Availability of Launch Vehicles
Falcon Family is Filling the Void for Space Science Missions

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Director
Civil Business Development

November 2009
SpaceX Vehicles

Falcon 1

Falcon 9

Dragon Spacecraft
### SpaceX Manifest

<table>
<thead>
<tr>
<th>Customer</th>
<th>Date</th>
<th>Vehicle</th>
<th>Launch Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpaceX Flight 4 – launched</td>
<td>Sept. 28, 2008</td>
<td>Falcon 1</td>
<td>Kwajalein</td>
</tr>
<tr>
<td>ATSB (Malaysia) – launched</td>
<td>July 13, 2009</td>
<td>Falcon 1</td>
<td>Kwajalein</td>
</tr>
<tr>
<td>Falcon 9 Inaugural Flight</td>
<td>2009</td>
<td>Falcon 9</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>NASA COTS - Demo C1</td>
<td>2010</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>NASA COTS - Demo C2</td>
<td>2010</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>NASA COTS - Demo C3</td>
<td>2010</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>Falcon 1e Inaugural Flight</td>
<td>2010</td>
<td>Falcon 1e</td>
<td>Kwajalein</td>
</tr>
<tr>
<td>MDA Corp (Canada)</td>
<td>2010</td>
<td>Falcon 9</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>ORBCOMM – Multiple Flights</td>
<td>2010 to 2014</td>
<td>Falcon 1e</td>
<td>Kwajalein</td>
</tr>
<tr>
<td>NASA CRS – Flight 1</td>
<td>2011</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
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<tr>
<td>Bigelow Aerospace</td>
<td>2011</td>
<td>Falcon 9</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>DragonLab – Mission 1 &amp; 2</td>
<td>2011 &amp; 2012</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
</tr>
<tr>
<td>CONAE (Argentina) – Two Flights</td>
<td>2012 &amp; 2013</td>
<td>Falcon 9</td>
<td>Vandenberg*</td>
</tr>
<tr>
<td>Astrium (Europe)</td>
<td>2014</td>
<td>Falcon 1e</td>
<td>Kwajalein</td>
</tr>
<tr>
<td>NASA CRS – Flights 2 through 12</td>
<td>2011 to 2015</td>
<td>Falcon 9/Dragon</td>
<td>Cape Canaveral</td>
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</tbody>
</table>

This list represents a total of 27 or more pending flights.  

*Vandenberg or Kwajalein, depending on range availability.*
SpaceX Overview

- Founded in mid-2002 with the singular goal of providing highly reliable, low cost space transportation for both cargo and crew
- Over 800 employees and growing
- 51,000 sq m (550,000 sq ft) of offices, manufacturing and production in Hawthorne, California
- 300 acre (121 hectares) state-of-the-art Propulsion and Structural Test Facility in central Texas
- Launch sites at Kwajalein and Cape Canaveral
- Developing launch site at Vandenberg

Hawthorne (Los Angeles) Headquarters

Central Texas

SLC-40, Cape Canaveral

SLC-4E, Vandenberg

Omelek, Kwajalein Atoll
Hawthorne Headquarters
Texas Test Facility

Dedicated 300 acre propulsion and structural testing operations

Falcon 9 stage test stands, hangar; Dragon structural test stand

Draco thruster test stand

Falcon 1 test stand; Merlin and Kestrel engine test stands; Blockhouse
Omelek Island Launch Site

Dedicated Falcon 1 near-equatorial launch facility
Cape Canaveral Launch Site

- ~40 full-time employees
- Facilities sized for 12 launches per year
**SpaceX: Reliable and Low Cost**

- Falcon launch vehicles have been designed to provide dramatically lower cost access to space.
  - Reduced prices do not come at the expense of reliability
  - SpaceX has pursued reliability and reduced cost hand-in-hand
  - The two are often inextricably linked in that the lower cost, simpler choice is also the most reliable

- Falcon vehicles designed for reliability from the beginning:
  - Engines
    - Pintle injector design is simple and robust
    - Single-shaft impeller turbopump for fuel and oxidizer
    - Design qualified to 10-20 full mission duty cycles
  - Architecture
    - Minimum number of staging events possible
    - Closed-loop engine TVC hydraulic system prevents possibility of failure by fluid depletion
  - Launch Operations
    - Highly automated countdown
    - Hold-before-release launch system
Falcon Reliability

• Simplest Possible Propulsion System
  – Robust first & second stage engines with simplest possible design
  – Pintle injector & single shaft impeller turbopump
  – Leverage booster engine across for Falcon 9 line to increase production rate, repeatability and product quality

• 1st Stage Hold Down to Prevent Engine Performance Failures
  – First stage is held down after ignition
  – Autonomous abort if off-nominal condition exists

• Minimal Separation Events to Minimize Failures
  – Minimum number of stages (2) to minimize separation events

• Lightweight, Flight Pressure Stabilized Structure
  – Improved ground handling & reduced cost
  – Most mass efficient stage for any liquid fueled rocket currently in use
  – Avoids ground handling difficulties of non-self-supporting structures

• Reusability
  – The first stage is designed to be recovered and reused — providing valuable opportunity for post-mission inspection
  – First stage tested to over 190 cryogenic pressure cycles with no evidence of fatigue

High Cost Does Not Equal High Reliability
SpaceX Falcon 1 Capabilities

- 1st privately developed liquid fuel rocket to orbit - 28 Sep 2008
- Delivered 1st commercial customer to orbit - 14 July 2009
- World’s lowest-cost dedicated orbital mission: ~$9M
- Two-stage light-lift launch vehicle
  - 1st Stage: Merlin engine, LOX / RP-1, ~95k lbf vac.
  - 2nd Stage: Kestrel engine, LOX / RP-1, ~7k lbf vac.
- Diameter: 1.7 m (5.5 ft); Length 21 m (68 ft)
- Falcon 1 Enhanced (F1e) block upgrade starting in 2010
- Payload capability to 185 km, 9.1° circular LEO:
  - Falcon 1 (2008-09): 420 kg (925 lb)
  - Falcon 1e (2010+): 1010 kg (~2,220 lb)
- Highly Responsive Mission Integration and Operations
- Falcon 1 (& 1e) on-ramped to NASA Launch Services (NLS)

All structures, engines, most avionics and all ground systems designed and mostly built by SpaceX
SpaceX Falcon 1 Secondary Pay loads

- Falcon 1 provides small satellites the opportunity to fly as primary payloads – often for less cost than flying as a secondary passenger on another mission.
  - Lower risk of delay or conflicts during development, integration and flight
  - Dedicated Secondary Missions

- Multiple small satellites that would otherwise compete for secondary slots can fly together as the primary mission.
  - Single customer
  - Multiple providers

- SpaceX seeks partnerships with companies interested in acting as the manifesting agent.
  - Buy and resell available payload mass & volume
  - Develop suitable multi-payload adapters
  - Select and integrate satellites with compatible requirements
Falcon 1 Reaches Orbit - twice
Falcon 9 Capabilities

- Inaugural flight from Cape Canaveral in early 2010
- Lowest mission price in this vehicle class
  - Greater than a factor of 5 cost reduction compared to our domestic competitors
- Two-stage EELV-class launch vehicle
  - Designed to meet NASA man-rated safety margins and failure tolerances
  - Engine-out reliability
- 1st Stage powered by 9 Merlin engines
  - Over 4.9 MN (1.1 million lbf) thrust in vacuum
- 2nd Stage powered by Merlin Vacuum engine
  - 42.7 kN (96,000 lbf) thrust in vacuum
- Engine-out capability from lift-off
  - 2-engine-out capability later in 1st stage burn
  - Each engine isolated with blast-shields to prevent cascading failures
- Diameter 3.6 m (12 ft); Length 55 m (180 ft)
- Payload capability (Block 2)
  - 5.2 m (17 ft) fairing
  - 10,500 kg to LEO
- Falcon 9 on-ramped to NASA Launch Services (NLS)

All structures, engines, most avionics and all ground systems designed and mostly built by SpaceX
Falcon 9 Hardware
Falcon 9 Avionics

• Avionics flight hardware in production and supporting engine & stage testing
Merlin Engines

Acceptance Test of Flight Merlin Engine (Qualification complete)

Full Mission-Duration (360 second) Test of Merlin-Vacuum Engine for Falcon 9 2nd Stage
Falcon 9 Multi-engine Testing

- Completed all COTS multi-engine test milestones
- Full mission duration (177 sec) 9-engine test completed 22 Nov 2008
- 30 sec flight acceptance test completed 16 Oct 2009
Falcon 9 at Cape Canaveral, January 2009
Flight 1\textsuperscript{st} Stage 30s Test – Oct. 16, 2009
Flight 2\textsuperscript{nd} Stage 40s Test – Nov. 15, 2009
Dragon spacecraft (trunk [left] and capsule [right]) arrives at launch pad at Cape Canaveral for first flight.
Interstage arrives at SpaceX’s Cape Canaveral launch pad hangar
Falcon 9 Evolution

- 2010: F9 / Dragon (Nov-17-09)
- 2010: Falcon 9
- 2012: Crewed
- 2012: F9-Heavy

Key Features:
- Raptor LOX/H₂ 2nd Stage
- Merlin 2 ~1.5M lbf LOX/RP
SpaceX Standard Pricing

- Open and fixed pricing for all customers
- Best price guarantee
- Modest discounts for contractually committed, multi-launch purchases

**SpaceX reserves the right to seek a co-passenger**

<table>
<thead>
<tr>
<th>Rocket</th>
<th>Payload Capacity</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>Falcon 1</td>
<td>420 kg to LEO</td>
<td>$8.9M</td>
</tr>
<tr>
<td>Falcon 1e</td>
<td>1010 kg to LEO</td>
<td>$10.5M</td>
</tr>
<tr>
<td>Falcon 9 LEO</td>
<td>Spacecraft &lt; 80%</td>
<td>$44.0M</td>
</tr>
<tr>
<td></td>
<td>vehicle capacity</td>
<td></td>
</tr>
<tr>
<td>Falcon 9 LEO</td>
<td>Spacecraft ≥ 80%</td>
<td>$49.5M</td>
</tr>
<tr>
<td></td>
<td>vehicle capacity</td>
<td></td>
</tr>
<tr>
<td>Falcon 9 GTO</td>
<td>Spacecraft &lt; 3,000 kg**</td>
<td>$44.0M</td>
</tr>
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<td>Falcon 9 GTO</td>
<td>Spacecraft ≥ 3,000 kg</td>
<td>$49.5M</td>
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- Standard prices assume payment in full within the noted calendar period.
- Payments made over time subject to LIBOR +2.5% financing rate. Contact SpaceX for standard payment plan.
- Reflight insurance offered at 6.0% of Standard Launch Services Price.
- Standard price includes a SpaceX-developed and produced payload adapter and tension-band separation system. Other systems can be accommodated or provided — contact SpaceX for more information.
Dragon Spacecraft

- Dragon spacecraft designed for transport of pressurized and unpressurized cargo to and from space.

- Dragon Cargo Transport
  - 3 NASA COTS flights
  - 12 NASA CRS flights

- DragonLab Space Platform
  - 2 missions on manifest

- Dragon Crew Transport
  - Falcon 9 / Dragon system designed from the start with human safety rating margins

All structures, thrusters, most avionics and all ground systems designed and mostly built by SpaceX
Dragon Spacecraft

Nosecone
Jettisoned after stage separation.

Capsule – fully recoverable
Contains pressurized cargo, experiments or crew, hatches, thrusters & propellant, parachutes and heat shield.

Trunk – not recoverable
Contains unpressurized cargo and small deployable satellites. Supports solar panels, thermal radiator. Jettisoned before reentry.

Total Payload Capacity: 6,000 kg to LEO
Capsule Down-mass Capability: 2500 kg
Dragon Spacecraft Structure
Dragon “Draco” Thrusters

Draco thruster in Qualification testing

Propellant tank in Qual

FIPS-Certified Crypto Module

Draco flight thrusters

Nov-17-09 © SpaceX
Dragon Spacecraft Applications

**NASA’s “COTS” Program**
- Commercial Orbital Transportation Services
- SpaceX receives $278M over 3.5 years
- Demonstrates cargo services to and from the ISS

**NASA’s “CRS” Program**
- Commercial Resupply Services
- SpaceX awarded $1.6B for 12 cargo missions, 2010 – 2015
- Minimum of 20,000 kg delivered
- Option for additional missions

**SpaceX’s “DragonLab” Program**
- Free-flying recoverable platform for microgravity research & technology demo
- Regular, frequent, commercial access to space
- First mission in early 2011
DragonLab Free-Flying Recoverable Spacecraft

For payloads/experiments that don’t require crew interaction

- Microgravity Research
  - Biology & Life sciences
  - Biotech/pharmaceutical
  - Materials
  - Fluids & micro-fluidics
  - Combustion physics
  - Fundamental physics

- In-space Research
  - Space environments
  - Radiation effects
  - Space physics & relativity

- Technology demonstration / risk retirement
  - Instrument & sensor developers

- Orbital spacecraft bus
  - Earth science & observation
  - Space weather, helio-physics…
Concept of Operations
DragonLab Features

• Benefits:
  – Both pressurized and unpressurized accommodations available
    • Host electronics inside & sensors/apertures outside
    • Lab-conditions pressurized environment for electronics
    • Feed-throughs to Sensor Bay or trunk if needed
  – Capsule Payloads are recoverable
  – Sensor Bay provides some recoverable, unpressurized volume - 0.1 m³ (4 ft³)
    • For sensors, collectors, witness plates etc. that need the exposure to space but also
      recovery
  – Can host large unpressurized payloads in trunk (>14 m³ payload; 3.5 m dia.)
  – Can deploy spacecraft from the trunk (separation signal available)
  – Power, data & thermal payload services are available
  – Streamlined (SpaceX) Payload Safety Review requirements
  – Highly responsive payload hosting (5mth typical integration)
  – No need to develop a spacecraft bus to test an instrument in space
• Firm flight opportunities starting in 2010
  – Project 1 or 2 missions per year
• Total Mission Cost ~$80M
  – Includes Falcon 9, Dragon, launch and mission operations, and recovery
SpaceX Crew Transport Capability

This is why SpaceX was founded

- Both Falcon 9 and Dragon were designed from inception to readily accommodate crew

- In every design decision, the ability to attain human rating rapidly AND at low additional cost is paramount.

- Many human-rating requirements are mandated on the cargo vehicle because it must be safe for ISS crew
Dragon Evolution

Cargo Dragon

- ISS Cargo Delivery
- DragonLab Micro-gravity
- ISS Crew Service
- Life-boat

Crew Dragon

- Boost/De-Orbit
- Robotic Servicing
- Rendezvous & Inspection
- Crewed Servicing
- Orbital Tourism

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