LAUNCH VEHICLE OVERVIEW

The Falcon 1 is designed to provide the world's lowest cost access to orbit. The vehicle is designed above all for high reliability, followed by low cost and a benign payload flight environment.

FALCON 1 VEHICLE ARCHITECTURE

The Falcon 1 is a two-stage, liquid oxygen (LOX) and rocket-grade kerosene (RP-1) powered launch vehicle which combines a turbopump-fed first stage powered by a SpaceX-developed *Merlin* engine with a pressure-fed second stage powered by a SpaceX-developed *Kestrel* engine.

FIRST STAGE

The first stage of the Falcon 1 generates 78,400 lbf (349 kN) of sea-level thrust using a single Merlin engine. The Merlin rocket engine, shown in

Figure 2, was designed and developed internally at SpaceX. Like the rest of the Falcon 1, the Merlin was designed for high reliability and low cost. This was achieved by keeping the design as simple as possible and drawing on a long heritage of space-proven engines. The Merlin engine has demonstrated large margins in heat flux, mixture ratio tolerance and turbopump operating speed during ground testing, and has exceeded the performance goals set during the design phase.

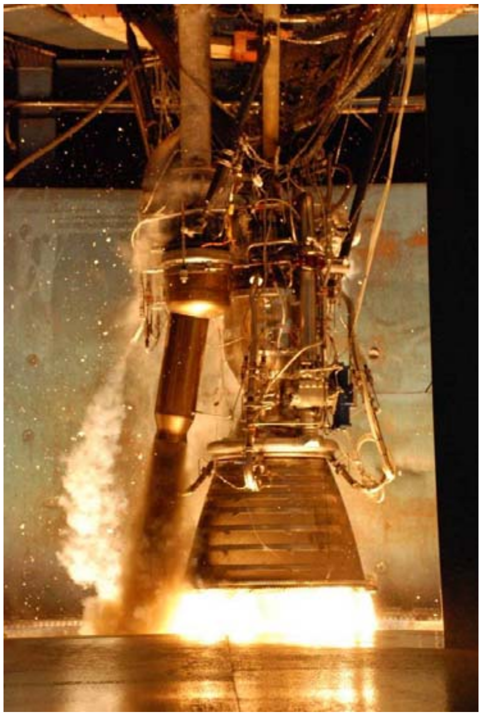

Figure 2: Merlin engine during test fire.

The Merlin engine utilizes a low-cost pintle injector similar to the pintle-style injector which was first used in the Apollo lunar module landing engine. Simplicity and robustness were key design trade considerations in selecting this type of injector which is tolerant to acoustic instabilities and contamination, stable over a wide range of operating conditions and capable of being throttled. Merlin engine propellant constituents are fed to the engine via a single shaft, dual impeller turbopump assembly. In order to reduce the number of subsystems in the launch vehicle, the turbopump also delivers high pressure kerosene as the hydraulic fluid for the hydraulic thrust vector control steering system affecting vehicle pitch and yaw. This elegant design eliminates the need for a separate hydraulic power system and means that thrust vector control failure by running out of hydraulic fluid is not possible. Another elegant feature of the Merlin engine is that the fuel is also used to cool the thrust chamber and nozzle. The fuel acts as a coolant and flows through hundreds of milled channels and tubes to provide cooling to the hot wall before being injected into the thrust chamber for combustion. This allows for increased performance and reusability. A third elegant feature of the Merlin engine is the use of turbo pump exhaust to control vehicle roll during first stage flight.

The primary structure of the first stage of the Falcon 1 is highly mass efficient with propellant tanks constructed from 2219 aluminum and both fuel and liquid oxygen tanks sharing a common dome to separate the propellant and oxidizer while minimizing both mass and cost. In addition, these tanks employ a monocoque design for mass savings and serve as the primary structure. They are structurally stable under ground handling and transportation loads. During flight, the tanks are pressurized to withstand the maximum flight loads. This tank design traded between a fully structural-stable design which would have been much heavier and one that is completely dependent upon pressurization similar to the original Atlas tank designs. The resulting tank design is both operations friendly and offers substantial weight savings.

Following stage separation during flight, the first stage descends to a water landing under a 70’ diameter parachute. Recovery of the first stage will allow SpaceX to practice recovery operations (important for Falcon 1, Falcon 9 and Dragon) while also allowing for engineering evaluation and potential reuse.

SECOND STAGE

The second stage of the Falcon 1 generates 7,000 lbf (31 kN) of vacuum thrust using a single Kestrel engine, which is capable of multiple re-starts on orbit. Propellant is pressure-fed to the engine via a heated helium blow down system. Pith and Yaw thrust vector control steering is accomplished via in-house designed and qualified electro-mechanical actuators. Roll control is accomplished using cold gas helium thrusters. The second stage tank is constructed from 2014 aluminum for mass savings. Similar to the first stage, the propellant and oxidizer tanks are separated by a common dome as shown in Figure 3.

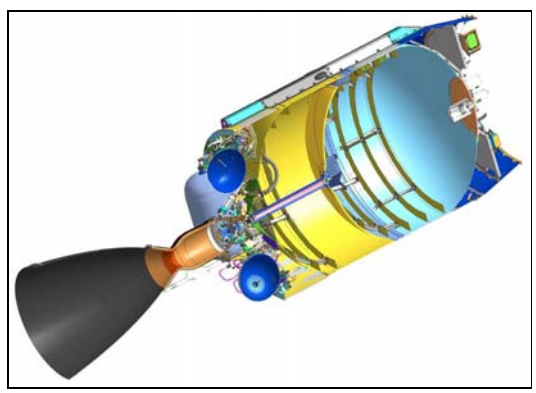

Figure 3: ***Falcon 1 second stage.***

FALCON 1 UPGRADE PATH

Consistent with SpaceX’s corporate philosophy of rapid and continuous improvement, Falcon 1 has a planned upgrade path based upon experience from the demonstration missions. These vehicle enhancements are being implemented as block upgrades and will increase the payload capability beyond that of the original Falcon 1 configuration.

FIRST STAGE UPGRADES

The Merlin engine employed for the first two demonstration flights of the Falcon 1 utilized an ablatively cooled thrust chamber and nozzle. To increase reliability and allow for reuse, the chamber and nozzle have been upgraded to regeneratively cooled designs. Because it is able to operate at higher temperatures and pressures, the regeneratively cooled (Merlin 1C) design provides a greater level of thrust, as shown in Figure 4.

Parameter	Merlin 1A (Demo Flights)	Merlin 1C-F1 (Interim upgrade)	Merlin 1C-F9 (Falcon 1e and future)
Sea Level Thrust (lbf)	73,000	78,400	92,000
Vacuum Thrust (lbf)	83,000	88,700	105,500
Mixture Ratio (O/F)	2.20	2.20	2.20
Chamber Pressure (psia)	782	825	959
Nozzle Expansion Ratio	14.5	14.5	14.5
Isp Sea Level (sec)	244	256	263
Isp Vacuum (sec)	288.5	302.5	302
Engine Length (ft)	9.5	9.6	9.4
Engine Diameter (ft)	5.5	5.5	4.7

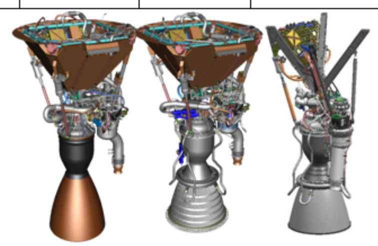

Figure 4: ***Merlin engine upgrade path.***

The full thrust of the Merlin 1C engine exceeds the structural margins of the current Falcon 1 first stage tank design, which was originally qualified based on the lower thrust of the ablatively cooled engine. In addition, when operating at full thrust, the Merlin 1C requires an increased propellant flow rate – and thus a greater volume of propellant. Therefore, the first stage tank structure will be redesigned and qualified to meet the increased load requirements and propellant needs of the Merlin 1C engine. This full block upgrade, called the Falcon 1e ('e' for *enhanced*) will be available beginning in the second quarter of 2010. However, as an interim upgrade, the Merlin 1C engine is being flown at a reduced thrust level (within the first stage structural limits) for launches in 2008 and 2009.

SECOND STAGE UPGRADES

Addressing the control anomaly experienced during the second Falcon 1 demonstration flight, slosh baffles have been added to the second stage propellant and oxidizer tanks. Reliability improvements have been made to the Kestrel engine, which also allowed for some minor mass reductions. For the Falcon 1e, additional mass savings will be achieved by changing the second stage tank material to a 2195 aluminum lithium alloy similar to that used on the Space Shuttle external tank.

PAYLOAD FAIRING UPGRADES

The Falcon 1 employs a bi-conic aluminum payload fairing with a maximum inner diameter of 54 in (1.4 m) and an internal height of 110 in (2.8 m). For mass savings and to provide increased payload volume, the payload fairing for the Falcon 1e will be a composite ogive shape with a maximum inner diameter of 61 in (1.55 m) and an internal height of 150 in (3.8 m). A dimensional comparison of the Falcon 1 and Falcon 1e payload fairings is provided in Figure 5.

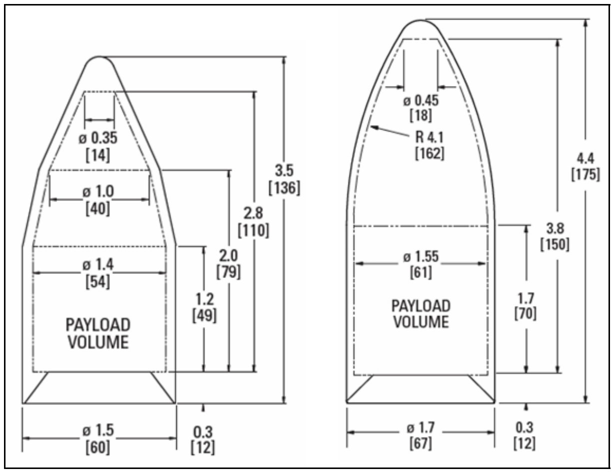

Figure 5: Falcon 1 and Falcon 1e payload fairing dimensions.

FALCON 1 PAYLOAD CAPABILITIES

The Falcon 1 is capable of delivering a 925 lb (420 kg) satellite into a circular reference orbit of 185 km inclined at 9.1 degrees. The Falcon 1e will provide the increased payload capability with the ability to deliver a 2,225 lb (1,010 kg) satellite into a reference orbit of 185 km inclined at 9.1 degrees. (see Figure 6)

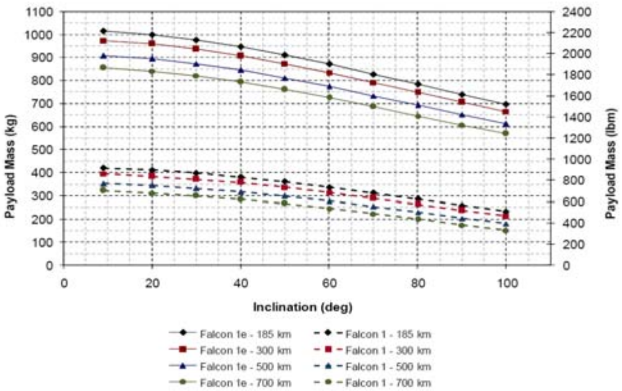

Figure 6: Falcon 1 and Falcon 1e payload performance.

FALCON 1 - FLIGHT 3 - ORS JUMPSTART MISSION OVERVIEW

The Third flight of the Falcon 1 launch vehicle took place on August 3, 2008 from the SpaceX launch complex in the Central Pacific Marshall Islands' Kwajalein Atoll (see Figure 7). The customer for this flight was the Operationally Responsive Space (ORS) Office out of Kirtland AFB. The ORS Jumpstart mission aimed to establish a preliminary framework for responsive contracting, and to demonstrate the ability to rapidly integrate and execute a mission, from initial call-up to launch.

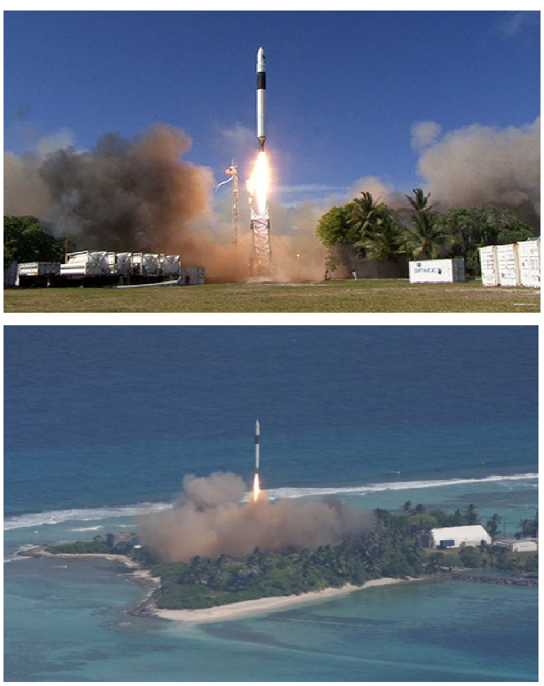

Figure 7: Falcon 1 Flight 3- ORS Jumpstart Mission Launch. Omelek Island View (top) and helicopter view (bottom)

This ORS Office tasked SpaceX with demonstrating its ability to perform responsive mission integration for three separate candidate payloads. The actual flight payload was to be determined by the ORS Office at or before the SpaceX Flight Readiness Review, which typically occurs two weeks before launch.

The list of ORS Office Jumpstart Mission candidate payloads considered for this mission included the following:

1. Air Force Research Laboratory (AFRL) Plug and Play (PnP) satellite bus – a third generation bus with multiple integrated payloads, that when flown, would be a risk reduction to future ORS missions.
2. SpaceDev, Inc. Trailblazer spacecraft bus, originally developed under a Missile Defense Agency contract, which demonstrates a flexible, modular commercial bus design using off the shelf components.
3. Air Force Office of Scientific Research (AFOSR)/AFRL NanoSat-4, CUSat – a Space Test Program experiment consisting of two nanosatellites developed by Cornell University in partnership with the AFRL under the University Nanosatellite Program.

In addition to the ORS Office primary payload, the Jumpstart mission also carried a Secondary Payload Adaptor and Separation System (SPASS) experiment for ATSB® of Malaysia. The SPASS has the ability to carry multiple cubesats and a nanosatellite with minimum interference to the primary payload and the launch vehicle. The SPASS development and launch was funded by ATSB while the design, fabrication, test, integration and secondary satellite manifesting was carried out by Space Access Technologies. For this flight, the SPASS carried two NASA cubesats each to be deployed using Cal Poly P-POD separation systems. The first cubesat to be deployed was called PharmaSat Risk Evaluation Satellite (PRESat). PRESat is a NASA Ames Research Center spacecraft and is designed to host and transmit data on biological experimentation in microgravity. The second cubesat to be deployed came from NASA Marshall Space Flight Center and was called NanoSail-D. The objective of NanoSail-D is to work with other NASA centers and industry to conduct a rapid low cost technology demonstration spacecraft to validate new deployable structure technology and show the utility of sails as an aerodynamic drag device.

In addition to the ORS primary payload and the SPASS with two NASA cubesats, SpaceX also flew two Celestis payloads from Space Services Incorporated.

Though the ORS Office objectives were met by SpaceX, a stage separation timing anomaly ultimately prevented the second stage from reaching orbital velocity and deploying the suite of payloads. The root cause of the anomaly was that the effects of first stage residual thrust transients from engine purges occurring in vacuum conditions were underestimated in stage separation timing and caused the first stage to re-contact the second stage shortly after stage separation. Other in-flight anomalies and observations exist, however the stage separation anomaly was the only known issue that prevented this mission from achieving orbit. Vehicle performance was within an acceptable range until the anomaly occurred approximately T+157 seconds into flight where the separated first stage recontacted with the second stage preventing a nominal stage 2 ignition.

The vehicle attained a peak altitude of 217 km, 3.2 km/s maximum velocity. Significant achievements for the flight of the Jumpstart mission include successful demonstration and verification of:

1. Ground control & support systems, including control software, highly automated operations & autonomous abort
2. Rapid response capability – launched after hot-fire abort in ~34 min
3. 1st stage performance from lift-off through MECO with new Merlin 1 C engine
4. Structural performance through lift-off, transonic & max-Q
5. The stage separation system worked properly, in that all bolts fired and the pneumatic pushers delivered the correct impulse
6. Fairing separation
7. Second stage ignited and achieved nominal chamber pressure
8. Launch & flight environments
9. Aero-thermal and base-heating models

JUMPSTART MISSION OBJECTIVES

While orbit was ultimately not achieved, all of the ORS Office objectives for this mission were met by SpaceX. The primary ORS Office objective for the Launch vehicle team on this mission was to perform complex payload integration tasks for all three possible ORS Office payloads in addition to completing a mission (Kick off to launch) in ~4 months. In addition to responsiveness being demonstrated by the launch service provider, responsiveness was also demonstrated by the payload and ORS Office teams by building and testing each of the three payloads being considered, then testing them together at an integrated payload stack level. In addition, each payload candidate team participated in a Jumpstart pathfinder exercise where they went to Kwajalein to plan and verify logistical operations and to set up and certify three separate ground stations for use in the mission should they be the one selected to fly.

JUMPSTART MISSION OPERATIONAL RESPONSIVENESS

Significant breakthroughs in Operational Responsiveness were demonstrated through the integration activities of this mission. The customer kickoff meeting was held in February 2008 and four months later the Launch vehicle with the integrated payload stack stood erect at the launch site poised to launch in June 2008. (See Figure 8, Figure 9, Figure 10, and Figure 11). The key responsiveness metrics demonstrated by SpaceX during the Jumpstart mission include:

1. Executed complex payload integration in <5 months
2. Stages integrated, rolled out and launched in less than 7 days
3. Fastest hot-fire recycle ever demonstrated ~34 min

Approximately four weeks prior to launch, the ORS Office made its determination on which of the three payload candidates would fly. The payload chosen was called Trailblazer and is built and operated by SpaceDev of Poway, CA. The Trailblazer spacecraft on the Jumpstart mission will serve as a flight test program to validate the hardware, software, and processes of an accelerated satellite launch. In preparation for the payload decision, the SpaceX team had demonstrated responsiveness by preparing for the possibility of flying any of the ORS payloads being considered. Specifically, documentation and analysis were completed in parallel prior to the final payload decision so that regardless of which payload was ultimately chosen, the final integration and verification activities could be completed within the final two to four weeks of the launch campaign. The multiple payload configuration analyses completed included coupled loads analysis, collision avoidance maneuver analysis, performance and trajectory analysis, virtual fit checks, and both FAA and Range safety analysis. Three separate interface control documents were negotiated between SpaceX, the primary payload under consideration, and the Secondary Payload System teams. Additionally, the FAA demonstrated responsiveness by licensing the launch regardless of payload selected. To do this, they took the payload safety information from all three candidates and reviewed each of them for acceptance prior to granting a commercial launch license enveloping them all.

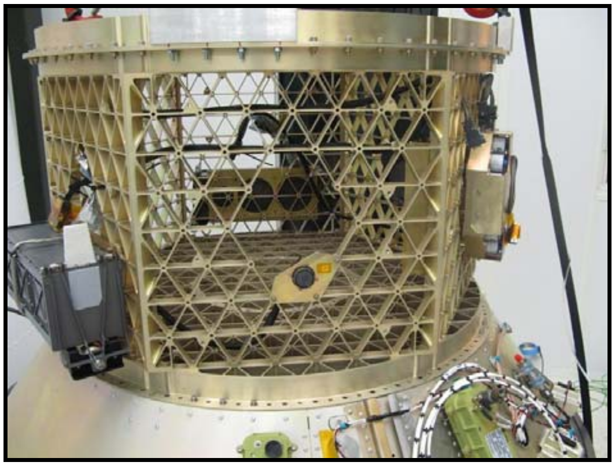

Figure 8: SPASS integrated onto launch vehicle payload adapter and ready for primary payload integration

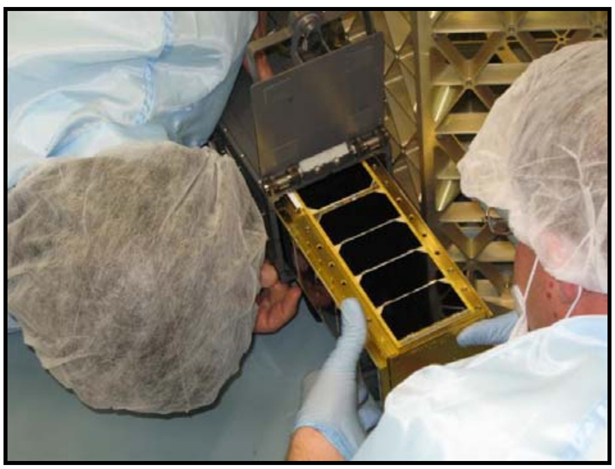

Figure 9: NASA Ames Research Center's PRESat being integrated into a PPOD on the SPASS

Figure 10: Jumpstart mission integrated payload stack ready for fairing encapsulation

Figure 11: Falcon 1 with Jumpstart mission payload team ready for launch.

It should be noted that some of the most difficult obstacles to responsiveness were not necessarily engineering related. Executing contracts and invoicing for engineering services and completed milestones proved to be somewhat non-responsive and is an area warranting considerable improvement and streamlining. Additionally, with complex missions such as Jumpstart where there are multiple parties involved, both foreign and domestic, signature cycles can be time consuming. This became evident when late ICD change notices or legal cross waivers affecting various parties became critical for maintaining schedule. Neither of these items are showstoppers to responsiveness, but this mission has already proven useful in uncovering these issues that can now be corrected to improve overall mission responsiveness and avoid this schedule risk in the future.

ORS OFFICE JUMPSTART MISSION CONCLUSIONS

This mission, although short of complete success, was nonetheless another step forward for SpaceX, the Falcon 1 launch vehicle and the ORS Office. A significant majority of mission objectives were met from both programmatic and technical perspectives.

Additional flight data was obtained and we put to rest some risks associated with first flight items such as the regeneratively cooled Merlin 1C engine. Additionally, operations concepts, procedures, ground systems and control automation systems were validated. A rapid response capability was also demonstrated with a hot-fire abort being followed within 34 minutes by a launch. Significant achievements in Operational Responsiveness for Call-up and Launch were also demonstrated.

One anomaly was identified that prevented us from reaching orbit and has been thoroughly investigated and corrected, allowing the Falcon 1 vehicle to return to flight. The many successes of this mission and the large amount of flight data obtained, including the anomalous behaviors, have greatly reduced risks for the next Falcon 1 mission.

FALCON 9 OVERVIEW

The Falcon 9 launch vehicle builds on the technologies and expertise developed during the design, assembly and commercial deployment of the Falcon 1. The design goal of the Falcon 9 is to produce an Evolved Expendable Launch Vehicle (EELV) class launch capability while attaining significant improvements in reliability, cost and responsiveness over existing vehicles. Design philosophies employed during the development of the Falcon 1 launch vehicle are being similarly employed for Falcon 9. These include simplicity of architecture and the elimination or minimization of failure modes. The Falcon 9 is designed for robustness and high launch availability to enable flexible manifests and launch schedules.

FALCON 9 VEHICLE ARCHITECTURE

The Falcon 9 is a fully reusable, two-stage launch vehicle powered by SpaceX-developed Merlin engines. It is the only launch vehicle in its class with first stage engine-out capability. The Falcon 9 also meets human rating requirements and is designed to launch Dragon, SpaceX's cargo and crew capsule. Overall specifications of the Falcon 9 are given in Table 1.

Table 1: Specifications of the Falcon 9 launch vehicle.

Falcon 9 Specifications (Block 1)	
Length	180 ft (55 m)
Width	12 ft (3.6 m)
Mass	716,000 lb (325,000 kg)
Thrust at Liftoff	855,000 lbf (3.8 MN)

FIRST STAGE

The Falcon 9 first stage generates 855,000 lbf (3.8 MN) of sea-level thrust using nine Merlin engines. The engines are arranged in a 3x3 grid pattern and the vehicle is controlled by gimbaling the engines, as shown in Figure 12. An aluminum thrust frame provides mounting points for the nine Merlin engines and a load path from the engines to a composite thrust skirt constructed of carbon fiber face sheets with an aluminum honeycomb core, which transfers loads from the thrust frame to the tanks.

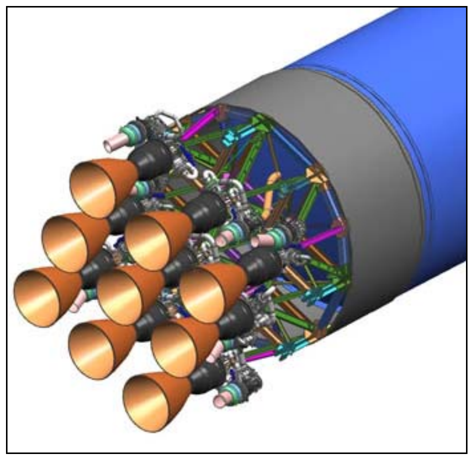

Figure 12: Aft view of Falcon 9 first stage engine configuration.

The first stage of the Falcon 9 is comprised of aluminum-lithium tanks, a composite thrust skirt and an aluminum thrust frame. The tanks are constructed from a 2198 aluminum-lithium alloy that is lighter in weight than traditional aluminum while providing improved stiffness. A common dome is used to separate the fuel and oxidizer tanks, minimizing mass and cost. The tanks are produced using friction stir welding, which creates an extremely high-quality, repeatable weld. The tanks employ a combination of monocoque and skin-and-stringer design and are used as primary load-bearing structure.

The Falcon 9 launch vehicle is designed for a 5g acceleration during flight. For LEO missions, reduction of first stage burnout acceleration is achieved by shutting off two engines late in the first stage burn, leaving seven engines burning until MECO (main engine cut-off). The Falcon 9 thrust-to-weight ratio is sufficiently high that the vehicle is able to lose a single engine throughout most of the first stage burn, and multiple engines later in the burn.

Following stage separation, the first stage descends to a water landing under parachutes for recovery, engineering evaluation and reuse.

SECOND STAGE

The Falcon 9 second stage uses a vacuum-rated Merlin engine, which provides 96,000 lbf (427 kN) of vacuum thrust and is capable of multiple re-starts on orbit. It is nearly identical to the first stage Merlin engines, except for a larger niobium alloy nozzle extension with an expansion ratio of 117:1 for optimal vacuum performance. Roll control is provided by vectoring the turbine exhaust gases through a gimbaled roll nozzle. The Merlin engine also provides throttling capability from 60 to 100 percent, which allows for both reduced payload acceleration as well as a more precise injection orbit.

The second stage tank is simply a shorter version of the first stage tank, utilizing the same architecture and materials. By using a common architecture, much of the same tooling and processes can be used; resulting in both cost savings and manufacturing and operational efficiencies. The second stage is designed to survive reentry and both stages are recovered via parachute from a water landing. As a result, nearly the total mass of the Falcon 9 vehicle can be reused.

FALCON 9 PAYLOAD CAPABILITIES

The Falcon 9 is available in two payload configurations:

The first configuration is available with two payload fairing sizes: 17 ft (5.2 m) or 12 ft (3.6 m) in diameter. The fairing is of composite construction consisting of carbon fiber face sheets with a Nomex honeycomb core. The 5.2 m fairing will be used for the first Falcon 9 flights which are not NASA COTS (Commercial Orbital Transportation Services) missions. SpaceX anticipates design and production of a 3.6 m diameter fairing in the future that will primarily be used for GTO missions, or for LEO missions with smaller payloads. In the payload fairing configuration, the Falcon 9 is able to deliver 22,000 lb (10,000 kg) to LEO or 11,000 lb (5,000 kg) to GTO.

The second configuration replaces the fairing with the Dragon capsule – SpaceX's cargo and crew vehicle, shown in Figure 13. In the Dragon configuration, the Falcon 9 is capable of delivering 5,500 lb (2,500 kg) of cargo or 7 crew members to LEO. The Dragon capsule will initially be used for transport to and from the International Space Station (ISS), but will also be offered for future use by non-ISS related commercial customers.

Figure 13: The Dragon cargo and crew capsule.

CURRENT FALCON LAUNCH VEHICLE MANIFEST

The Falcon launch vehicle family manifest (see Table 2) currently consists of five additional Falcon 1 launches and seven Falcon 9 launches before the end of 2011. The next Falcon 1 launch will be a SpaceX demonstration mission which will then be followed by the launch of satellite for ATSB of Malaysia. Both of these launches will be on the standard Falcon 1 and are to be launched from Omelek Island in the Kwajalein Atoll.

Table 2 – Falcon 1 Launch Manifest

Customer	Launch	Vehicle	Launch Site
DARPA Demo 1*	Q1 2006	Falcon 1	Kwajalein
DARPA Demo 2*	Q1 2007	Falcon 1	Kwajalein
ORS and ATSB*	Q2 2008	Falcon 1	Kwajalein
Flight 4	Q3 2008	Falcon 1	Kwajalein
US Government	Q4 2008 †	Falcon 9	Cape Canaveral
ATSB (Malaysia)	Q1 2009	Falcon 1	Kwajalein
MDA (Canada)	2009	Falcon 9	Cape Canaveral
Avanti (UK)	2009	Falcon 9	Cape Canaveral
NASA	2009	Falcon 9	Cape Canaveral
NASA	2009	Falcon 9	Cape Canaveral
SpaceDev (US)	2009	Falcon 1	Kwajalein
NASA	2010	Falcon 9	Cape Canaveral
MDA (Canada)	2010	Falcon 1	Kwajalein
SSC (Sweden)	2010	Falcon 1	Kwajalein
Bigelow (US)	2011	Falcon 9	Cape Canaveral

* completed
† hardware at launch site

CONCLUSION

The ORS Office Jumpstart mission has shown that responsive missions can be, and are being, executed. By going through the responsive mission integration process, many areas are highlighted where further improvements can be made to enhance responsiveness. The Falcon 1 vehicle upgrade path will ensure that launch manifest commitments are met while continuing to improve on the baseline design, keep cost low, and reliability high.

The lessons learned from both Falcon 1 successes and anomalies are being captured and applied to the Falcon 9 design in order to further increase reliability. The Falcon 9 and Falcon 1e launch vehicles will build on the technologies and expertise developed during the design, assembly and commercial deployment of the Falcon 1 in order to reach the goal of revolutionizing access to space.

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