Monster Progress Update (Mostly Falcon 9)

This has been an incredibly busy period for SpaceX and for me personally, with one side effect being that non-critical tasks like website updates have been postponed. Now that we have finished submitting materials for the NASA COTS (Commercial Orbital Transportation Services) demonstration program critical design review and have hired some additional resources to help compile information, website updates should be posted every four to six weeks.

Speaking of hiring, the SpaceX team has expanded to about 350 employees. Most are located at our headquarters in California, but an increasing number of people are at our engine and structural development site in Texas, the SpaceX launch complex at Kwajalein, our launch complex at Cape Canaveral or our Washington, DC office. At current growth rates, I expect the personnel count will be between 500 and 600 by the end of 2008.

Financially, this is shaping up to be a pretty good year. Even if we don't sign any additional launch contracts, it looks like we will be both cash flow positive and possibly profitable in 2007, our fifth full year of operation. The incoming cash flow is a combination of payment for the March Falcon 1 flight, mission unique development revenue, NASA COTS milestones and payments for upcoming launches (we have 11 launches on contract right now). GAAP rules specify partial recognition of revenue for long term contracts on a percentage of completion basis, hence the potential for profitability.

Before diving into Falcon 9, let me provide a short update on Falcon 1. Our current schedule shows the next rocket arriving at our Kwajalein launch complex in December and, due to vacation schedules, the first launch opportunity in mid January. This could have happened sooner, but, in addition to addressing the flight anomalies, there were some important performance upgrades that we decided to implement.

Mostly significant is switching from the ablatively cooled Merlin 1A main engine to the regeneratively cooled Merlin 1C, which has higher thrust, higher efficiency and a number of robustness improvements. The Merlin 1C will also be used to power the first and second stages of Falcon 9, giving us flight heritage on that engine well before Falcon 9 lifts off for the first time. We've also switched the second stage tank to a higher strength aluminum alloy and upgraded to our Kestrel 2 upper stage engine (higher efficiency, lighter and better manufacturing tolerances).

Falcon 9 Overview

Reliability comes first

More than anything else, the Falcon 9 design is absolutely focused on reliability. This is one of the few launch vehicles in the world designed to the higher safety and reliability standards required for manned spaceflight. Before carrying astronauts to the International Space Station, the Falcon 9 will undergo an intense NASA safety review and will be required to have far higher structural safety margins and ability to tolerate sub-system failure than are needed simply to launch satellites.

A significant advantage of the Falcon 9 is the ability to lose any engine on the first stage and still safely complete the mission, much as a Boeing 747 can lose an engine and still be ok. Like jet engines, each of our Falcon 9 Merlin engines is wrapped in a Nomex and Kevlar flak jacket, so that even a worst case fire or explosion is contained and cannot affect other engines or the stage itself. In the event of an engine failure, it just means that the first stage will fire for a little longer than would otherwise be the case.

Unlike Falcon 1, where very few systems had flight heritage, the Falcon 9 will have considerable flight heritage. It will use the same engines and much of the same avionics, mission assurance processes and automated health monitoring, as well as hundreds of lessons learned from Falcon 1. The reason SpaceX started out with the Falcon 1 was primarily so that we could learn our lessons at a small scale before transitioning to a much larger vehicle. That said, I should be clear that the Falcon 1 will always be an important part of the SpaceX product line – five of our eleven upcoming missions are on the Falcon 1.

What does it look like?

It is important to appreciate that the Falcon 9 is a *big* vehicle. To give you a sense of scale, it stands about 18 stories (54 meters) tall on the launch pad and has a cargo area in the nose that is 17 feet in diameter and 50 feet long – big enough to carry a bus to orbit. Falcon 9 has a maximum thrust of just over one million pounds, which is *four times* the maximum thrust of a Boeing 747. The Falcon 9 Heavy, which I expect will fly about two years after the standard Falcon 9, will have over three million pounds of thrust, which is almost halfway to a Saturn V.

Capable of lofting 22,900 pounds (10,400 kilograms) into orbit, the two-stage Falcon 9 launcher has considerable heritage from Falcon 1 design, production, propulsion, and avionics technologies. Our team's focused efforts (sometimes around the clock) have kept us on track to deliver our first Falcon 9 to Launch Complex 40 at Cape Canaveral by the end of 2008 (more on this below).

Development progress

First Stage

Primary Structure – A few months ago, we completed serial number 1 of the first stage primary structure assembly of Falcon 9. As you can see in the pictures, the tank completely filled the production floor, something that won't happen once we move to our new 550,000 square foot building in Hawthorne.

Falcon 9 First Stage on the production line

The Falcon 9 first stage tank alone compares in size to the fuselage of a Boeing 737. It measures 86 feet (25.8 meters) in length, and has a diameter of 12 ft (3.6 m). An internal dome separates it into two chambers; the upper one for liquid oxygen and the lower for RP-1 (rocket propellant grade kerosene) – the same propellants used in the Soyuz and first stage of the Saturn V.

Moving the First Stage Tank from the manufacturing line to the road

Mounted on the transport trailer and about to leave for Texas

Awaiting pressure testing in Texas

A flatbed semi carried the completed tank from SpaceX headquarters in El Segundo, California half way across the USA to the SpaceX Texas development facility, located midway between Dallas and Austin. Upon arrival, it was pressure tested and inspected for structural integrity (X-ray and dye penetration).

The 235 ft tall Test Stand for Falcon 9 stage hold down firing can be seen in the background

Then we lifted the tank off the trailer and lowered it on to the rollers on the floor of the new 10,000 square foot hangar building. We're now cleaning the interior (liquid oxygen tanks require special cleaning), as well as painting and insulating the exterior. When that is done, we will attach the engine bay and lift the stage onto the stand. When ready, the engines will be lifted up and mounted into the engine bay one at a time.

Engine Bay - The Falcon 9 thrust skirt and thrust structure join the giant main tank to the nine Merlin engines. It contains all the structural members that support the enormous weight of the vehicle pressing down, and the thrust of the engines pushing up, as well as the manifolds, wiring and piping needed to operate the nine Merlin 1C engines.

This is arguably the most difficult section of the entire vehicle. It contains extensive shielding to protect both against normal flight conditions and a worst case engine fire or RUD (rapid unscheduled disassembly). In the event of an engine shutdown, well protected propellant pre-valves and pressurant fuse valves immediately cut off flow to that engine.

This Structural Test Stand can apply up to 1,500,000 lbs of force to the Engine Bay

We delivered the first engine bay assembly to Texas and installed it into the structural test stand above. The stand applies enormous hydraulic loads to simulate both the weight of a fully loaded Falcon 9, and the dynamic forces from the thrust of the engines during flight, including substantial side loads. For ease of testing, the thrust assembly is placed in the test stand "upside down" from its flight orientation.

The test regimen pushes the "corners of the envelope", and allows us to apply forces to the structure that would never be encountered under nominal flight conditions. The engine bay passed the proof loads without a problem and strain measurements were very close to our finite element model predictions. Back in California, we've almost finished manufacturing the second engine bay and then will be starting on a third. As each part of the Falcon 9 production line activates, it goes into continuous production at a rate of one unit every three months.

For the next phase of Falcon 9 first stage testing, the assembled tank and thrust structure will get lifted up on to the big stand and secured in place. If all goes reasonably well, we should do our first stage hold down firing, starting with one engine, within a few months and our first multi-engine firing in the December timeframe. Since we'll have up to nine engines firing at once on the big test stand, our Texas team has installed extensive propellant management and data collection systems, and built out the flame trenches and related ground systems in preparation.

Falcon 9 will undergo dozens of long duration stage firings on this stand

Merlin Engine – We continue to conduct Merlin engine test firings on our development engine, and have accumulated over 2,200 seconds of operation on a single engine – equivalent to 13 complete first stage flights.

Merlin 1C engine firing on the vertical test stand. The blast extends dozens of feet and is ducted out to the side in a long trench.

Check out the video of a recent Merlin engine test. (1.4 MB .mov file)

The engine has exceeded or met its development targets for thrust, Isp (specific impulse), and mass. We are very close to completing the development phase of the Merlin 1C, pending only an improved method of attaching the injector to the manifold. The first "flight ready" Qualification Engine has already been built and is ready to ship to Texas, pending verification of the new injector to manifold attachment method.

The first flight-ready Merlin engine on display at the DARPATech event in Anaheim CA, August 2007, before shipment to Texas for qualification testing.

We are gearing up to produce Merlin engines at a rate approaching one every two weeks by the end of this year. It is worth noting that the SpaceX Merlin engine is the first all-new American hydrocarbon engine for an orbital booster to be flown in forty years, and only the second new American rocket booster engine of any kind in twenty-five years.

Avionics

The Falcon 9 avionics and software have a great deal of flight heritage carryover from Falcon 1. The biggest differences are that Falcon 9 has a triple redundant voting architecture, compared with the primarily single string Falcon 1. This means that any component can fail, even in subtle ways such as a slight data corruption, without affecting the mission success.

Another change relative to Falcon 1 is increased radiation tolerance. Falcon 9 is capable of missions to geosynchronous orbit and beyond. Missions of long duration or that travel through the Van Allen belts require increased resistance to radiation damage, as compared with low Earth orbit missions.

Falcon 9 Launch Sites

In April of this year, the Air Force awarded Launch Complex 40 (LC-40) at Cape Canaveral to SpaceX. This is a world class heavy lift launch pad, capable of supporting both the Falcon 9 and Falcon 9 Heavy. To be awarded what is arguably the best available launch pad at the Cape is in effect a significant endorsement of SpaceX and the Falcon 9. We owe a debt of gratitude to those within the government that fought hard for us to be granted this facility.

Until last year, LC-40 was home to the heavy lift Titan IV launch vehicle. It lies just south of LC-39, used for Saturn V and Space Shuttle missions. Our Florida operations are already very busy preparing to outfit LC-40 with state-of-the-art launch support systems.

To further expand the launch options we offer our customers, SpaceX will establish a Falcon 9 launch site at Vandenberg Air Force Base in California. Polar and other high inclination launches cannot be performed from Florida, as the vehicle would pass over highly populated portions of either Canada or South America during the early phases of ascent. From Vandenberg however, rockets can fly south over the Pacific Ocean until finally crossing Antarctica. High inclination orbits provide coverage of nearly the entire globe for many types of Earth monitoring and communications satellites.

We are also looking into flying Falcon 9 from our Kwajalein facility in the middle of the Pacific, the site of our next Falcon 1 launch. Located just a few degrees north of the equator, it provides an excellent starting point for flights to geosynchronous orbit – a major destination for weather, communications and broadcast satellites. Our Omelek island site already houses satellite processing facilities, equipped with a 10K clean room, tight temperature and humidity controls, and dedicated guest offices for our customers.

The combination of Florida, California and Kwajalein launch sites will also give us launch site redundancy. We can almost always get to any orbit from multiple locations. That means if there is a hurricane in Florida or a hold up of some kind in Kwajalein, we can still ensure that our customers launch without delay.

Our Customers

We now have six Falcon 9 flights on our launch manifest, in addition to five Falcon 1 missions. We have scheduled the debut Falcon 9 demonstration launch for late 2008. Then will come the first of three demonstration flights under the NASA COTS program, followed by a satellite launch for MDA Corp. of Canada (developer of the Shuttle's robotic arm and many other satellite systems), our first commercial satellite launch for Falcon 9.

The NASA COTS flight demonstrations will culminate in delivery of cargo to the International Space Station and return of cargo safely back to Earth. Much as early commercial airplane flights began by delivering air mail for the U.S. government and later opened up the world of regular passenger air travel, frequent resupply missions to the Space Station may one day lead to opening up orbital spaceflight to the general public.

Our Need for "Space"

But getting back to Earth, as I mentioned at the beginning of this update we're preparing for a big move to our new location in Hawthorne, just down the road from our present headquarters in El Segundo. Our new facility is adjacent to the Hawthorne Airport, and within sight of the 105 Freeway. Previously, this building was used to build 747 fuselage sections, which gives an idea of its epic size.

Aerial view of the new Hawthorne HQ of SpaceX, covering over 11 acres

Interior of the new building – just one small portion of it

These images don't convey its true scale – we can fit two Falcon 9s or five Falcon 1s, nose to tail, along the *short* side of the building! We are working hard at upgrading the facility with a cool, modern esthetic and Silicon Valley style amenities, such as free soda and snacks and a game room.

Borrowing a page from Google, we will have a free cafeteria with food prepared by a first rate chef. Once settled, we plan on running comfortable SpaceX shuttle buses with built in WiFi on daily trips east, south and north to alleviate a commute that can be pretty awful for some people. The overarching goal is that people really look forward to coming to work in the morning and regret leaving the office. :)

We're Looking for Great People

SpaceX is always looking for world class people to join the team. Most of our needs are in California, but we're also growing our Florida team in preparation for increased Falcon 9 activities at Cape Canaveral, and are expanding our Texas team. Besides a competitive salary, comprehensive benefits and significant stock options, joining SpaceX offers the opportunity to help open up space for humanity.

--Elon--

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