Space Exploration Technologies

Falcon 9 Launch Vehicle
Payload User's Guide

Rev 1

Approved for Public Release.
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1. Introduction

1.1. Revision History

This is the first publicly available version of the Falcon 9 Launch Vehicle User's Guide.

1.2. Purpose

The Falcon 9 User's Guide is a planning document provided for potential and current customers of Space Exploration Technologies (SpaceX). This document is not intended for detailed design use. Data for detailed design purposes will be exchanged directly between a SpaceX Mission Manager and the Payload Provider. This User's Guide highlights the Falcon 9 Block 2 launch vehicle and launch service. The Block 2 launch vehicle offers improved mass-to-orbit performance when compared to the Falcon 9 Block 1. Specific differences between Block 1 and Block 2 will be identified, when appropriate. Performance and environments information are based upon Falcon 9 requirements and analyses, but are not yet validated by flight data.

1.3. Company Description

In an era when most technology-based products follow a path of ever-increasing capability and reliability while simultaneously reducing costs, today's launch vehicles are little changed from those of 40 years ago. SpaceX is changing this paradigm with a family of launch vehicles which will ultimately reduce the cost and increase the reliability of access to space. Coupled with the newly emerging market for private and commercial space transport, this new model will re-ignite humanity's efforts to explore and develop space.

SpaceX was founded on the philosophy that simplicity, reliability, and low-cost are closely coupled. We approach all elements of launch services with a focus on simplicity to both increase reliability and lower cost. The SpaceX corporate structure is flat and business processes are lean, resulting in both fast decision making and delivery. SpaceX products are designed to require low infrastructure facilities (production and launch) with low maintenance overhead, while vehicle design teams are co-located with production and quality assurance staff to tighten the critical feedback loop. The result is highly producible and low cost designs with quality imbedded. To better understand how SpaceX can achieve low cost without sacrificing reliability, please see the Frequently Asked Questions at www.spacex.com.

Established in 2002 by Elon Musk, the founder of PayPal and the Zip2 Corporation, SpaceX has already developed a light lift launch vehicle, the Falcon 1, nearly completed development of the Falcon 9, and developed state of the art testing and launch locations.

In addition, NASA has selected the SpaceX Falcon 9 launch vehicle and Dragon spacecraft for the International Space Station (ISS) Cargo Resupply Services (CRS) contract award. The contract is for a guaranteed minimum of 20,000 kg to be carried to the International Space Station. The firm contracted value is $1.6 billion and NASA may elect to order additional missions for a cumulative total contract value of up to $3.1 billion. SpaceX is on sound financial footing as we move towards volume commercial launches.

Our design and manufacturing facilities are conveniently located near the Los Angeles International airport. This location also allows the company to leverage the deep and rich aerospace talent pool available in Southern California. The SpaceX state-of-the-art propulsion and structural test facilities are located in Central Texas.

1.4. Falcon Program Overview

Drawing upon a rich history of prior launch vehicle and engine programs, SpaceX is privately developing the Falcon family of rockets from the ground up, including main and upper-stage engines, the cryogenic tank structure, avionics, guidance & control software and ground support equipment.

With the Falcon 1, Falcon 1e, Falcon 9 and Falcon 9 Heavy launch vehicles, SpaceX is able to offer a full spectrum of light, medium and heavy lift launch capabilities to our customers. We are able to deliver spacecraft into any inclination and altitude, from low Earth orbit (LEO) to geosynchronous orbit (GEO) to planetary missions. The Falcon 9 and Falcon 9 Heavy are the only US launch vehicles with true engine-out reliability. They are also designed such that all stages are reusable, making them the world's first fully reusable launch vehicles. The Dragon crew and cargo capsule, in conjunction with our Falcon 9, have been selected by NASA to provide efficient and reliable transport of cargo and potentially crew to the International Space Station (ISS) and other LEO destinations.

1.5. Mission Management

To facilitate and streamline communication, each customer works with a single SpaceX contact, a Mission Manager. The Mission Manager works closely with the customer, SpaceX technical execution staff and all associated licensing agencies in order to achieve a successful mission. Specifically, the SpaceX Mission Manager is responsible for coordinating mission integration analysis and documentation deliverables, planning integration meetings and reports, and coordinating all integration and test activities associated with the mission.

The Mission Manager will also facilitate customer insight during the launch campaign. Though the launch operations team is ultimately responsible for customer hardware and associated Ground Support Equipment (GSE), the Mission Manager will coordinate all launch site activities to ensure customer satisfaction during this critical phase.

1.6. Key Customer Advantages

1.6.1. Reliability

The vast majority of launch vehicle failures in the past two decades can be attributed to three causes: engine, avionics and stage separation failures. An analysis by Aerospace Corporation[1] showed that 91% of known failures can be attributed to those subsystems.

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[1] http://www.aero.org/publications/crosslink/winter2001/03.html. A hard copy of this reference can be made available upon request.

With this in mind, Falcon 9 launch vehicles are designed for high reliability starting at the architectural level and incorporate the flight-proven design and features of the Falcon 1 launch vehicle. Some of the significant contributors to reliability include:

- Robust design margins
  Falcon 9 is designed with the goal of carrying humans into space aboard the SpaceX Dragon capsule. This goal drives the initial design of Falcon 9 through the incorporation of increased factors of safety (1.4 versus the traditional 1.25 for uncrewed flight). Payload customers using the Falcon 9 can take advantage of this increased design robustness. The first and second stages are also designed to be recovered and reused, and therefore, must have significantly higher margins than an expendable stage. This also provides a unique opportunity to examine recovered hardware and assess design and material selection in order to continually improve Falcon 9.

- Propulsion and separation event design
  The heart of Falcon 9 propulsion is the Merlin 1C liquid propellant rocket engine. The Merlin engine features a robust, reliable turbopump design incorporating a single shaft for both the liquid oxygen and fuel pumps, and a gas generator cycle versus the more complex staged combustion. The regeneratively-cooled thrust chamber uses a milled copper alloy liner chamber that provides large margins on heat flux. In addition, the pintle injector was selected for its inherent combustion stability. As a part of our launch operations, we hold the first stage after ignition and monitor engine prior to release to watch engine trends. If an off-nominal condition exists, an autonomous abort is conducted. This helps prevent an engine performance issue from causing a failure in flight. Falcon 9 makes use of ten Merlin 1C engines on each vehicle (nine on the first stage, one on the second stage) resulting in high volume engine production, which results in much higher quality through process control. Flying ten engines on each mission also builds substantial heritage quickly. Importantly, by employing nine first stage engines, SpaceX debuts the world's first Evolved Expendable Launch Vehicle (EELV)-class launch vehicle with engine-out capability through much of first stage flight. With the qualification and first flight units in build and several domestic and international purchased flights currently manifested, Falcon 9 is an ideal workhorse for payload customers.

  SpaceX has also minimized the number of stages (2) to minimize separation events. The separation system between the first and second stages does not incorporate electro-explosive devices, instead relying upon a pneumatic release and separation system that allows for acceptance testing of the actual flight hardware. This is not possible with a traditional explosive-based separation system.

- Failure mode minimization
  SpaceX minimized the number of failure modes by minimizing the number of separate subsystems. The first stage thrust vector control (TVC) system makes use of pressurized

rocket- grade kerosene (RP-1). The engine pulls from the high pressure RP-1 side of the pump to power the TVC. This eliminates the separate hydraulic system. In addition it eliminates the failure mode associated with running out of pressurized fluid. Also, the avionics and guidance/navigation/control systems are designed with single fault tolerance, supporting the ability of Falcon 9 to be human rated.

- Rigorous testing
  In addition to SpaceX's unique design decisions, Falcon 9 will undergo an exhaustive series of tests from the component to the vehicle system level. This includes component level qualification and workmanship testing, structures load and proof testing, flight system and propulsion subsystem level testing, full first and second stage testing up to full system testing, including stage static firings at the test and launch sites (as appropriate). In addition to testing environmental extremes (plus margin), all hardware is tested to account for off-nominal conditions. For example, both stage and fairing separation tests require testing for off-nominal cases with respect to geometrical misalignment, anomalous pyro timing and sequencing.

A major contributor to a reliable system is its operations. To support robust launch operations, the SpaceX launch countdown is fully automated with thousands of checks made prior to vehicle release. After first stage ignition, the vehicle is not released until the first stage engines are confirmed to be operating normally. A safe shutdown is executed, should any off nominal conditions be detected. Falcon 9 benefits from the design and operations concepts established for and proven with the successful Falcon 1 program.

1.6.2. Pricing

The standard price per launch for Falcon 9 Launch Vehicles can be found here[2]. Pricing includes range, standard payload integration and third party liability insurance. Please see Section 5.4 for a description of the standard services. Non-standard services are also available. If non-standard services are required, please identify these in the Payload Questionnaire found in Section 8 of this Guide.

[2] http://www.spacex.com/falcon9.php#pricing_and_performance.

2. Vehicle Overview

2.1. Falcon 9 Launch Vehicles

Falcon 9 Launch Vehicles are designed to provide breakthrough advances in reliability, cost, and time to launch. The primary design driver is, and will remain, reliability. SpaceX recognizes that nothing is more important than getting a customer's payload safely to its intended destination. The initial flights of the Falcon 9, currently planned in 2009 and 2010, use the Falcon 9 Block 1. Beginning in late 2010/early 2011, SpaceX will begin launching the Falcon 9 Block 2. Block 2 features increased engine thrust, decreased launch vehicle dry mass, and increased propellant load - combined with lessons learned from the flights of the Falcon 9 Block 1. This results in increased mass-to-orbit performance for the Falcon 9 Block 2 when compared with Block 1 performance. This performance is shown in the Falcon 9 performance tables presented later in this document.

2.1.1. Structure and Propulsion

Like Falcon 1, Falcon 9 is a two-stage, liquid oxygen (LOX) and rocket grade kerosene (RP-1) powered launch vehicle. It uses the same Merlin engines, structural architecture (with a wider diameter), and launch control system.

The Falcon 9 propellant tank walls and domes are made from an aluminum lithium alloy. SpaceX uses an all friction stir welded tank, the highest strength and most reliable welding technique available. Like Falcon 1, the Falcon 9 interstage, which connects the upper and lower stages, is a carbon fiber aluminum core composite structure. The separation system is a larger version of the pneumatic pushers used on Falcon 1.

Nine SpaceX Merlin engines power the Falcon 9 first stage with 125,000 lbf sea level thrust per engine, for a total thrust on liftoff of just over 1.1 million lbf. After engine start, Falcon 9 is held down until all vehicle systems are verified as functioning normally before release for liftoff.

The second stage tank of Falcon 9 is simply a shorter version of the first stage tank and uses most of the same tooling, material and manufacturing techniques. This results in significant cost savings in vehicle production.

A single Merlin engine powers the Falcon 9 upper stage with an expansion ratio of 117:1 and a nominal burn time of 345 seconds. For added reliability of restart, the engine has dual redundant pyrophoric igniters (TEA-TEB).

The Falcon 9 fairing is 17 ft (5.2 m) in diameter.

2.1.2. Avionics, Guidance/Navigation/Control, Flight Termination Systems

Falcon 9 vehicle avionics features a single-fault tolerant architecture and has been designed with a view towards human-rating requirements in order to allow future qualification for crewed launch capability. Avionics include rugged flight computers, GPS receivers, inertial measurement units, SpaceX-designed and manufactured controllers for vehicle control (propulsion, valve, pressurization, separation, and payload interfaces), and a C-Band transponder for Range Safety tracking. Falcon 9 transmits telemetry from both the first and second stages, even after separation of the stages. S-band transmitters are used to transmit telemetry and video to the ground.

The guidance and navigation algorithms for Falcon 9 launch vehicles have been heavily influenced by the algorithms used on other launch vehicles, including Falcon 1. The guidance system takes into account the loss of an engine during first stage burn and adjusts the targeted trajectory accordingly. This mix of explicit and perturbation guidance schemes was selected in order to generate a smooth, computationally simple trajectory while maintaining orbital insertion accuracies.

The Falcon 9 launch vehicle is equipped with a standard flight termination system. This system includes two redundant strings of command receiver and encoder, batteries, safe and arm devices, and ordnance in the event of an anomaly in flight.

Table 2-1 - Falcon 9 Launch Vehicle (Block 2) Dimensions and Characteristics

Characteristic	Stage 1	Stage 2
Structure		
Length	180 feet [55m] (both stages with fairing & interstage)	
Diameter	12 feet [3.66m]	
Type	LOX tank - monococque; Fuel tank - stringer and ring frame	Monococque
Material	Aluminum lithium	Aluminum lithium
Propulsion		
Engine Type	Liquid, gas generator	Liquid, gas generator
Engine Manufacturer	SpaceX	SpaceX
Engine Designation	Merlin 1C	Merlin Vacuum
Number of engines	9	1
Propellant	Liquid oxygen/Kerosene (RP-1)	Liquid oxygen/Kerosene (RP-1)
Thrust	1,125,000 lbf (sea level) [5MN]	100,000 lbf (vacuum) [445kN]
Propellant feed system	Turbopump	Turbopump
Throttle capability	No	Yes (60-100%)
Restart capability	No	Yes - 2 restarts
Tank pressurization	Heated helium	Heated helium
Thrust Vector Control		
Pitch, Yaw	Gimbaled engines	Gimbaled engine
Roll	Gimbaled engines	Turbine exhaust duct (gimbal)
Reaction Control System		
Propellant	Not applicable	Monomethyl hydrazine, nitrogen tetroxide
Thrusters	Not applicable	Draco (4)
Thrust	Not applicable	90 lbf [400N] each
Staging		
Nominal burn time	170 sec	354 sec
Shutdown process	Commanded shutdown	Commanded shutdown
Stage separation system	Pneumatically actuated mechanical collets	Not applicable

2.2. Vehicle Axes/Attitude Definitions

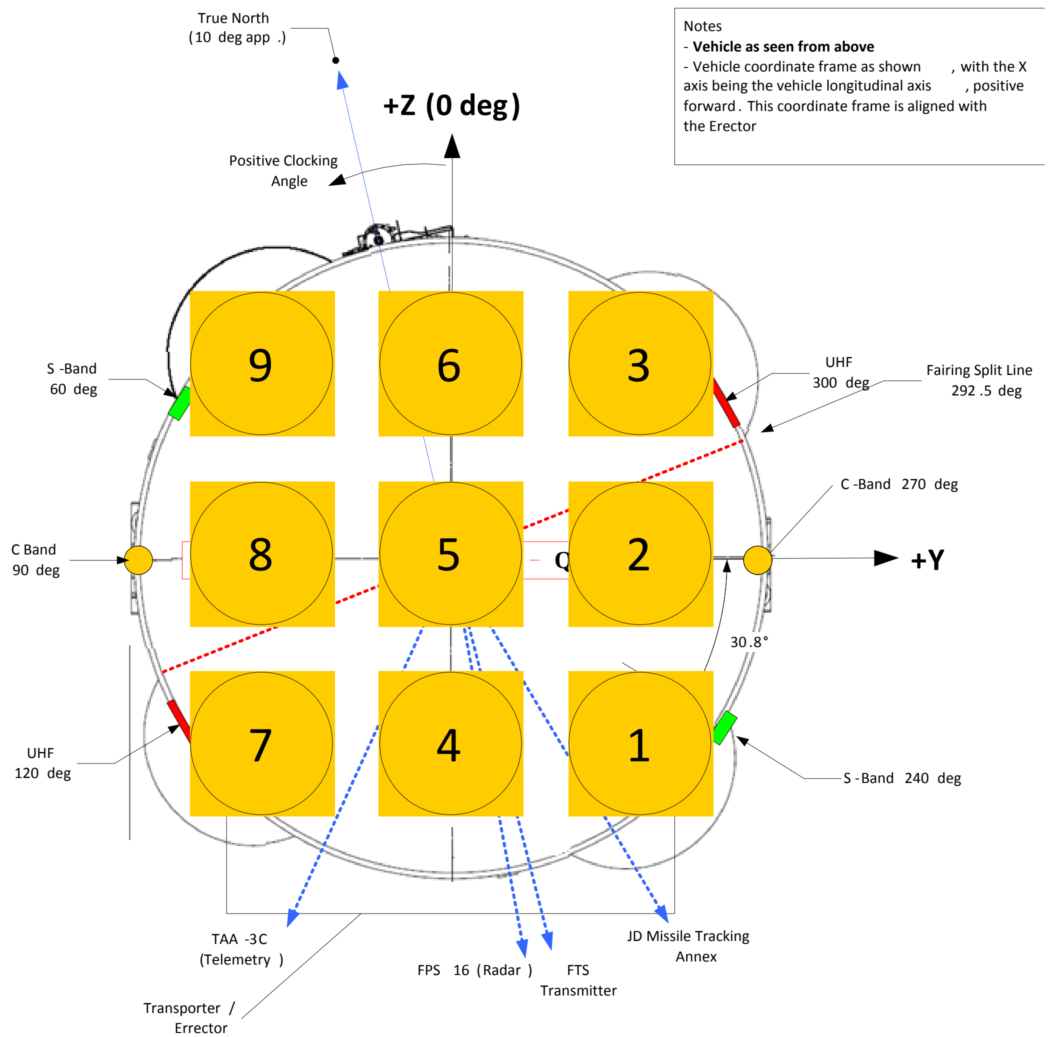


Figure 2-1 - Falcon 9 launch vehicle layout and coordinate system

3. Facilities Overview

3.1. Headquarters – Hawthorne, CA

SpaceX headquarters are conveniently located in Hawthorne, CA, a few miles inland from Los Angeles International Airport (LAX). The 550,000+ square foot (5.1 hectares) design and manufacturing facility ranks among the largest manufacturing facilities in California. Two complete Falcon 9s will fit end-to-end along the short length of the building. For production, there are three Falcon 1 lines, three parallel Falcon 9 lines, nearly two dozen Merlin engine assembly stations, and Dragon capsule production areas. Potential customers are encouraged to arrange a tour when in the Los Angeles area. Map and Directions.

Figure 3-1- Hawthorne, California Headquarters

3.2. Space Launch Complex 40, Cape Canaveral Air Force Station, Florida

SpaceX has a Falcon 9 launch site on Cape Canaveral Air Force Station (CCAFS). The launch site is Space Launch Complex 40 (SLC-40), former home of the Titan IV heavy lift rockets. SpaceX facilities at SLC-40 include a hangar, propellant/pressurant storage and supply areas, launch pad, and lightning towers. Adjacent to the launch complex is the SpaceX administrative office facility. SpaceX launch operations are managed from the Launch Control Center, located at the south entrance to CCAFS. A general layout of the launch facilities is presented in the following figures.

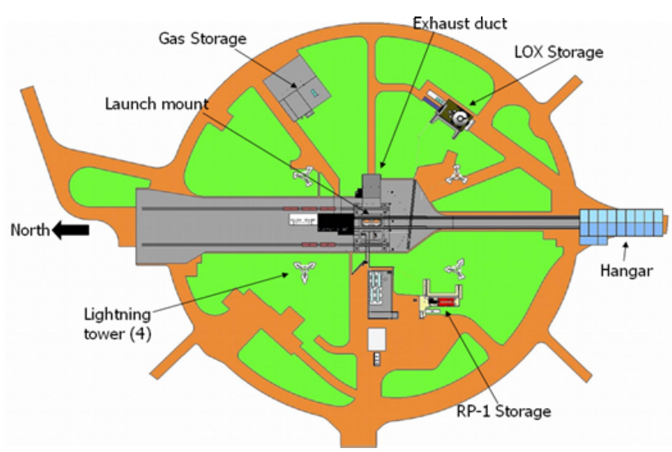
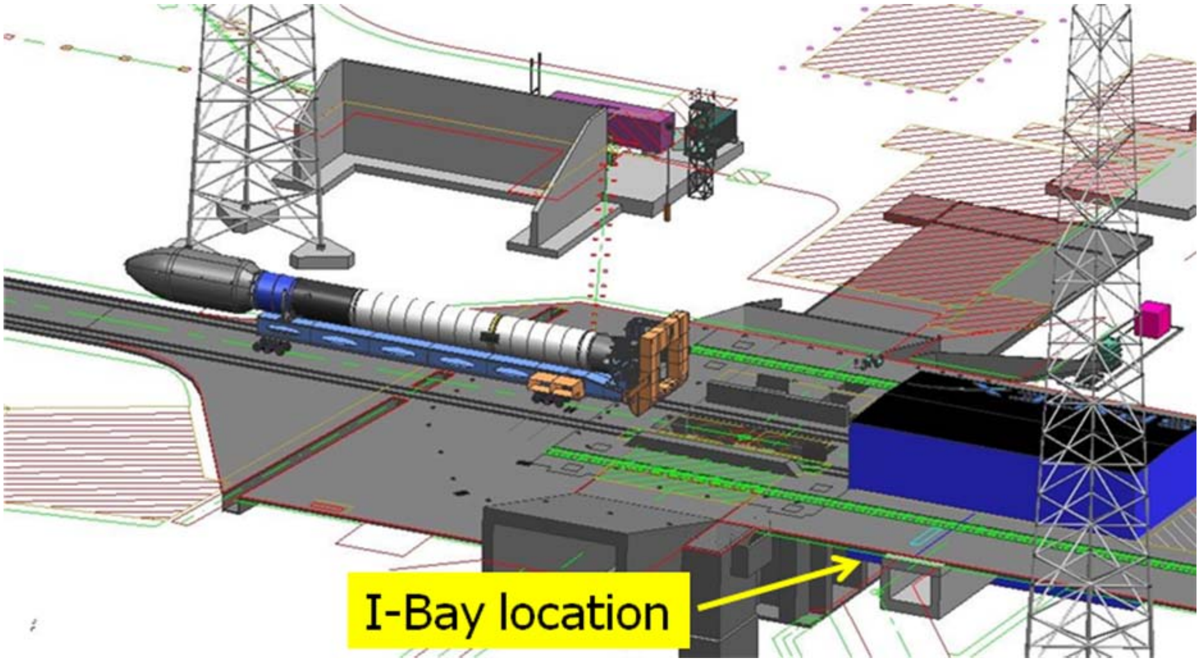


Figure 3-2 - Launch Complex 40 at Cape Canaveral Air Force Station (CCAFS), Florida



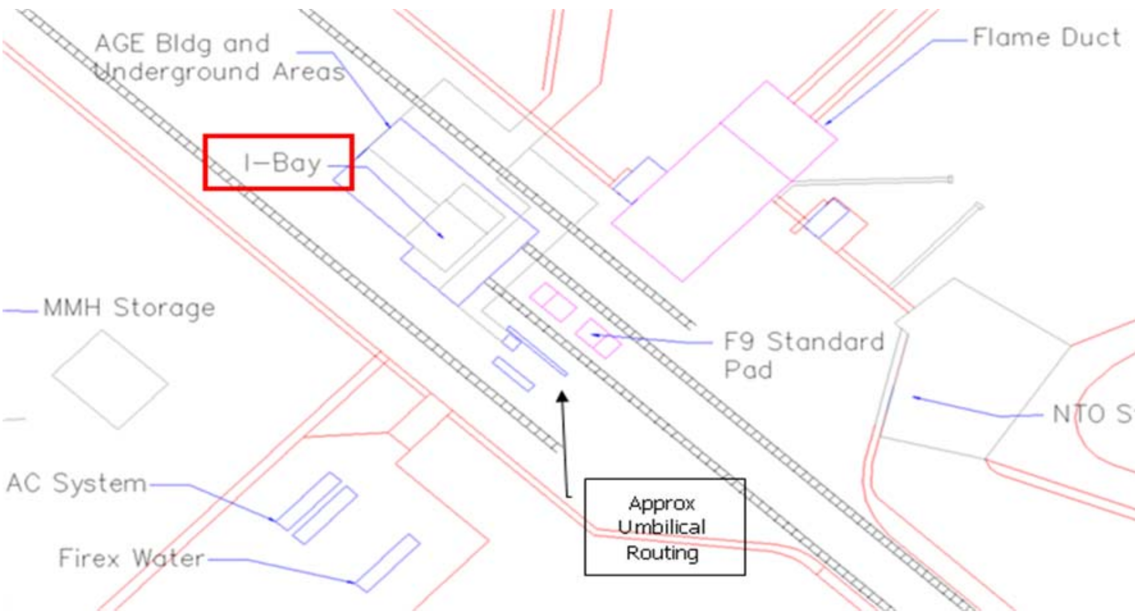


Figure 3-3 - Space Launch Complex 40 Instrumentation Bay location

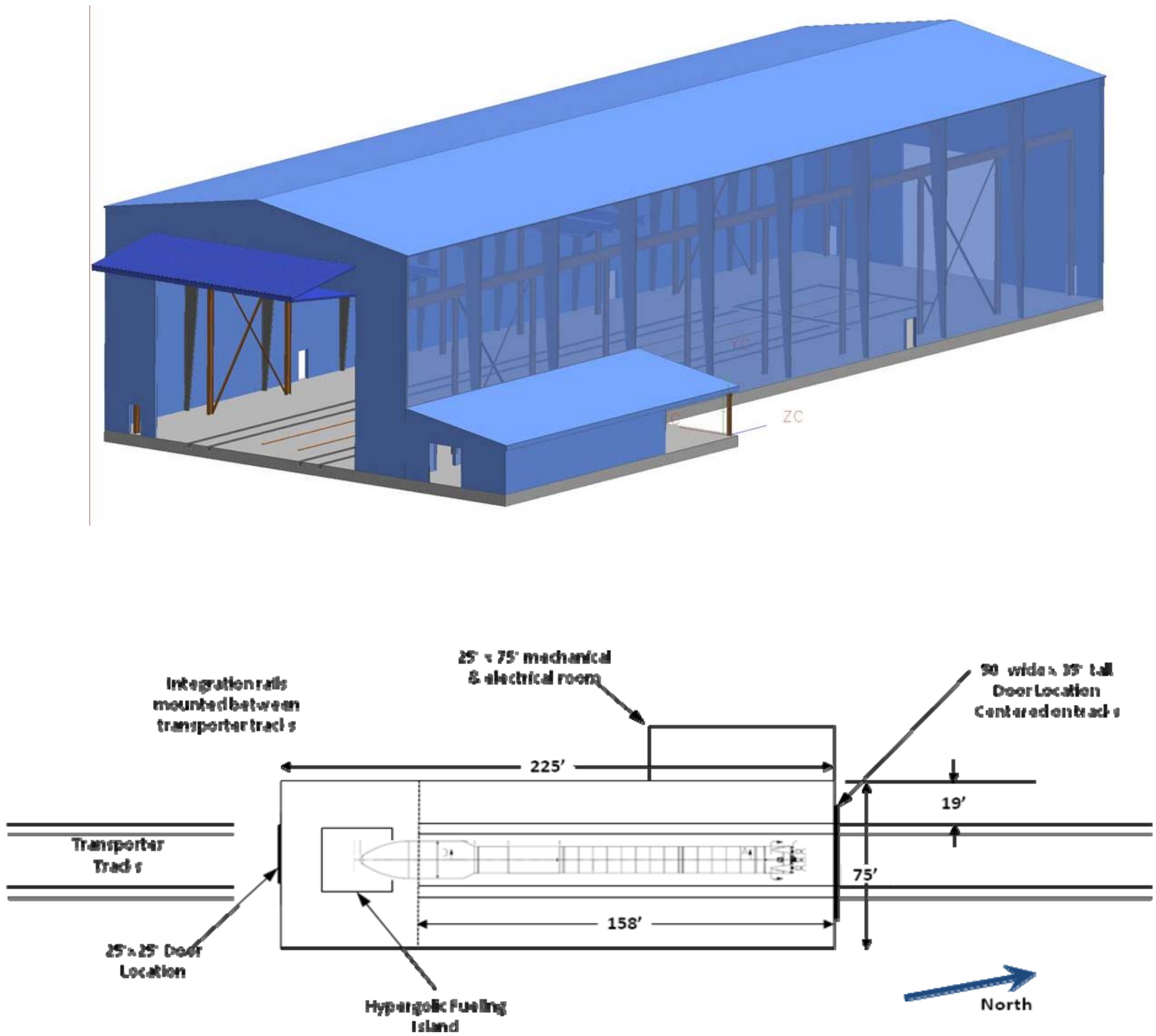


Figure 3-4 - Space Launch Complex 40 Hangar layout

3.3. Space Launch Complex - 4 East, Vandenberg Air Force Base (VAFB), California

SpaceX plans to establish a launch facility at Vandenberg Air Force Base (VAFB) in central California to meet customer needs for polar and sun-synchronous capability. SpaceX's headquarters, manufacturing and production facility is located in the Los Angeles area, within driving distance or a short flight to VAFB. SpaceX has previously worked with the Range at VAFB on Falcon 1 facilities, including conducting a static fire at SLC-3 West in 2005. The candidate launch site, pending discussions with the U.S. Air Force, would be at Space Launch Complex 4 East (SLC-4E). The design of the Falcon 9 launch site at VAFB will mirror the facilities and operations implemented at the Cape Canaveral launch site.

Figure 3-5 - SLC-4 East, VAFB

3.4. U.S. Army Kwajalein Atoll, Marshall Islands

SpaceX has an operational Falcon 1 launch site at the Kwajalein Atoll, about 2500 miles southwest of Hawaii. The Falcon 1 launch facilities are situated on Omelek Island, part of the Ronald Reagan Ballistic Missile Defense Test Site (RTS) at United States Army Kwajalein Atoll (USAKA). The location and a general layout of the launch facility are presented in Figure 3-6. SpaceX is evaluating establishing a launch facility for Falcon 9 at Kwajalein that would provide superior performance to geosynchronous transfer orbit as well as high-inclination orbits.

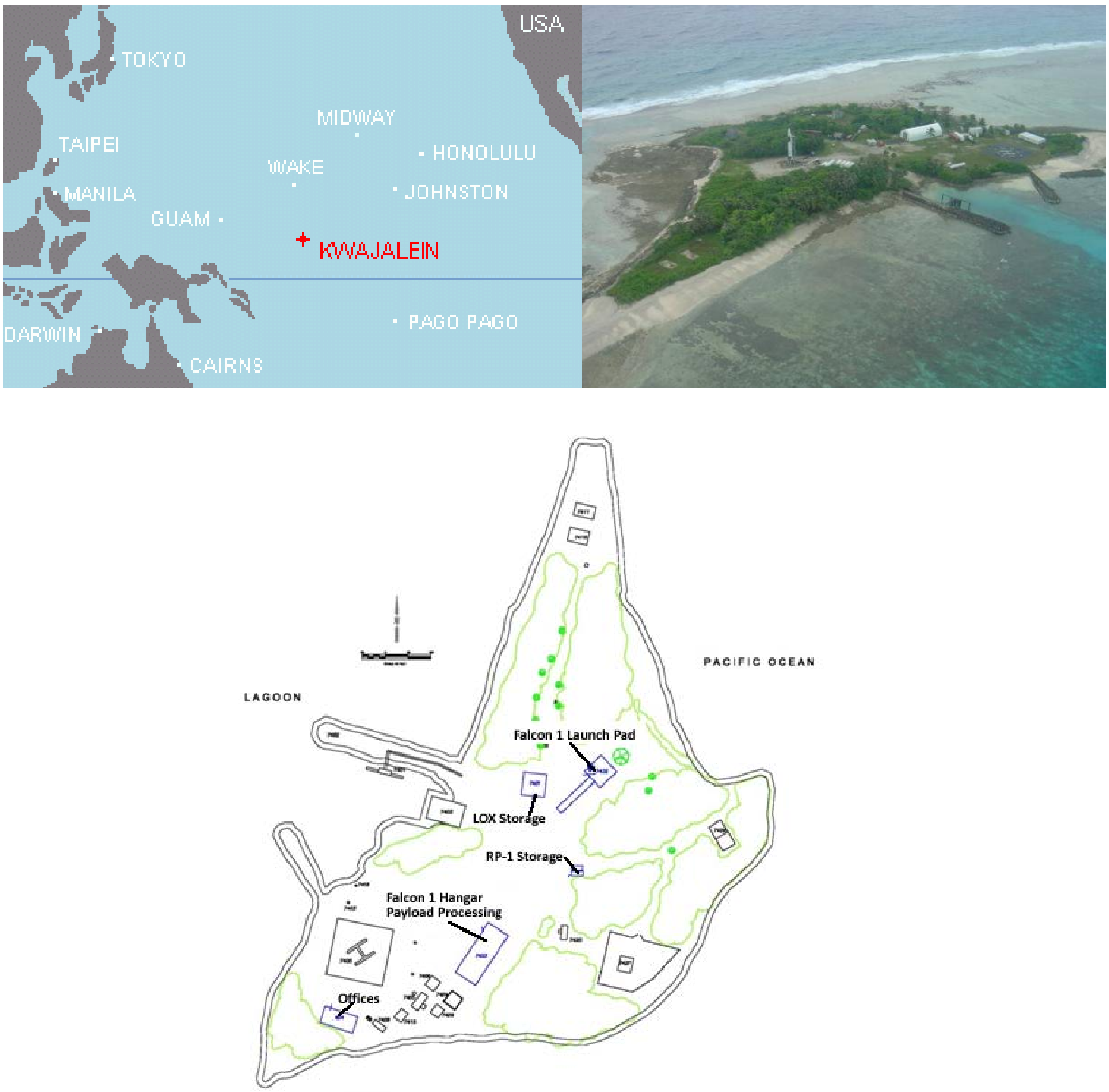


Figure 3-6 - Falcon 1 launch site, Kwajalein Atoll

3.5. Test Facility - Central Texas

Structural and propulsion tests are conducted at the rapidly growing and expanding test site located in McGregor, Texas, just west of Waco. Conveniently located 2 hours from both Austin and Dallas, the site is staffed with test engineers, technicians and management personnel. During preparation and testing, the site also plays host to personnel from the California headquarters who supplement the Texas team.

Figure 3-7 - SpaceX's Texas Test Facility

3.6. Government Outreach and Legal Affairs--Washington, DC

SpaceX's government outreach and licensing team is located in Washington, DC.

4. General Performance Capability

4.1. Performance Capability

The Falcon 9 launch vehicle performance presented in the following tables and figures is for the Block 2 (see paragraph 2.1.2 for details). The performance shown is the maximum capability of the Falcon 9 Block 2 with margin withheld by SpaceX to ensure mission success. Please note typical payloads in the Falcon 9 class typically below 15000 lbs (6800 kg). Potential customers should contact SpaceX if they contemplate flying extra-heavy payloads or using most of the listed performance of the Falcon 9.

For reference, the following is a list of tables and figures in this section:

Section 4.1 List of Figures

Section 4.1 List of Tables

4.1.1. Low Earth Orbit

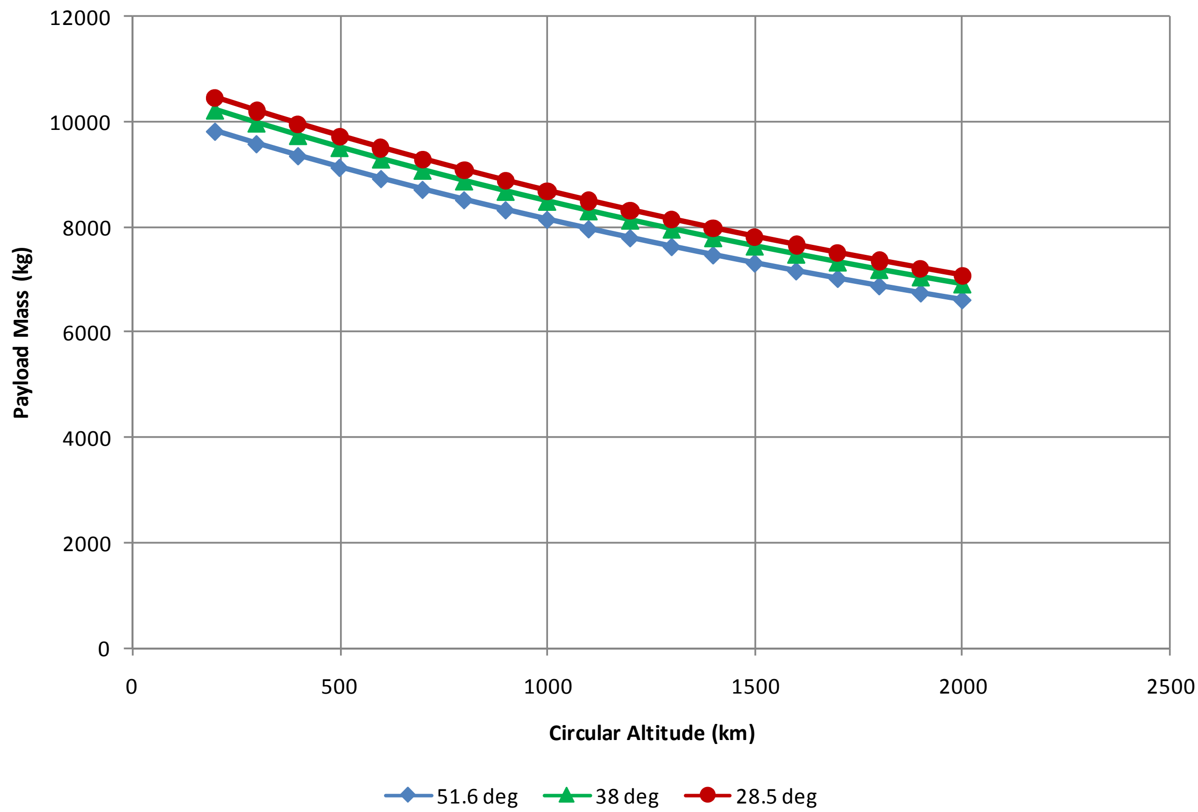


Figure 4-1 - Falcon 9 Block 2 Performance to Low Earth Orbit (Cape Canaveral)

Table 4-1 - Falcon 9 Block 2 Performance to Low Earth Orbit (Cape Canaveral)

Circular Orbit Altitude (km)	Payload Mass (kg)		
	Inclination (degrees)		
	28.5	38	51.6
200	10454	10221	9823
300	10202	9975	9586
400	9953	9737	9358
500	9727	9508	9138
600	9503	9289	8924
700	9287	9076	8719
800	9080	8872	8522
900	8879	8676	8331
1000	8687	8486	8148

Circular Orbit Altitude (km)	Payload Mass (kg)		
	Inclination (degrees)		
	28.5	38	51.6
1100	8500	8303	7970
1200	8320	8127	7799
1300	8147	7957	7635
1400	7979	7792	7475
1500	7817	7633	7320
1600	7662	7480	7172
1700	7510	7330	7028
1800	7364	7187	6888
1900	7221	7048	6753
2000	7085	6913	6622

4.1.2. Polar

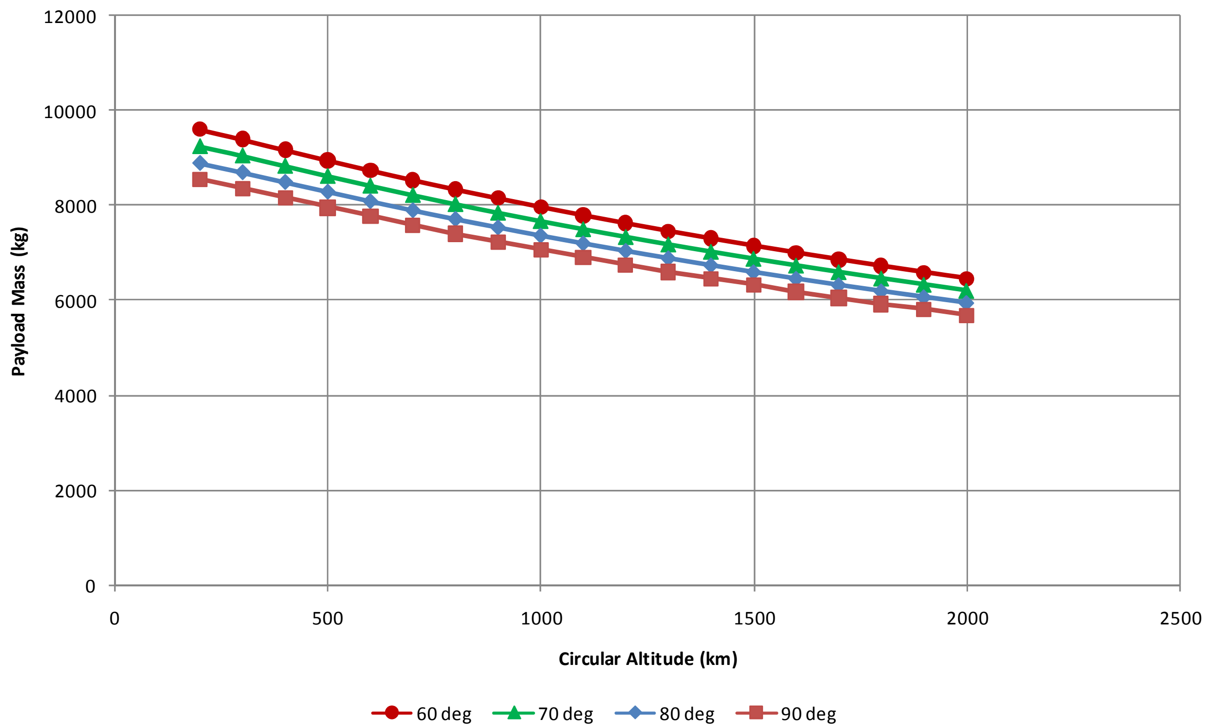


Figure 4-2 - Falcon 9 Block 2 Performance - Circular Polar Orbit

Table 4-2 Falcon 9 Block 2 Performance - Circular Polar Orbit

Circular Orbit Altitude (km)	Payload Mass (kg) Inclination (degrees) 60	70	80	90
200	9598	9254	8904	8561
300	9392	9057	8712	8377
400	9166	8841	8506	8175
500	8948	8628	8300	7969
600	8738	8424	8102	7782
700	8535	8227	7910	7597
800	8340	8037	7726	7418
900	8153	7854	7549	7246
1000	7972	7679	7378	7079

Circular Orbit Altitude (km)	Payload Mass (kg) Inclination (degrees) 60	70	80	90
1100	7797	7509	7213	6919
1200	7629	7345	7054	6765
1300	7466	7187	6900	6616
1400	7310	7034	6752	6472
1500	7158	6887	6609	6332
1600	7011	6744	6470	6198
1700	6869	6606	6336	6069
1800	6731	6473	6206	5943
1900	6599	6343	6081	5820
2000	6470	6215	5960	5702

4.1.3. Sun Synchronous

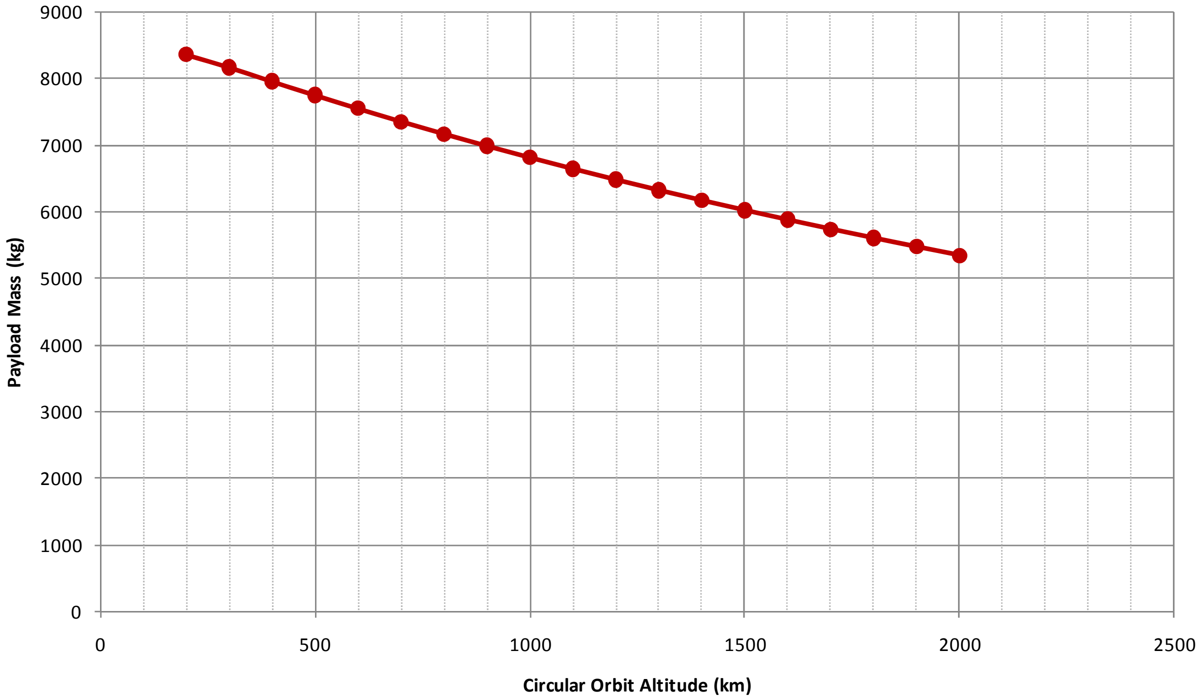


Figure 4-3 - Falcon 9 Block 2 Performance - Sun Synchronous Orbit

Table 4-3 - Falcon 9 Block 2 Performance - Sun Synchronous Orbit

Circular Orbit Altitude (km)	Inclination (degrees)	Payload Mass (kg)
200	96.3	8351
300	96.7	8159
400	97.0	7949
500	97.4	7742
600	97.8	7541
700	98.2	7348
800	98.6	7162
900	99.0	6981
1000	99.5	6807

Circular Orbit Altitude (km)	Inclination (degrees)	Payload Mass (kg)
1100	99.9	6639
1200	100.4	6476
1300	100.9	6319
1400	101.4	6166
1500	102.0	6017
1600	102.5	5874
1700	103.1	5735
1800	103.7	5600
1900	104.3	5468
2000	104.9	5340

4.1.4. C3 – Escape Velocity

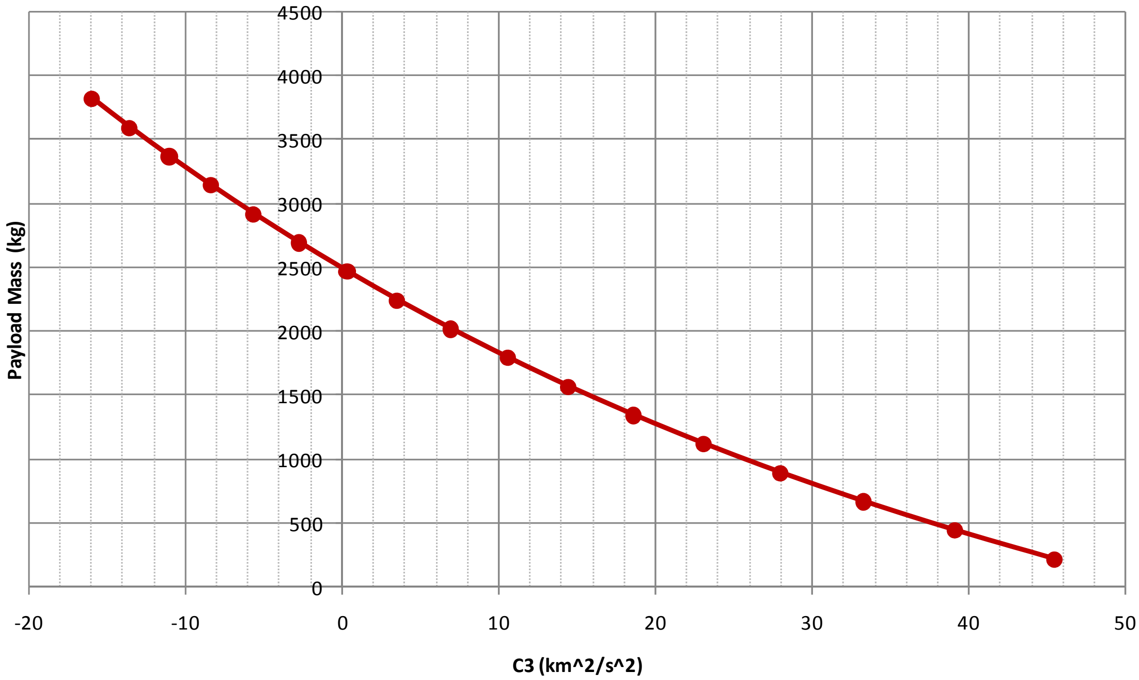


Figure 4-4 - Falcon 9 Block 2 Performance - Escape Velocity (Cape Canaveral)

Table 4-4 - Falcon 9 Block 2 Performance - Escape Velocity (Cape Canaveral)

C3 (km^2/s^2)	Payload Mass (kg) Escape Energy Performance Cape Canaveral
-16	3823
-14	3598
-11	3373
-8	3148
-6	2923
-3	2698
0	2473

C3 (km^2/s^2)	Payload Mass (kg) Escape Energy Performance Cape Canaveral
4	2248
7	2023
11	1798
14	1573
19	1348
23	1123
28	898
33	673
39	448
45	223

4.1.5. Geosynchronous Transfer Orbit (Cape Canaveral)

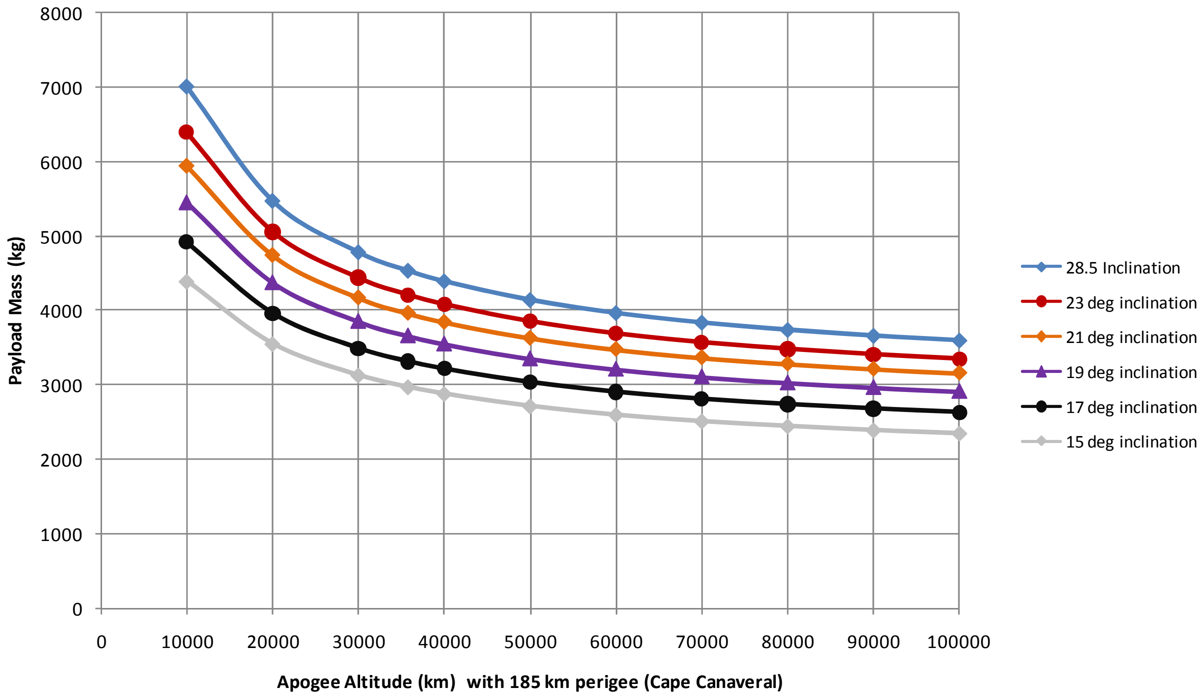


Figure 4-5 - Falcon 9 Block 2 Performance to Geosynchronous Transfer Orbit

Table 4-5 - Falcon 9 Block 2 Performance to Geosynchronous Transfer Orbit

Orbit Altitude (km)	Payload Mass (kg)						
	Inclination (deg)						
	15	17	19	21	23	25	28.5
10000	4392	4921	5447	5947	6391	6740	7002
20000	3551	3970	4374	4744	5060	5300	5471
30000	3130	3501	3853	4172	4442	4643	4784
35786	2972	3325	3660	3963	4216	4405	4536
40000	2880	3224	3550	3842	4087	4269	4394
50000	2715	3043	3351	3627	3857	4028	4144
60000	2598	2915	3212	3477	3697	3860	3969
70000	2512	2820	3109	3365	3578	3736	3841
80000	2445	2747	3029	3279	3487	3641	3742
90000	2391	2688	2966	3211	3415	3565	3664
100000	2348	2641	2914	3156	3356	3504	3601

4.1.6. Geosynchronous Transfer Orbit (Kwajalein)

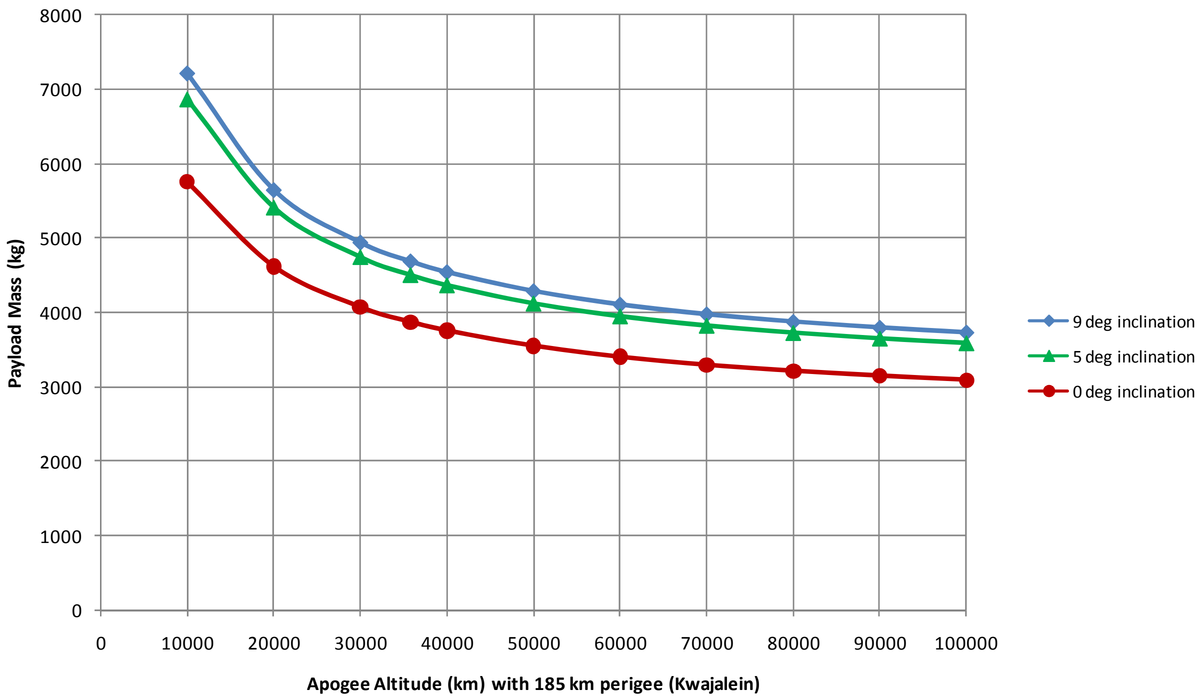


Figure 4-6 - Falcon 9 Block 2 Performance to Geosynchronous Transfer Orbit (Kwajalein)

Table 4-6 - Falcon 9 Block 2 Performance to Geosynchronous Transfer Orbit (Kwajalein)

Orbit Altitude (km)	Payload Mass (kg)		
	Inclination (deg)		
	9	5	0
10000	7203	6859	5750
20000	5638	5408	4618
30000	4935	4744	4074
35786	4682	4503	3875
40000	4537	4365	3759
50000	4282	4120	3552
60000	4103	3949	3407
70000	3972	3823	3299
80000	3871	3727	3216
90000	3792	3650	3150
100000	3727	3588	3097

4.1.7. Geosynchronous Transfer Orbit (Delta-Velocity To Go) [Cape]

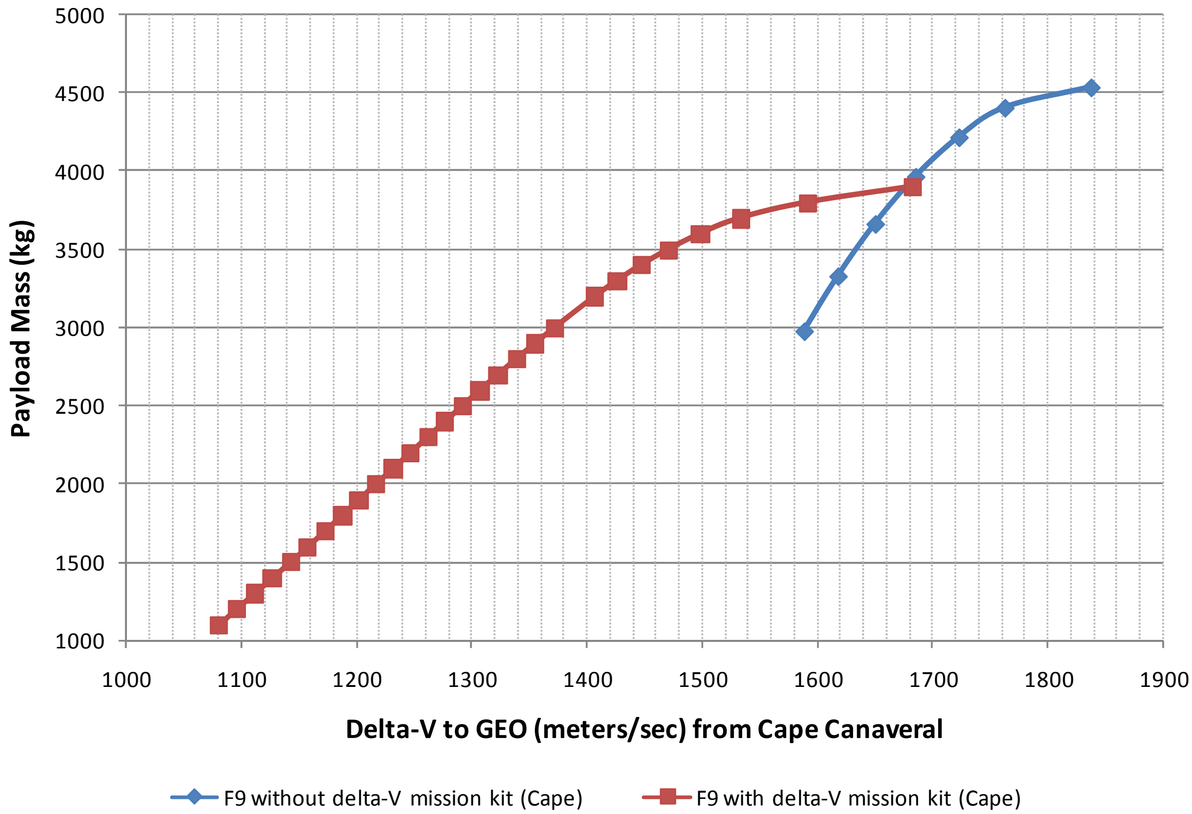


Figure 4-7 - Geosynchronous Transfer Orbit (Delta-Velocity to Go) from Cape

Table 4-7 - Geosynchronous Transfer Orbit (Delta-Velocity to Go) from Cape

Without delta-V mission kit	
Delta-V to GSO (m/s)	Payload Mass (kg)
1588	2972
1617	3325
1650	3660
1685	3963
1723	4216
1763	4405
1837	4536

With delta-V mission kit	
Delta-V to GSO (m/s)	Payload Mass (kg)
1127	1400
1158	1600
1202	1900
1307	2600
1407	3200
1498	3600
1533	3700
1682	3900

4.1.8. Geosynchronous Transfer Orbit (Delta-Velocity To Go) [Kwajalein]

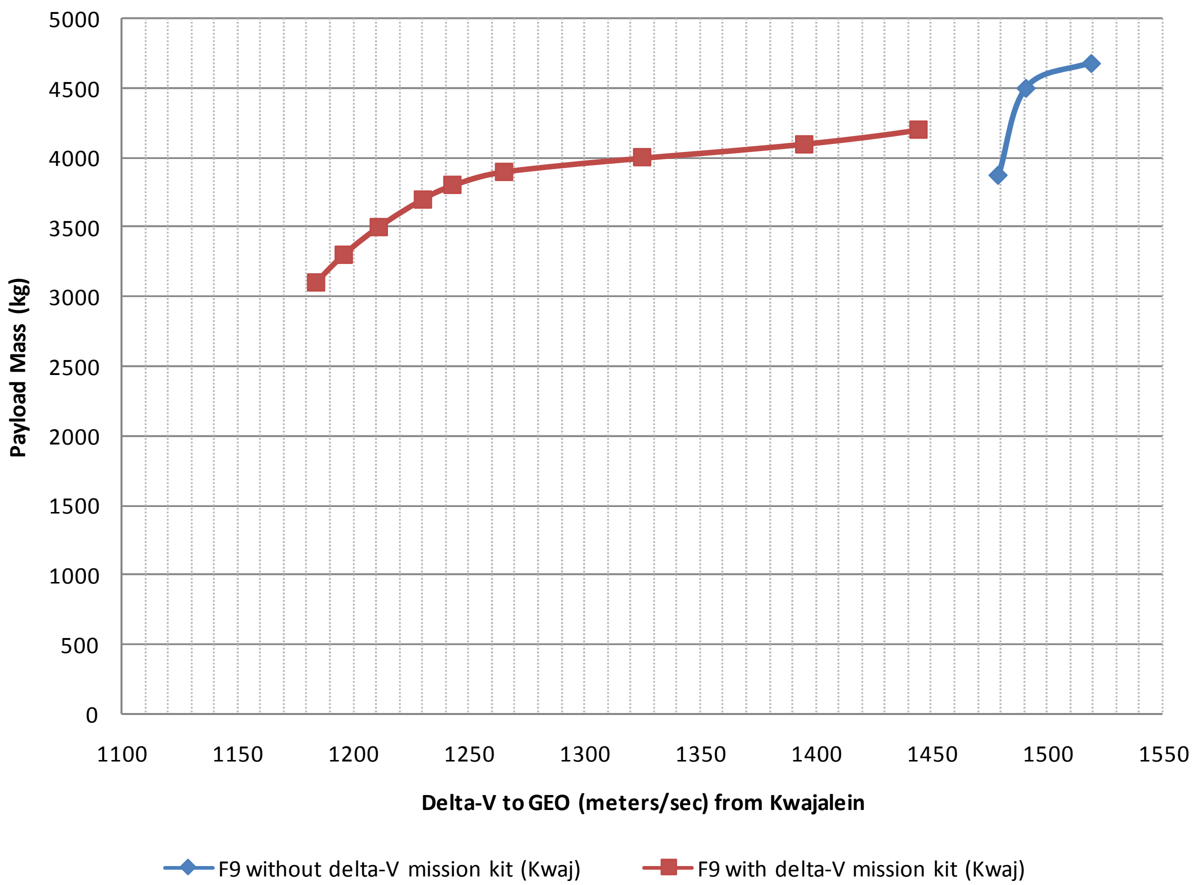


Figure 4-8 - Geosynchronous Transfer Orbit (Delta-Velocity to Go) from Kwaj

Table 4-8 - Geosynchronous Transfer Orbit (Delta-Velocity to Go) from Kwaj

Without delta-V mission kit	
Delta-V to GSO (m/s)	Payload Mass (kg)
1479	3875
1491	4503
1519	4682

With delta-V mission kit	
Delta-V to GSO (m/s)	Payload Mass (kg)
1196	3300
1325	4000
1395	4100
1444	4200

4.2. Sample Mission Profiles

Each mission is unique in its flight profile. However, a typical flight profile for a maximum-capability geosynchronous transfer orbit mission (including a delta-V mission kit) is shown in the Figure 4-9, below, and in Table 4-9.

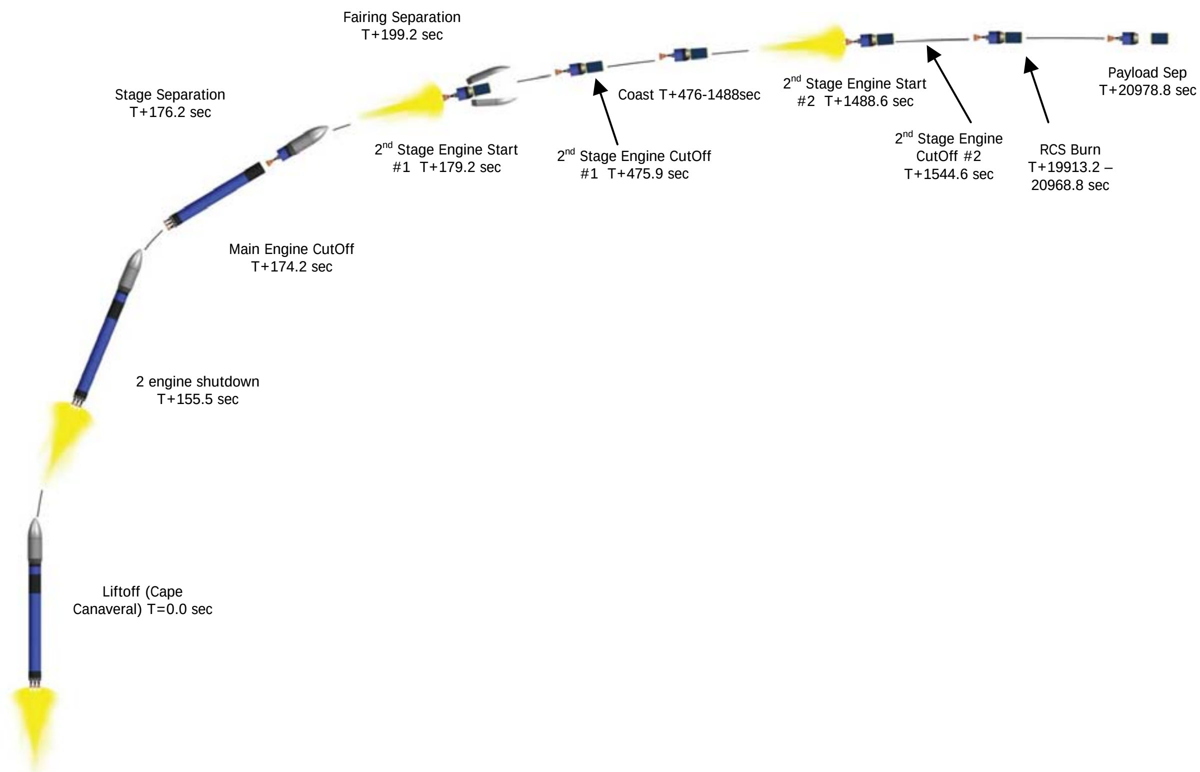


Figure 4-9 - Falcon 9 Sample Flight Profile, Geosynchronous Transfer Orbit Mission

Table 4-9 - Falcon 9 Sample Flight Timeline, Geosynchronous Transfer Orbit Mission

Time After Liftoff (seconds)	Event
0.0	Liftoff from Cape Canaveral
7.5	Initial Pitch Kick
55.0	Begin gravity turn
76.0	Max-Q
115.0	Release angle of attack restrictions
155.5	Shutdown 2 engines for acceleration limit
174.2	Main Engine Cut Off
176.2	Stage 1/Stage 2 separation
179.2	Second stage engine start #1
199.2	Payload fairing jettison
475.9	Second stage engine cut off #1
1488.6	Second stage engine start #2
1544.6	Second stage engine cut off #2
19913.2	Reaction Control System ignition (apogee kick)
20968.8	Reaction Control System cut off
20978.8	Payload separation (T+ 5hrs, 49 min)

4.3. Mass Properties

Falcon 9 can accommodate typical payloads with mass from 3000 - 15000 lbs (1360 - 6800 kg). For these payloads, the maximum allowable center of gravity lateral offset is less than 5 inches (12.7 cm) for non-spin stabilized missions and 0.5 inches (1.25 cm) for spin-stabilized missions. The maximum center of gravity offset from the mechanical interface on top of the second stage payload adapter is 120 inches (305 cm).

4.4. Separation Accuracy

Prior to separation, Falcon 9 can point the upper stage/payload to any desired attitude and minimize all rotation rates. Attitude errors will be no greater than 1.4 degrees about each axis. Attitude rotation rates will be less than 0.2 degree/sec in pitch and yaw, and 0.25 degree/sec in roll. For spin stabilized missions, prior to separation, Falcon 9 points the upper stage/payload to the desired attitude and provides a spin about the longitudinal axis. The spin axis orientation will be accurate to within 1.75 degrees, assuming a maximum 0.5 inches payload center of gravity offset as mentioned in Section 4.3.

4.5. Mission Accuracy Data

As a liquid propellant vehicle with restart capability, Falcon 9 provides the flexibility required for payload insertion into orbit with higher eccentricity and for deploying multiple payloads into slightly different orbits. Until verified by actual operations, SpaceX expects to achieve the following minimum target orbital insertion accuracy:

Low Earth Orbit

- Perigee $\pm$10 km
- Apogee $\pm$10 km
- Inclination $\pm$0.1 deg
- Right Ascension of Ascending Node $\pm$0.15 deg

Geosynchronous Transfer Orbit

- Perigee $\pm$7.4 km
- Apogee $\pm$130 km
- Inclination $\pm$0.1 deg
- Right Ascension of Ascending Node $\pm$0.75 deg
- Argument of Perigee $\pm$0.3 deg

5. General Payload Information

5.1. Payload Fairing

5.1.1. General Description

The Falcon 9 fairing is 17 ft (5.22 m) in diameter and can accommodate a combination of up to three access doors or radio frequency (RF) windows in the cylindrical portion. The standard payload fairing door is a maximum of 24 inches (61 cm) in size. Combinations of acoustic surfaces are used inside the payload fairing to help achieve the acoustic environment.

5.1.2. Falcon 9 Fairing

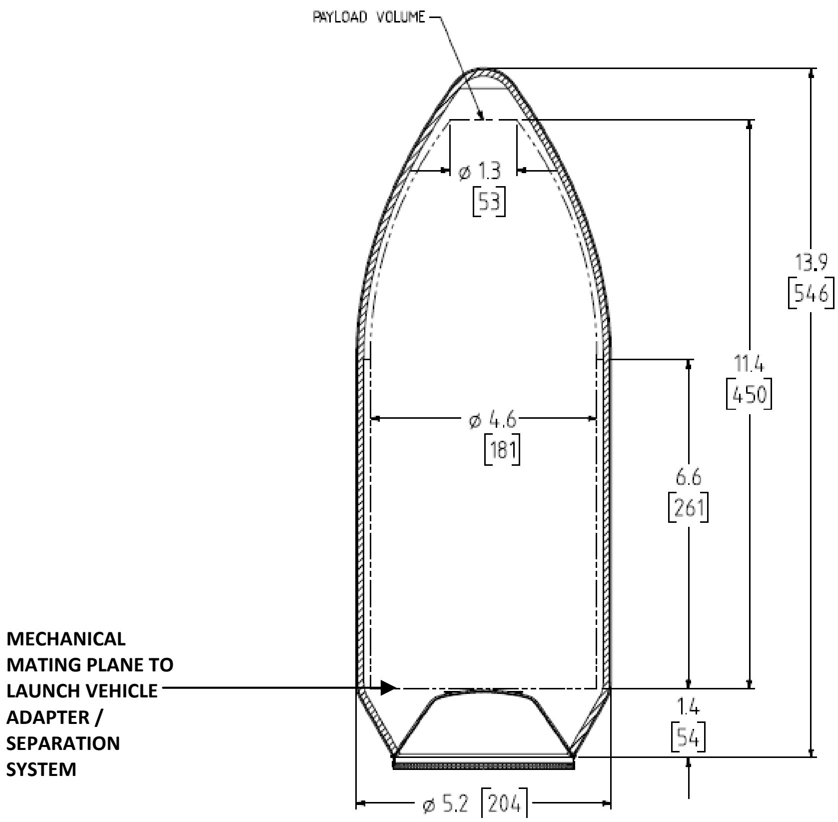


Figure 5-1 - Falcon 9 standard fairing and dynamic envelope*, meters [inches]

**Dynamic envelope (shown as PAYLOAD VOLUME above) indicates the volume that the spacecraft can move within.*

5.1.3. Payload Separation

Payload separation is a typically a timed event (usually in reference to completion of an engine event and associated coast period) issued by the Falcon 9 flight computer. The Falcon 9 second stage can hold a stable attitude for payload separation or can spin up to a maximum of 5 rotations per minute (RPM) (non-standard service).

The launch vehicle can provide a signal to the payload at separation to initiate payload power-up. Alternate configurations for separation signals (break-wires, separation switches monitored directly by the payload or other configurations) can be accommodated as options.

5.1.4. Collision Avoidance

As a standard service, a Collision Avoidance Maneuver (CAM) analysis can be completed, performance permitting.

5.2. Payload Environments

Falcon 9 launch vehicles use liquid propellant with a single staging event, low thrust-to-weight, and low dynamic pressure flight. The environments presented below are intended to reflect typical mission levels; mission specific analyses are to be performed and documented in the Interface Control Document (ICD) per payload needs. Specific individual environments are defined in the following sections.

Throughout pre-flight and flight operations, various environmental contributions may vary in importance. Certain events, such as pyrotechnic firings and stage burnout, add specific quasi-static or dynamic loads for specified durations, which may or may not need to be added to other environments experienced at the same time.

5.2.1. Transportation Environments

SpaceX is in the process of quantifying the transportation environments that a spacecraft will encounter while being transported from the payload processing facility (if processed outside of the SpaceX Hangar at SLC-40) to the hangar and from the hangar to vertical on the launch pad. This transportation segment will be primarily accomplished by wheeled vehicle (payload transporter from a customer selected payload processing facility and on the transporter erector to the launch pad) when launching from Cape Canaveral. Future launches from the Kwajalein Atoll location will also require shipment from the main island of Kwajalein across to the Falcon 9 launch site island via ship.

5.2.2. Humidity, Cleanliness and Thermal Control

Payload environments during various processing phases are:
In hangar, encapsulated:

- Temperature: 70° F ± 5° F
- Humidity: 50% ± 5%
- Cleanliness: Class 10,000
- Flow rate: 1,000 cfm

During rollout (& transport from Payload Processing Facility [PPF])*:

- Temperature: 70° F ± 5° F
- Humidity: 50% ± 5%
- Cleanliness: Class 10,000
- Flow rate: 1,000 cfm

On pad payload environmental control system (horizontal or vertical):

- Temperature: any setting between 50° F and 85 ° F ± 5° F
- Humidity: any setting between 20% and 50% ± 5%
- Cleanliness: Class 5,000
- Flow rate: Variable from 1000 to 4500 cfm

*Conditioned air will be disconnected for a short duration when the erector arrives at the pad and the fairing umbilical is switched over to the pad air conditioning supply.

5.2.3. Launch and Flight Environments

This section provides details on the maximum predicted environments (MPE) the payload will experience during Falcon 9 launch vehicle ground operations, integration, flight, and initial orbital operations.

5.2.3.1. Design Load Factors

During flight, the payload will experience a range of axial and lateral accelerations. Axial acceleration is determined by the vehicle thrust history and drag, while maximum lateral acceleration is primarily determined by wind gusts, engine gimbal maneuvers, first stage engine shutdowns, and other short-duration events. Falcon 9 Design Load Factors are shown using the envelope plotted in Figure 5-2. The design load factors provided here are expected to be conservative for payloads with the following basic characteristics: a fundamental bending mode greater than 10 Hz, a fundamental axial mode greater than 25 Hz, and a mass between 3,000 and 20,000 lbs (1360 – 9070 kg). A positive axial value indicates a compressive net-center of gravity acceleration, while a negative value indicates tension. Actual spacecraft loads, accelerations, and deflections are a function of both the launch vehicle and payload structural dynamic properties and can only be accurately determined via a coupled loads analysis.

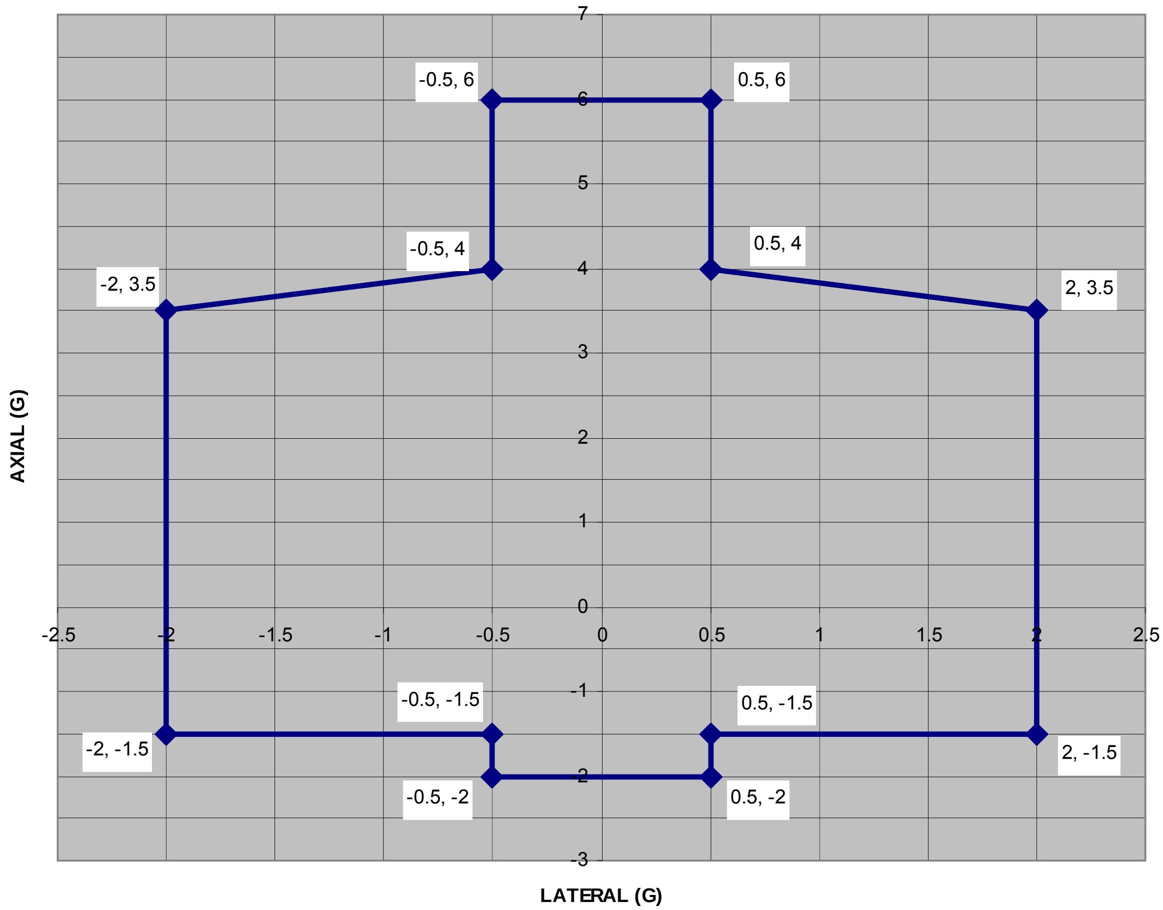


Figure 5-2 - Falcon 9 Design Load Factors

5.2.3.2. Shock Environment

There are four events during flight that are characterized as shock loads:

1) Vehicle hold-down release at lift-off
2) 2nd stage separation
3) Fairing separation
4) Payload release and separation

Of the shock events, (1) and (2) are negligible for the payload relative to (3) and (4) due to the large distance and number of joints over which shocks (1) and (2) will travel and dissipate. Maximum shock loading (3) and (4) is measured and scaled for various preloads required for the payload fairing and payload separation systems. The resulting maximum shock environment predicted at payload interface for payload fairing separation and payload separation (for a 937-mm clampband separation system) is shown in Figure 5-3. Actual shock from the payload-specific separation system requires selection of a separation system and the associated payload mass properties.

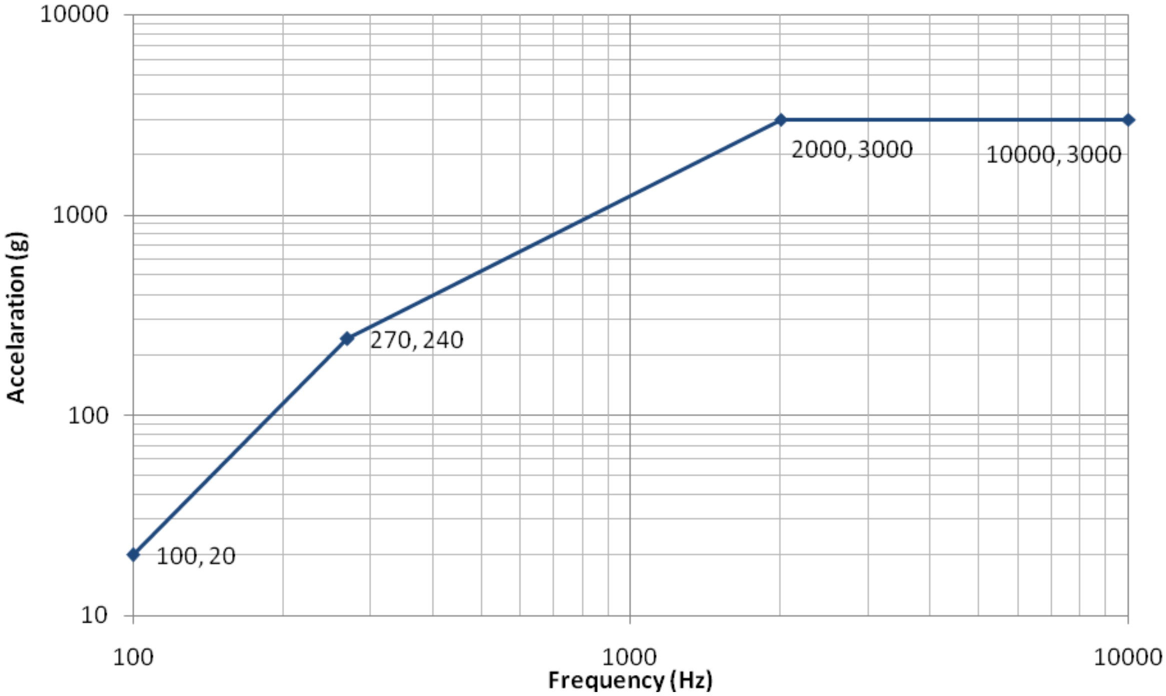


Figure 5-3 - Falcon 9 shock response at payload interface

5.2.3.3. Acoustic Environment

During flight, the payload will be subjected to a varying acoustic environment. Levels are highest at lift off and during transonic flight, due to aerodynamic excitation. The environment shown in Figure 5-4 does not include margin for qualification or for acceptance testing. This is the maximum predicted acoustic environment.

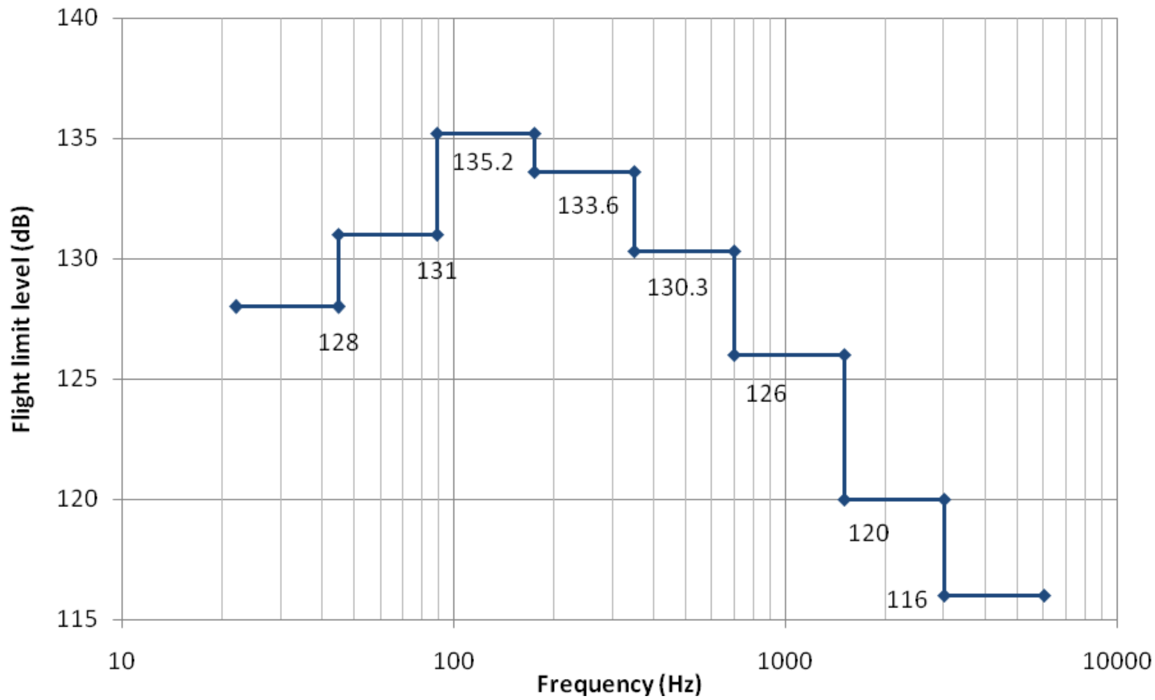


Figure 5-4 - Falcon 9 acoustic environment requirement (OASPL=139.6 dB)

Table 5-1 - Falcon 9 acoustic environment

Octave Center Frequency (Hz)	F9 Maximum Predicted Acoustic Environment (OASPL = 139.6 dB)
31.5	128.0
63	131.0
125	135.2
250	133.6
500	130.3
1000	126.0
2000	120.0
4000	116.0

5.2.3.4. Sine-Vibration Environment

SpaceX recommends deriving a payload-specific sine vibration environment curve based upon a coupled loads analysis if significant flight history is not available. Actual spacecraft loads, accelerations, and displacements are a function of both the launch vehicle and payload structural dynamic properties and can only be accurately determined via a coupled loads analysis.

The SpaceX approach for Falcon 9 is to use results from coupled loads analysis to derive a shock response spectrum on the vibration levels at the payload interface. For a given modal damping value, a smoothed envelope of peak responses is created that is used to produce a sine-vibration input curve.

Sine-Vibration Derivation Methodology:

- Perform shock response spectrum (SRS) analysis on vibration levels at launch vehicle/spacecraft interface
  - Use measured historical data, if available
  - Use results from coupled loads analysis, if no measured data available
  - Requires analyst to assume damping (Q)
- Divide peak response values at each frequency by Q
- Determine a smoothed envelope of peak responses to produced sine-vibration input curve
- Minimize over-testing by response limiting and notching input base motions
  - Limit peak acceleration and interface forces/moments using Coupled Loads Analysis CLA results
  - Limit critical component accelerations

SpaceX can convert Craig-Bampton and Data Recovery Matrices (DRM's) from Metric to US Standard Inch-Pound-Second (IPS). SpaceX prefers to have the payload math models in IPS units, but can accept SI units.

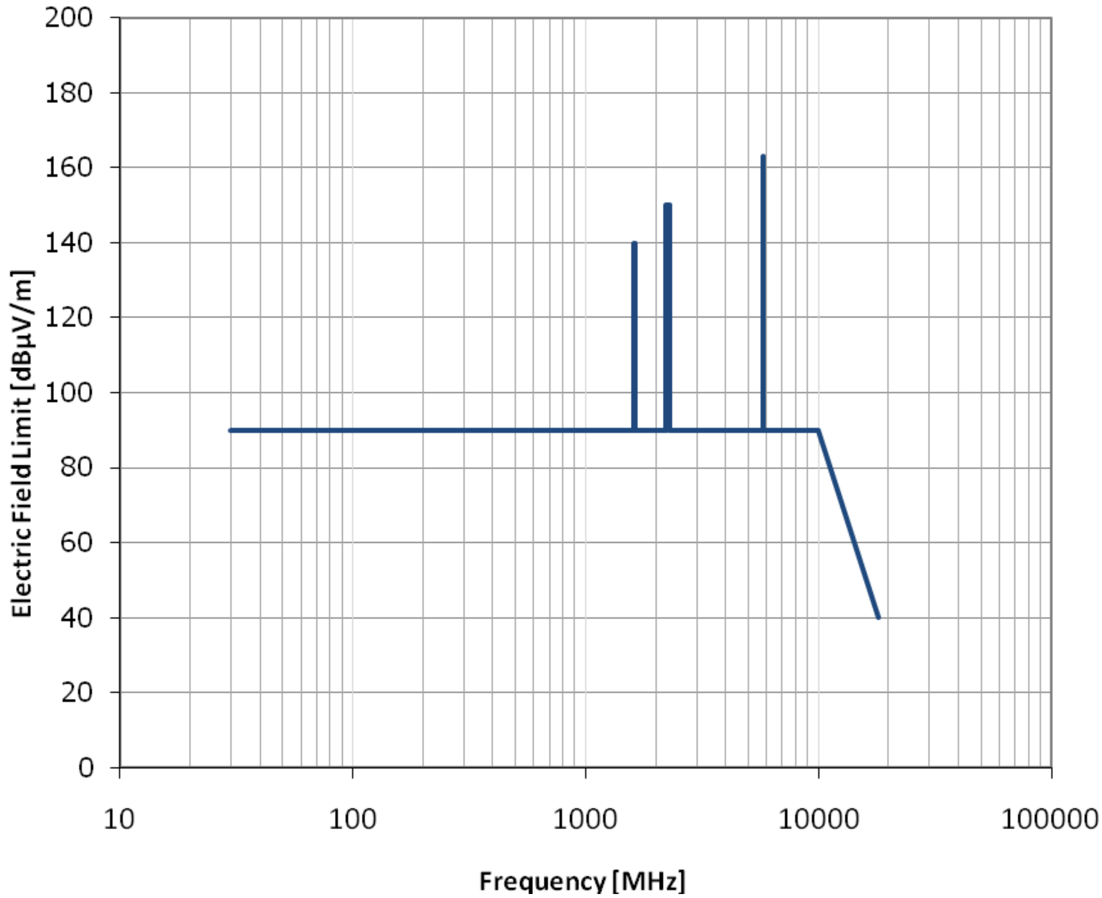
5.2.3.5. Radio Frequency (RF) Environment

Payload customers must ensure that spacecraft materials or components sensitive to an RF environment are compatible with both the launch pad environment and the RF environment during flight. The spacecraft RF characteristics should satisfy the limitations shown in Figure 5-6.

Table 5-2 - Falcon 9 Launch vehicle RF system characteristics

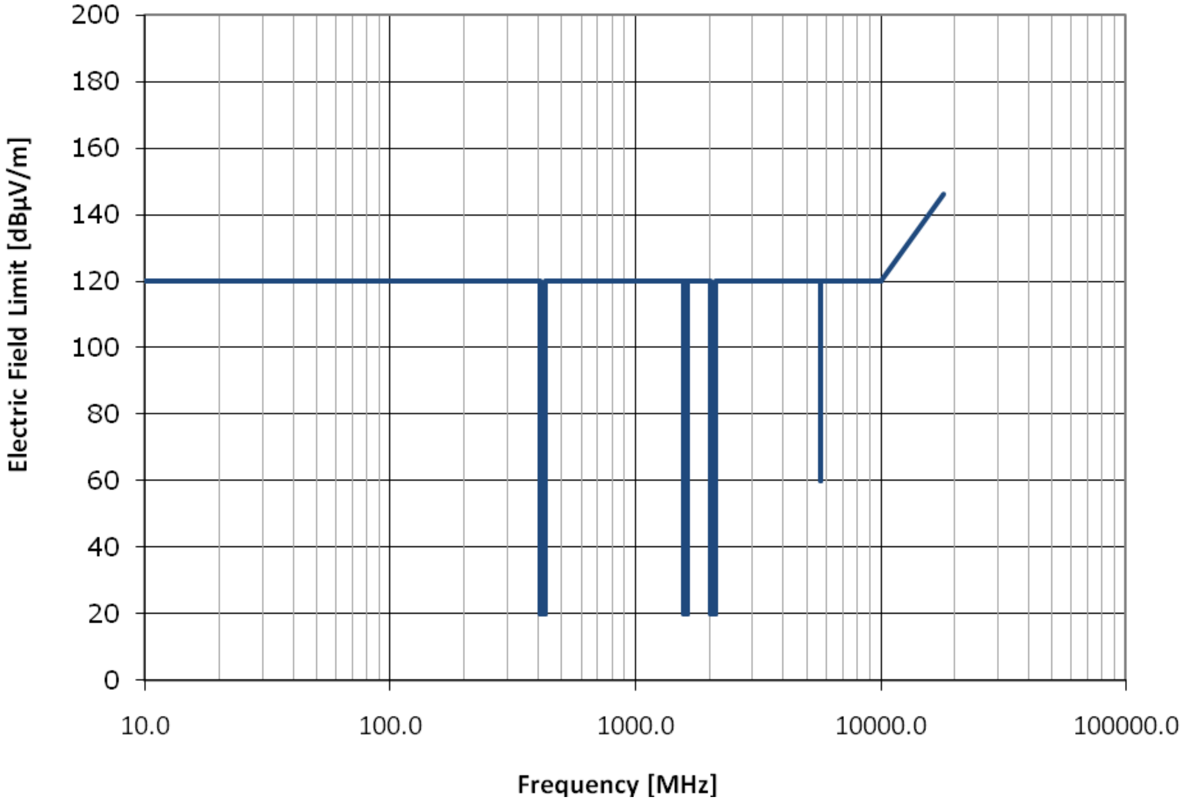
	Source				
	1	**2**	**3**	**4**	**5**
Function	Command Destruct	Radar Transponder	Radar Transponder	Stg 1 Launch Vehicle Telem	Stg 2 Launch Vehicle Telem
Rate	Receive	Transmit	Receive	Transmit	Transmit
Band	UHF	C-Band	C-Band	S-Band	S-Band
Frequency (MHz)	421	5765	5690	2221.5	2213.5
Power Output	N/A	400W peak	N/A	10W	20W
Modulation		Pulse	Pulse	PCM/FM	PCM/FM
Data Rate		2000 pps	3000 pps	1.8 Mbps	1.8 Mbps

	Source					
	6	**7**	**8**	**9**	**10**	**11**
Function	Stage 1 Launch Vehicle Video	Stage 2 Launch Vehicle Video	GPS L1	Recovery-Iridium	Recovery-Iridium	Telecommand
Rate	Transmit	Transmit	Receive	Receive	Transmit	Receive
Band	S-Band	S-Band	L-Band	L-Band	L-Band	S-Band
Frequency (MHz)	2273.5	2251.5	1575.42	1610-1625.5	1610-1626.5	2038.265
Power Output	5W	10W	N/A	-	-	N/A
Modulation	FM/NTSC	FM/NTSC	BPSK/DSSS	QPSK	QPSK	PM/PSK/PCM
Data Rate	NTSC	NTSC	10 Mbps	2.4 kbps	2.4 kbps	2 kbps



Freq (MHz)	E Field Limit (dBµV/m)
30.0	90
1609.9	90
1610.0	140
1626.0	140
1626.1	90
2199.5	90
2200.0	150
2300.0	150
2300.5	90
5754.9	90
5755.0	163
5775.0	163
5775.1	90
10000.0	90
18000.0	40

Figure 5-5 – Falcon 9 Worst Case Radiated Environment



Freq (MHz)	E Field Limit (dBµV/m)
0.0	120.0
409.5	120.0
410.0	20.0
430.0	20.0
430.5	120.0
1564.5	120.0
1565.0	20.0
1585.0	20.0
1585.5	120.0
1609.5	120.0
1610.0	20.0
1630.0	20.0
1630.5	120.0
2024.5	120.0
2025.0	20.0
2110.0	20.0
2110.5	120.0
5679.5	120.0
5680.0	60.0
5700.0	60.0
5700.5	120.0
10000.0	120.0
18000.0	146.0

Figure 5-6 - Allowable Payload Radiated Emissions for Falcon 9 RF Susceptibility

5.2.3.6. Fairing Internal Pressure Environment

Payload fairing internal pressure decay rates are limited to 0.4 psi/sec (2.76 kPa/sec), except for a transonic spike to 0.9 psi/sec (6.2 kPa/sec).

5.2.3.7. Payload Temperature Exposure During Flight

The Falcon 9 payload fairing is a composite structure consisting of a 1-inch (2.5-cm) thick aluminum honeycomb core surrounded by carbon fiber face sheet plies. The emissivity of the payload fairing is approximately 0.9. Based upon this emissivity, the payload fairing inner wall temperature is bounded as shown in Figure 5-7. The curve is truncated at 250 seconds, although the approximate time of payload fairing jettison for a geosynchronous transfer orbit mission from Cape Canaveral is earlier, at 200 seconds. Payload fairing jettison timing is determined by customer requirements.

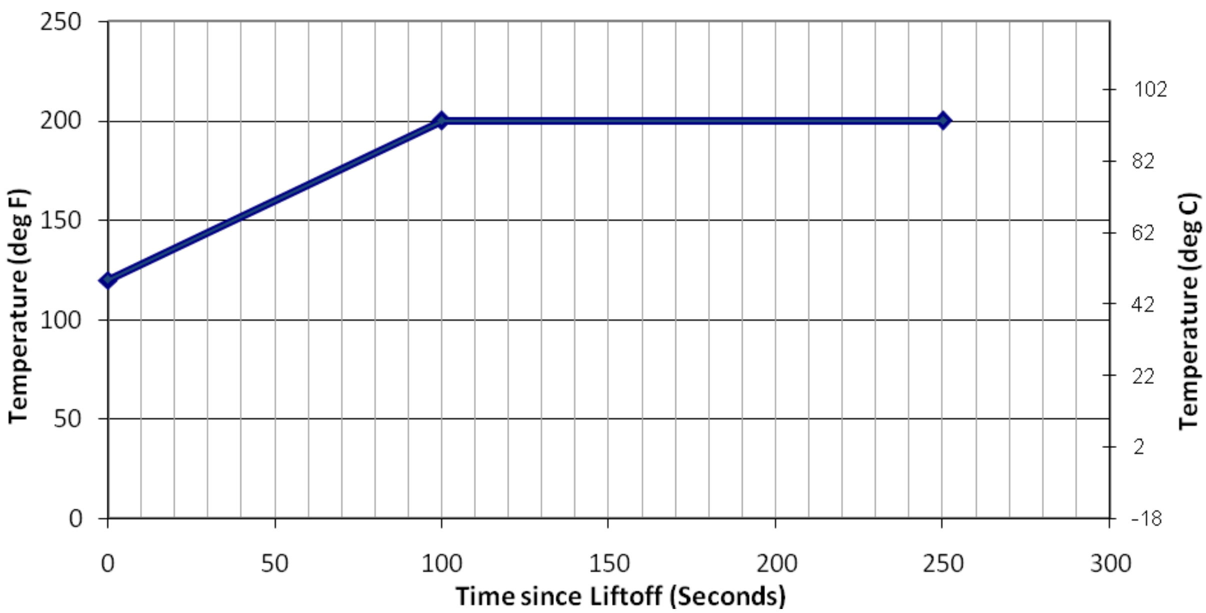


Figure 5-7 - Maximum Payload Fairing Temperature Seen By Payload

5.3. Payload Interfaces

Falcon 9 will provide the pyrotechnic impulses necessary to initiate separation events. The launch vehicle will also provide a signal to the payload at separation to initiate payload power-up. Alternate configurations for separation signals (break-wires, separation switches monitored directly by the payload, or other configurations) can be accommodated as options.

The standard payload fairing provides up to 3 access doors, 24" (61 cm) in height, for prelaunch access. These doors are not designed for emergency access into the payload fairing once the launch vehicle is on the pad. Under nominal operating conditions, all processing that requires access to the payload must be complete prior to fairing installation. In the event of a spacecraft propellant system failure that requires contingency propellant offload, the standard concept of operations for Falcon 9 is to return the launch vehicle to the hangar.

5.3.1. Falcon 9 Payload Attach Fittings

Falcon 9 launch vehicles do not baseline a specific separation system. Customers have the option to provide the payload adapter and separation system to interface directly with a payload adapter attachment location provided as a standard service by SpaceX. Alternatively, SpaceX can supply the payload adapter and separation system as a non-standard service.

The Falcon 9 Payload Interface Ring is used in the 5.2 m (17 ft) fairing configuration. This simple interface is provided for customers with medium- and intermediate-class payloads that prefer to provide their own launch vehicle adapter/separation system. A diagram of the Falcon 9 payload interface, which consists of a 1575 mm diameter bolt pattern, follows in Figure 5-8.

SpaceX has experience integrating numerous commercially-available and internally-developed payload separation systems. A Marmon clamp system was flown on the first Falcon 1 demonstration flight 1 and a LightBand system from Planetary Systems Corporation was employed on the second Falcon 1 demonstration flight. Additionally, SpaceX is currently developing a low-shock tension band separation system for the Falcon 9, which uses a non-pyrotechnic release mechanism.

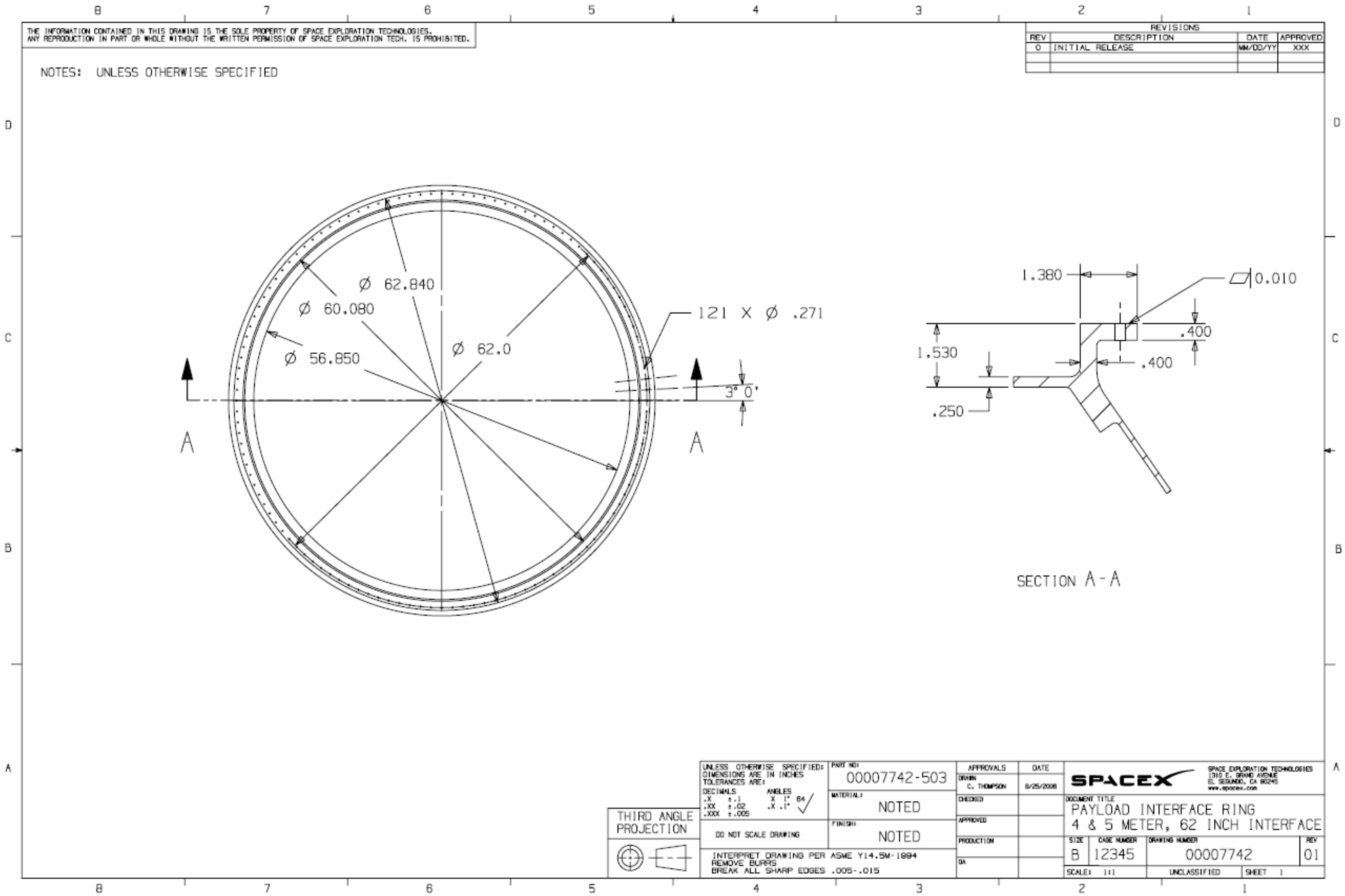


Figure 5-8- Falcon 9 Payload Interface Ring (Note: units are in inches)

5.3.2. Test Fittings and Fitcheck Policy

A mechanical fit check (including electrical connector locations) may be conducted with the spacecraft or a representative spacecraft using a mechanical template. This is typically done prior to shipment of the spacecraft to the launch site. SpaceX personnel will be available to conduct this activity at the SpaceX facility. Specific requirements for the fit check will be taken in to consideration during the integration process with the SpaceX Mission Manager.

5.3.3. Electrical Interfaces

Payload electrical ground support equipment (EGSE) is located in Room B-9 (see Figure 3-3) beneath the launch pad deck at SLC-40. This room is 8x28 feet in size and 8 feet tall. It is adjacent to Room B-10. An interface panel would be installed between rooms B-9 and B-10 to provide a minimum of:

- Six unbalanced transistor–transistor logic (TTL) circuits terminated with BNC connectors
- Six balanced RS-422 circuits terminated with Trompeter RL-75C connectors
- Six RS-232 circuits terminated with DB25 Male connectors
- Six Ethernet circuits terminated with RJ-45 jacks

The customer typically provides a 20-foot cable to interface between the spacecraft to EGSE room wiring junction box and the spacecraft EGSE. SpaceX will connect the cable to the junction box. SpaceX can provide this interface cable as a non-standard service.

Wiring between the spacecraft umbilical junction box on the erector and the spacecraft electrical ground support equipment (EGSE) in Room B-10 consists of:

- 80 conductors of 18 AWG copper wiring
- 24 conductors of 22 AWG copper wiring
- 24 conductors of 12 AWG copper wiring
- 12 RG-6 Coax cables
- 5 Cat-6 Ethernet cables

Cable length between the EGSE interface box in room B-10 and the erector quick disconnect is 175 feet, and from the quick disconnect to the spacecraft is approximately 180 feet. The wiring given above is the wiring run up to the top of the tower. The maximum amount of conductors to the spacecraft is limited by the quick disconnect connector at the vehicle skin and using the ICD worksheet the customer needs to select which of the listed conductors to use.

Spacecraft electrical signals are carried from the erector junction box to the second stage umbilical plate. At the umbilical plate, the spacecraft umbilical is mated to a dedicated spacecraft electrical connector. SpaceX has the ability to modify the electrical connector to provide different combinations of current, total pins, or coax capability. For example, the spacecraft umbilical could be configured to provide:

- 120 signal contacts -- wire size 22 AWG, 4 amp current, or

- 24 signal contacts -- wire sizes 12 AWG, 17 amps current

There are no standard provisions for an electrical umbilical through the payload fairing to mate with the payload.

From the umbilical plate, the payload harness(es) are routed along the exterior of the second stage propellant tanks. Tunnel covers provide protection during ground operations and flight. The payload electrical harnesses are then routed back inside the Falcon 9 along the payload adapter. Electrical harnesses are mated to the spacecraft using SpaceX or customer-supplied electrical connectors. The Falcon 9 electrical interface to the spacecraft itself is typically one or two in-flight disconnect connectors that include a breakwire ground. SpaceX provides Deutsch in-flight disconnect(s) as a standard payload electrical interface. The connector designations for the 37-pin in-flight disconnect are:

- D8174 E37-0SN-1A (Payload side)
- D8179 E37-0PN-1A (Launch Vehicle side)

Connectivity between the payload EGSE, located in the Instrumentation Bay below the launch pad, and the payload is provided by an electrical umbilical. This umbilical is routed up the erector and mates to the payload-dedicated electrical connector on the second stage umbilical plate.

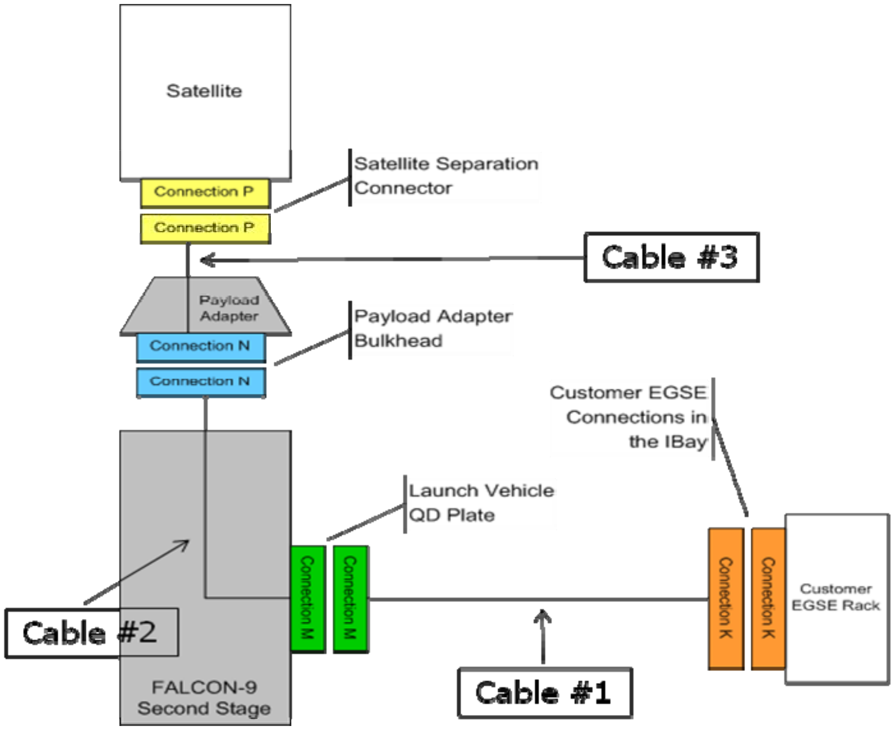


Figure 5-9 - Spacecraft to Launch Vehicle/Launch Pad Electrical Architecture

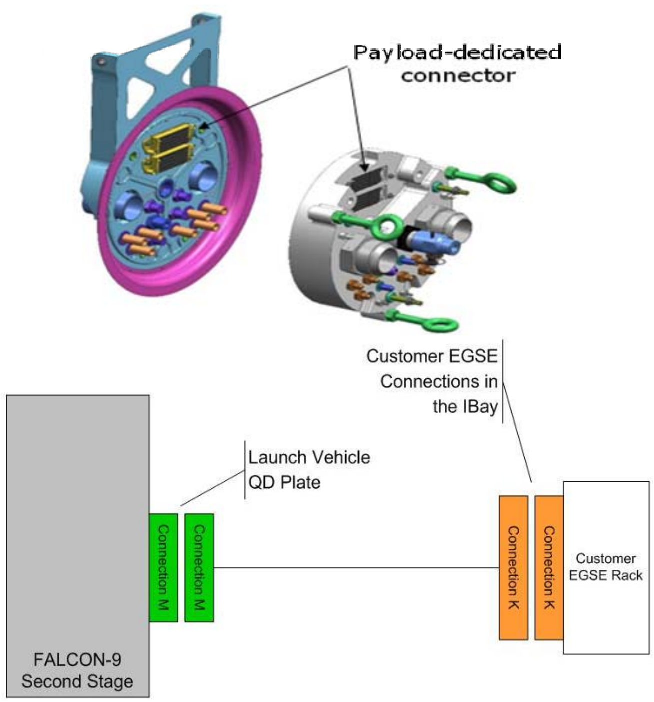


Figure 5-10 - Spacecraft umbilical to Falcon 9 second stage connection

5.4. Payload Integration

While SpaceX does not require the payload to be at the launch site until two weeks prior to launch, the Payload Processing Facility (PPF) will be made available for payload operations for up to 3 weeks prior to launch at each of our sites. Additional time in the processing facility may be available as a non-standard service.

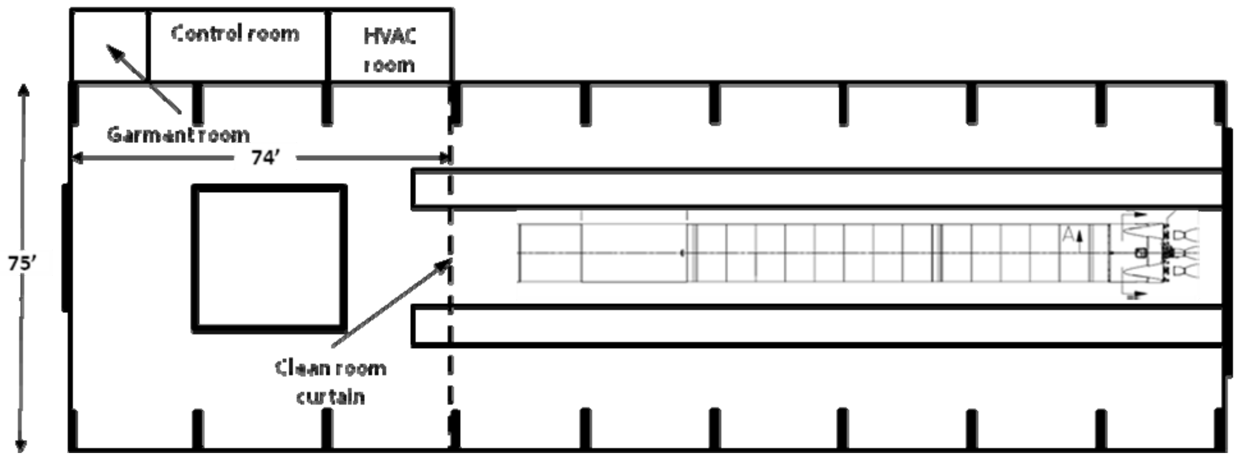


Figure 5-11 – SLC-40 Payload Processing Clean Area in Hangar

The PPF is a designated Clean Area within the hangar. A 33 ft tall clean area curtain provides separation from the launch vehicle side of the hangar, while allowing the 34 ft bridge cranes access to the entire hangar. An additional heating, ventilation and air conditioning (HVAC) system keeps the PPF at Class 100,000 or better. All payload activities including equipment unload, unpacking/packing, payload checkout and hypergolic fueling may be performed in this area.

SpaceX will monitor relative humidity, temperature and cleanliness in the payload processing facility, with the exception of periods when the satellite is mated to the second stage and during launch vehicle maneuvering on the pad.

As a non-standard service, SpaceX will help arrange the use of AstroTech facilities near CCAFS for payload processing.

5.4.1. Integration Schedule

At approximately launch minus 18 days, the integration process begins (see Figure 5-14) and includes the following:

- The payload is vertically integrated onto the payload adapter
- The payload and adapter are then installed on the breakover fixture, rotated horizontally and encapsulated by the fairing in the PPF (NOTE: SpaceX has the capability to encapsulate a payload in either a vertical or horizontal position using an

encapsulation breakover fixture. However, if encapsulation occurs in the SpaceX hangar at the launch site, it must be performed horizontally.)

- The encapsulated payload is then moved horizontally to the launch vehicle/launch complex
- Once inside the hangar at the launch complex, the encapsulated payload assembly is mechanically mated to the launch vehicle
- Electrical umbilicals between the second stage and the payload are mated and the payload is connected to electrical ground support equipment (if required)
- Following electrical interface verification, the entire launch vehicle is lifted onto the erector
- The Falcon 9 launch vehicle is transported to the pad on the erector
- Final connections between ground support equipment, the launch mount, and Falcon 9 are made
    - While on the pad, the vehicle goes vertical for necessary checkouts.
    - There is no access to the payload while Falcon 9 is vertical.
- Access to the payload while the vehicle is outside of the Hangar on the launch pad requires special accommodations and is a non-standard service.
- Falcon 9 is launched

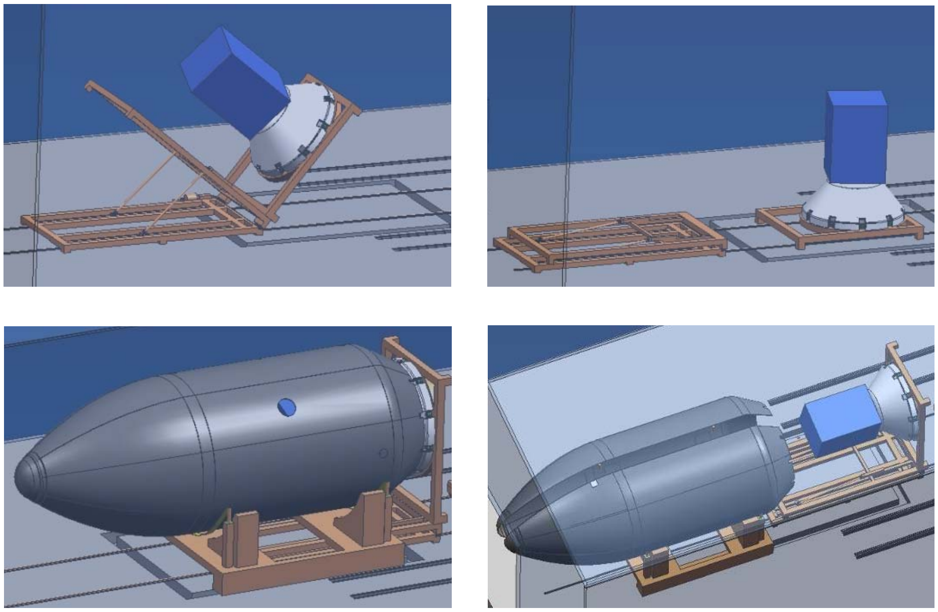


Figure 5-12 - Falcon 9 Payload Encapsulation

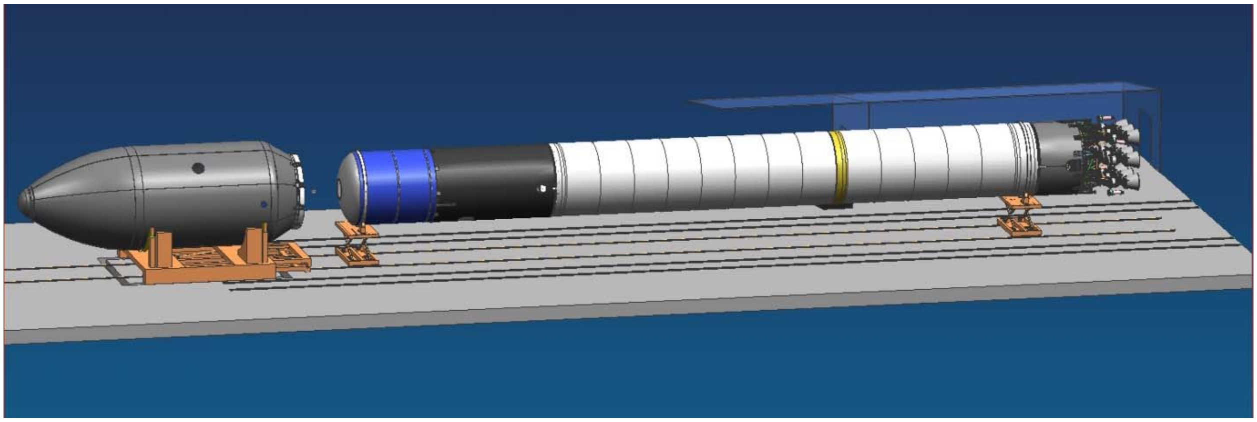


Figure 5-13 – Encapsulated Payload Mate to Falcon 9 2nd Stage

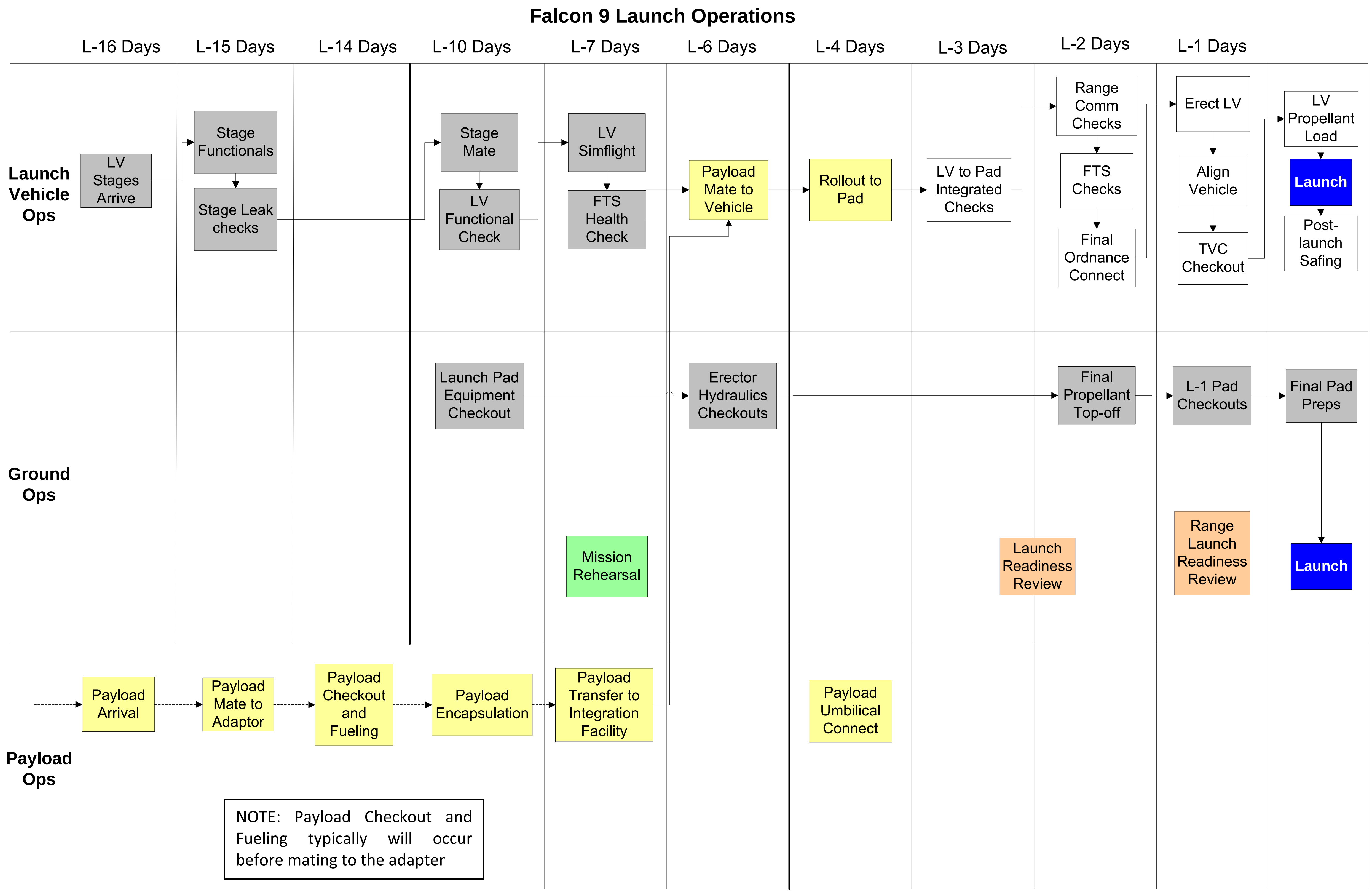


Figure 5-14 - Nominal Launch Operations Flow

5.4.2. Documentation Requirements

The payload customer is responsible for generating their own range, range safety, and Federal Aviation Administration (FAA) documentation. However, SpaceX will facilitate the required discussions and will coordinate submittals with the appropriate organizations. At a minimum, the following documents must be provided:

- Program introduction to the range
- Spacecraft design overview with graphics
- Safety documentation including: hazard analyses and reports, vehicle break-up models (debris data) and detailed design and test information for all hazardous systems (batteries, pressurized systems or other hazardous or safety critical materials, propellant data)
- Launch site operations plan and detailed procedures (Note: hazardous procedures must be approved by range safety)
- Interface verification statement
- Application for a payload determination (for non-US Government payloads only)
- Environmental statement

In addition to these documents, input is required to support development of the ICD, launch countdown procedures, and the Launch Readiness Review (LRR) package.

5.4.3. Standard Services

As part of any standard launch service, SpaceX provides the following:

- Personnel, services, hardware, equipment, documentation, reviews, analyses and facilities necessary to support mission planning, launcher production, mission and payload integration and launch
- One (1) preliminary coupled loads analysis and one (1) verification couple loads analysis
- ElectroMagnetic Compatibility (EMC) assessment
- One (1) flight set of electrical connectors
- Class 100,000 cleanroom integration space for the spacecraft for up to four weeks prior to the scheduled launch date on the launch range with additional and adjacent square feet for ground support equipment (GSE) and personnel
- Certified mechanical GSE to support physical mating of the spacecraft to the payload adapter, encapsulate the fairing and integrate the encapsulated system onto the second stage
- Conditioned air into the fairing
- A combination of up to three (3) payload access doors or RF windows in the fairing
- A mission simulation test exercising operational readiness, vehicle equipment and ground systems
- A Mission Dress Rehearsal, similar to the mission simulation test, for key launch team members

- Process the launch vehicle, integrate and encapsulate the payload, and test electrical and signal interfaces with the spacecraft at the launch range
- Provide all range and safety interfaces (per AFSPCMAN 91-710) document templates for the spacecraft provider
- Facilitate the range and range safety integration process
- Launch the spacecraft into the specified orbit within the specified environmental constraints
- Perform a Collision Avoidance Maneuver (as required)
- Support post-flight analysis and generate a report documenting separation from the launch vehicle, the spacecraft insertion orbit and confirmation that environments met requirements
- Generate all mission required licensing including FAA and the State Department

5.4.4. Non-standard Services

- Add a GN_2 purge
- Class 10,000 cleanroom processing and air in the fairing
- Visibly clean Level 1
- Accommodation for spacecraft fueling in payload processing facility
- ElectroMagnetic Compatibility integrated power-on testing
- Facilitate the use of AstroTech for payload processing
- Spin stabilization to rates as high as 5 rpm (dependent upon payload mass properties)

Other non-standard services can be provided on a case-by-case basis. For more information or inquiries about a specific non-standard service, contact SpaceX or include the information in the Payload Questionnaire found in Section 8 of this guide.

6. Launch Operations

Initial launches of the Falcon 9 will occur from SLC-40 at Cape Canaveral Air Force Station (CCAFS) in Florida. SLC-40 was previously used by the US Air Force for Titan III and Titan IV launches. Launch azimuths from SLC-40 support mid-inclination and geosynchronous transfer orbit missions. In addition, SpaceX has developed operational launch facilities at Omelek Island on the Reagan Test Site (RTS) for Falcon 1 launches to a wide range of orbital inclinations. Additional details on the launch sites are provided in Section 3.

Future plans include establishing Falcon 9 launch sites at Vandenberg Air Force Base (VAFB), California and at the US Army Reagan Test Site on Kwajalein Atoll in the Central Pacific. The candidate launch site at VAFB, pending discussions with the US Air Force, would be at Space Launch Complex - 4 East (SLC-4E). The design of the Falcon 9 launch site at VAFB will mirror the facilities and operations implemented at the Cape Canaveral launch site.

SpaceX makes pre-launch operations as simple and streamlined as possible. SpaceX allows the payload to be brought to the launch site as late as 2 weeks prior to launch. For customer convenience, SpaceX can provide a clean area (<100k cleanliness) within the hangar at SLC-40. This capability provides for non-hazardous spacecraft processing for up to 4 weeks as a standard service. Hazardous fueling operations can also be performed in the hangar as a non-standard service. Alternatively, SpaceX can facilitate payload processing, including hazardous operations, at AstroTech's payload processing facility in Florida as a non-standard service. If a spacecraft is processed at a facility other than SLC-40, SpaceX will provide environmentally-controlled transportation from that facility to the hangar at the launch complex. Once the satellite standalone checkouts are completed, and fairing encapsulation, integration to the launch vehicle can be completed in approximately 24 hours.

SpaceX has the capability to encapsulate a payload in either a vertical or horizontal position using an encapsulation breakover fixture. However, if encapsulation occurs in the SpaceX hangar at the launch site, it must be performed horizontally. The payload is mated to the payload adapter in the vertical configuration and then lifted onto the breakover fixture. Fairing encapsulation can then occur in this configuration vertically, or the breakover fixture can be rotated horizontally prior to encapsulation. Once fully encapsulated and horizontal, the Environmental Control System (ECS) is connected and the encapsulated system is integrated to the second stage. Post-mate checkouts are conducted and followed by a Flight Readiness Review (FRR).

Once the FRR is complete, preparations are made for vehicle roll-out to the pad. The erector is brought into the north end of the hangar and the entire launch vehicle is lifted and placed onto the erector. Environmental control is maintained by connecting to the portable ECS. Then, the T-0 umbilical quick disconnects QDs are mated. A weather briefing is held, and after clearance is received, the vehicle is rolled out to the pad. After rollout is complete, the portable ECS is replaced with the payload air conditioning system that functions through liftoff, maintaining environmental control. The vehicle is now ready to go vertical.

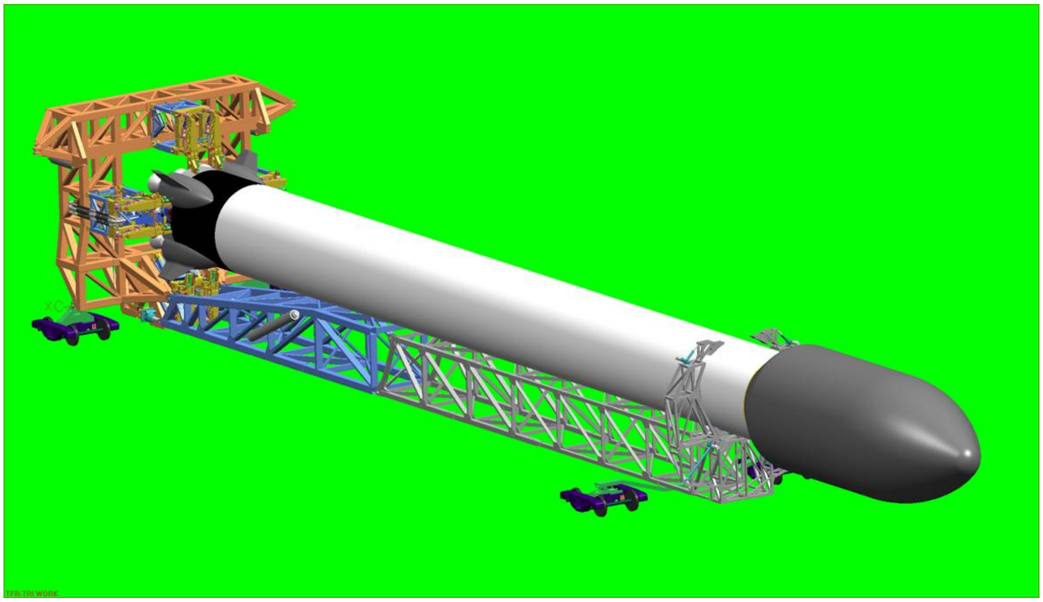


Figure 6-1- Falcon 9 on the erector

Note that the integrated payload and launcher go vertical within 6 days of the lift off, however the capability exists to easily return to horizontal, if necessary.

Once the vehicle is vertical a series of vehicle and range checks confirm operation of the launch system. Twenty-four hours prior to lift off, SpaceX confirms launch readiness with the range at the Launch Readiness Review (LRR).

6.1. Launch Control Organization

SpaceX uses the organizational concepts established and demonstrated on Falcon 1 launches as the basis for Falcon 9 missions. The main decision-making components of the launch control organization are shown in the table below. Note that these are not all the stations participating in the launch, merely those that have input to the decision-making process.

Table 6-1 - Launch Control Organization

Position	Abbrev.	Responsible Organization
Mission Director	MD	SpaceX standard Customer—non-standard service
Missile Flight Control Officer or Flight Safety Officer	MFCO/FSO	Launch Range
Operations Safety Manager or Ground Safety Officer	OSM/GSO	Launch Range
Launch Director	LD	SpaceX
Payload Director	PM	Payload Customer
Flow Director (Pad Operations)	FD	SpaceX

The launch control organization and its lines of decision-making are shown in the figure below. Please note that this organization is somewhat dependent on the mission and customer. The payload manager or his/her representative will sit at the Payload Station in the SpaceX Launch Control Center (LCC).

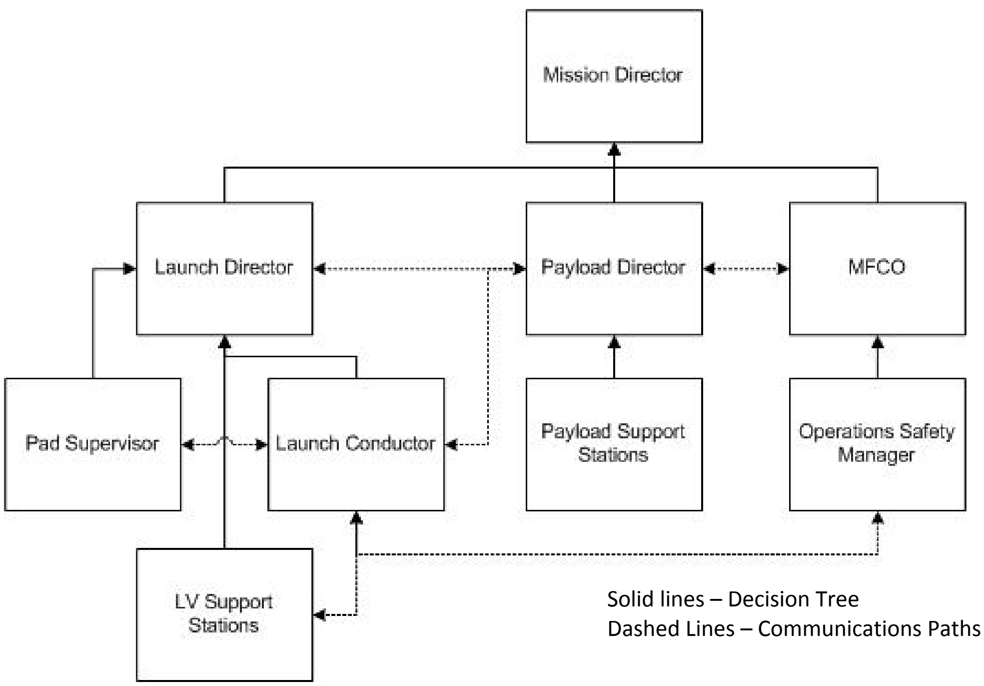


Figure 6-2 - Launch Control Organization

6.2. Spacecraft Transport to Launch Site

There are two locations for the customer to bring in the payload and associated equipment at Cape Canaveral; the Shuttle Landing Facility and the CCAFS Skid Strip. Upon arrival of the spacecraft at either location, SpaceX will arrange, as a standard service, for the spacecraft container and all associated test/support equipment to be offloaded from the plane and transported to the hangar at SpaceX's SLC-40. This service can also be provided by AstroTech, which SpaceX will facilitate as a non-standard service.

6.2.1. Processing Services and Equipment

The services and equipment provided for satellite processing in the cleanroom area inside the SpaceX hangar at SLC-40 are outlined in Table 6-2. SpaceX baselines a Class 100,000 clean room facility for payload processing.

Table 6-2 - Services and equipment for satellite processing

Capability	Space Launch Complex 40
Clean Room	
Dimensions (H x D x W) – (ft)	47 x 75 x 75
Class	100,000
Temperature (°F)	70.0 +/- 15
Humidity (% RH)	20-50
Overhead Crane	
Hook height (ft)	34
Capacity (ton)	20 (2 total)
Lift rate (m/min)	<3.0
Electrical (grounding per MIL-STD 1542)	
110V AC	TBD
208V AC	TBD
Office Space	
Desks	TBD
Ethernet/Internet	TBD
Shop Air	Yes
Security	
Locking Facility	Yes
Launch Site Badges	Yes
Communications	
Area Warning System	Yes
Paging System	Yes
Administrative Phone	Yes

6.2.1.1. Fueling

Spacecraft fueling is not provided as a standard service in the SpaceX payload processing area for the Falcon 9 launch vehicle family. Please contact SpaceX if this non-standard service is required.

6.2.1.2. Electrical Power Supply

The electrical power supplied in the payload processing area is shown in Table 6-2. The Payload Provider shall provide the necessary cables to interface GSE to payload processing room power. The Payload Provider shall also define the power requirements for the payload in the launch vehicle ICD.

6.2.1.3. Payload Monitoring and Control Space

TBD

6.2.1.4. Launch Control Center

The SpaceX Launch Control Center (LCC) is located at CCAFS. This facility, as illustrated in Figure 6-3, is equipped with fiber optic connections to the launch site and a connection into CCAFS's main data system. This allows easy data transfers between the LCC, the pad, and the range, along with required external users and agencies. The LCC has a primary control room, a support room, a smaller auxiliary support room, and a conference room. The primary room has fourteen consoles, the support room has eleven consoles, and the auxiliary room has eight.

SpaceX console design is modular, expandable, and completely modern. SpaceX uses standard computer and display systems with software designed for industrial system control. Consoles also include fully functional voice communications capabilities, including voice nets, voice-over IP integration with remote sites, and IP phones. Video viewing and control is provided using the video over IP systems. SpaceX launch console systems are currently in use at our Texas Test Facility and our Kwajalein launch control centers.

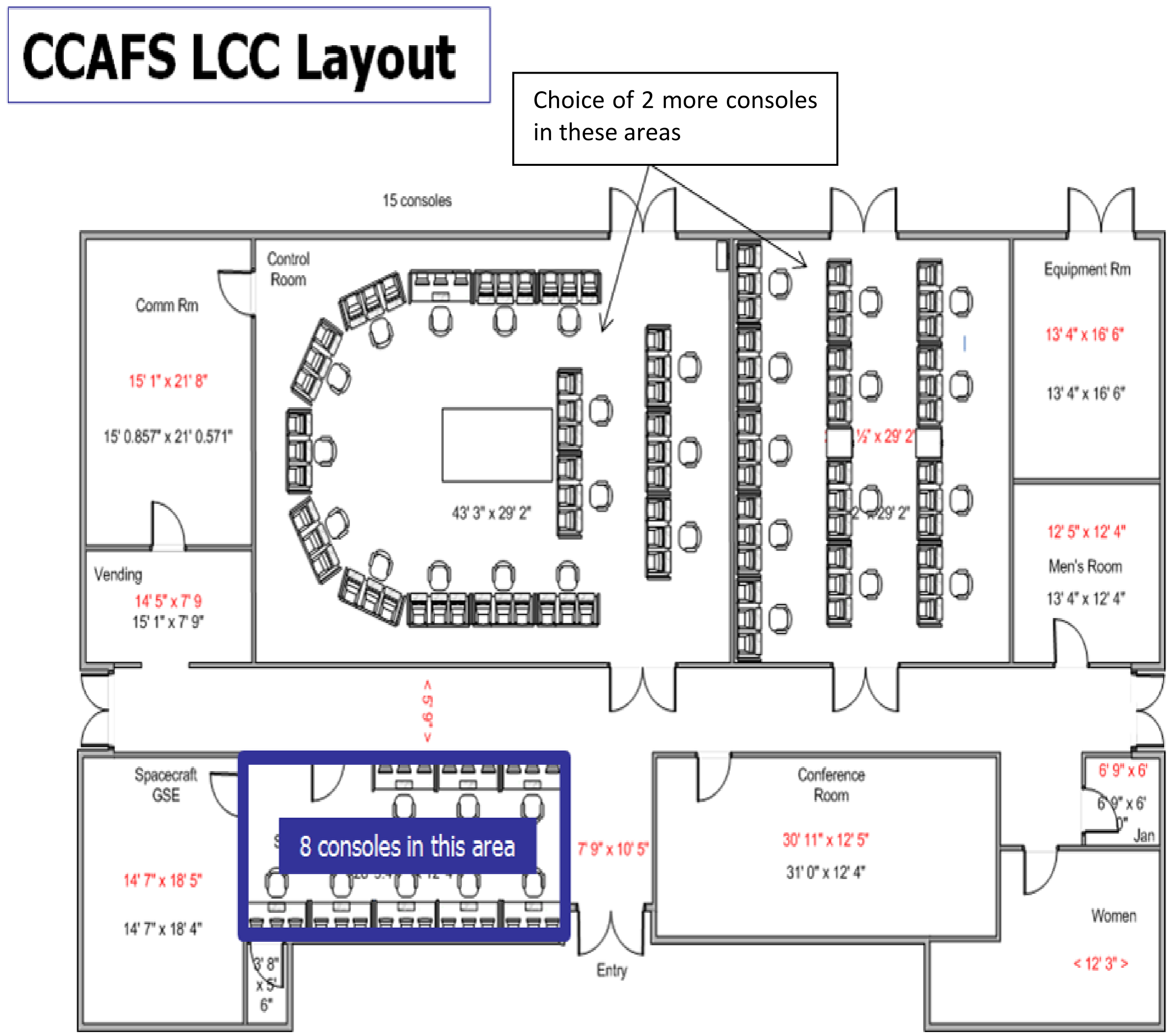


Figure 6-3 - SpaceX Launch Control Center (Cape Canaveral)

6.2.1.5. Administrative

Customer administrative offices are currently under construction will be located within SpaceX's Falcon Support Building at SLC-40.

6.3. Plans and Schedules

The launch vehicle to payload interfaces, payload environmental conditions, and general capabilities are described in this guide. SpaceX will supply a single point of contact from contract award through launch—your Mission Manager. The Mission Manager will assess the launch vehicle capabilities and payload requirements throughout the integration process. This process is accomplished by teleconferences, integration meetings and mission unique design reviews (as required). The result of this process is documented in the Launch Vehicle to Spacecraft ICD—the master document for any SpaceX mission. Following signature approval of the ICD, configuration control is maintained by SpaceX. SpaceX also coordinates all aspects of the launch vehicle production, range and range safety integration, and all mission required licensing. The Mission Manager facilitates these interfaces for the Payload Provider.

Once the payload arrives at the launch site, the physical accommodation for the spacecraft is turned over to the Payload Integration Manager—part of the operations crew. The Mission Manager will continue to manage the customer interface at the launch site.

6.3.1. Mission Integration Plan

Table 6-3 – Standard Launch Integration Process

Launch – 18 months or more	**Contract signing and authority to proceed** • Estimated payload mass, volume, mission, operations and interface requirements • Safety information (Safety Program Plan; Design information: battery, ordnance, propellants, and operations) • Mission analysis summary provided to the Customer within 30 days of contract
Launch – 6 months	**Final payload design, including: mass, volume, structural characteristics, mission, operations, and interface requirements** • Payload to provide test verified structural dynamic model
Launch – 4 months	**Payload readiness review for Range Safety** • Launch site operations plan • Hazard analyses
Launch – 3 months	**Verification** • Review of Payload test data verifying compatibility with Falcon 9 environments • Coupled payload and Falcon 9 loads analysis completed • Confirm payload interfaces as built are compatible with Falcon 9 • Mission safety approval
Launch – 4-6 weeks	**System Readiness Review (SRR)** • Pre-shipment review (per stage; prior to shipment to the launch site) have occurred or are about to occur • Verify launch site, Range, Regulatory agencies, launch vehicle, payload, people and paper are all in place and ready to begin launch campaign
Launch – 2-4 weeks	**Payload arrival at launch location**
Launch – 8-9 days	**Payload encapsulation and mate to Launch Vehicle**
Launch – 7 days	**Flight Readiness Review (FRR)** Review of LV and payload checkouts in Hangar. Confirmation of readiness to proceed with Vehicle rollout
Launch – 1 day	**Launch Readiness Review (LRR)**
Launch	
Launch + 4 hours (depends upon length of Falcon 9 flight)	**Post-Launch Reports- Quick look**
Launch + 4 weeks	**Post-Launch Report- Final Report**

6.3.2. Launch Vehicle Schedules

Falcon 9 missions and associated operations have been designed for minimal complexity and minimal time at the pad. The payload will be integrated horizontally to the launcher approximately 7 days prior to launch. Once integrated, the vehicle is moved to the pad and is erected using the Falcon 9 Launch Vehicle erector. Final system close-out, fueling and testing is then completed. Twenty four hours prior to launch, the Launch Readiness Review (LRR) is held. Once the launch approval is given, the 24-hour countdown begins.

7. Safety

7.1. Safety Requirements

Falcon 9 customers are required to meet AFSPCMAN 91-710 Range User's Manual requirements in the design and operation of their flight and ground systems. These requirements encompass mechanical design, electrical design, fluid and pressurant systems, lifting and handling systems, ordnance and RF systems, ground support equipment, and other design and operational features. SpaceX can assist the customer in determining which requirements pertain to the customers systems, and can also assist in completing required documentation.

7.2. Hazardous Systems and Operations

Most ranges consider hazardous systems or operations to include ordnance operations, pressurized systems that operate below a 4-to-1 safety factor, lifting operations, operations or systems that include toxic or hazardous materials, high power RF systems, laser systems, as well as a variety of other systems and operations. The details of the system design and its operation will determine whether the system or its operation are considered hazardous. Typically, additional precautions are required for operating systems that are considered hazardous, these will be determined during the safety approval process with SpaceX and the launch range. All hazardous operations will require procedures that are approved by both SpaceX and the launch range prior to execution. Ordnance operations, in particular, require coordination to provide reduced RF environments, cleared areas, safety support, and other requirements.

7.3. Waivers

For systems or operations that do not meet safety requirements but are believed to be acceptable for ground operations and launch, a waiver is typically produced for approval by the launch range safety authority. Waivers are a last resort solution and require considerable coordination. They should not be considered a standard practice. SpaceX will assist the customer in determining whether an issue should be elevated to require a waiver as the integration process evolves.

8. Payload Questionnaire

Completion of the following Payload Questionnaire is necessary for use in evaluating the compatibility of any new payload with Falcon 9 launch vehicles. If you are considering using Falcon 9 launch vehicles, please complete as much of the questionnaire provided below and return it to:

SpaceX
ATTN: Lauren Dreyer
1 Rocket Rd.
Hawthorne, CA 90250

lauren.dreyer@spacex.com

Note: SpaceX will treat all customer supplied data as proprietary information and will not disclose or retransmit any part of the information contained herein to any outside entity without the expressed written consent of your organization.

Payload Information
Payload Name/Title/Acronym
Payload Contractor or Sponsor
Points of Contact and Contact Information

Payload Mission Information
Desired Launch Date/Timeframe
Mission Timeline Description
Launch Window Constraints

Item		*Stowed Configuration*	*Tolerance*
Center of Gravity (mm)	X		±
	Y		±
	Z		±
Moment of Inertia ($kg.mm^2$)	I_{XX}		±
	I_{YY}		±
	I_{ZZ}		±
Product of Inertia ($kg.mm^2$)	I_{XY}		±
	I_{YZ}		±
	I_{XZ}		±

Payload Trajectory Requirements		
Parameter	**Value**	**SI Units**
Desired Orbit Apogee		km
Accuracy		km
Desired Orbit Perigee		km
Accuracy		km
Desired Orbit Inclination		deg
Accuracy		deg
Desired Right Ascension of Ascending Node		deg
Accuracy		deg
Desired Argument of Perigee		deg
Accuracy		deg

Payload Orbital Injection Conditions		**SI Units**
Maximum Allowable Tip-Off Rate		deg/sec
Desired Spin-Up Rate		rpm
Pointing Requirement (Please Specify)		
Maximum Allowable Pointing Error		deg

Payload Mass Properties		**SI Units**
Spacecraft Mass (Maximum)		kg
Spacecraft Coordinate System		

Payload Mechanical Interface		**SI Units**
Spacecraft Height (Maximum)		mm
Spacecraft Diameter (Maximum)		mm
Fairing Access Door Location Preference		
Mechanical Attachment Bolt Circle Diameter		mm

Do you have a Spacecraft Separation System? If so, provide details here:
Note: SpaceX can design/provide the Spacecraft Separation System if desired.

Payload Thermal Environment		**SI Units**
Pre-launch Temperature Range		°C
Pre-launch Allowable Water Vapor in Air		grains/lb dry air
Maximum Pre-launch Gas Impingement Velocity		m/sec
Maximum Ascent Heat Flux		W/m^2
Maximum Free-Molecular Heat Flux		W/m^2
Maximum Fairing Ascent Depressurization Rate		mbar/sec

Payload Contamination Control		**SI Units**
Desired Payload Processing Capabilities		Class
Desired Fairing Air Cleanliness		Class

Payload Dynamic Environment		**SI Units**
Maximum Allowable Acoustic Sound Pressure Level		dB OASPL
Maximum Allowable Sine Vibration		Grms
Maximum Allowable Shock		g
Maximum Lateral Acceleration		g
Maximum Axial Acceleration		g
Fundamental Frequency - Lateral		Hz
Fundamental Frequency - Longitudinal		Hz

Additional Data:

1. **Please provide a description of the payload testing planned during payload processing at the launch site, as well as any testing planned while encapsulated. Please describe each test in terms of personnel required, duration of test, tools/GSE required, and any possible safety concerns that should be considered.**

2. **Please describe any safety issues associated with the spacecraft.**

3. **Please describe the propulsion systems to be used on the spacecraft.**

4. **Please describe the pressure vessels to be used on the spacecraft.**

5. **Please describe the power systems (batteries, solar cells, etc).**

6. **Please describe the RF systems to be used on the spacecraft. Please detail each RF transmitter or receiver, its function, frequency, sensitivity, power output, and bandwidth.**

7. **Please provide the spacecraft allowable or test acoustic profile, random vibration spectrum, shock spectrum, and sine vibration curve.**

8. **Please provide Dimensional Drawings and/or CAD models of the spacecraft if available. These drawings/models should include the spacecraft separation system. Rather than attaching to this PDF, if you prefer to send these via email, please submit to Lauren@spacex.com.**

9. **Please describe any security concerns or requirements you have.**

10. **Please describe any additional spacecraft requirements that we should be made aware of.**

9. Quick Reference

9.1. List of Figures

9.2. List of Tables

9.3. List of Acronyms

AWG .... American Wire Gauge
CAM .... Collision Avoidance Maneuver
CCAFS .... Cape Canaveral Air Force Station
CLA .... Coupled Loads Analysis
CVCM .... Collected Volatile Condensable Mass/Material
DRM .... Data Recovery Matrices
FAA .... Federal Aviation Administration
FRR .... Flight Readiness Review
GN_2 .... Gaseous Nitrogen
GPS .... Global Positioning System
GSE .... Ground Support Equipment
ICD .... Interface Control Document
IPS .... Inch-Pound-Second
LRR .... Launch Readiness Review
LV .... Launch Vehicle
MPE .... Maximum Predicted Environments
Max-Q .... Maximum Dynamic Pressure
OASPL .... Overall Sound Pressure Level
PPF .... Payload Processing Facility
QD .... Quick Disconnect
RF .... Radio Frequency

RPM .... Rotations per Minute
RTS .... Reagan Test Sit
SC .... Spacecraft
SI .... International System of Units
SLC .... Space Launch Complex
SpaceX .... Space Exploration Technologies
SPL .... Sound Pressure Level
SRR .... System Readiness Review
VC .... Visibly Clean
TML .... Total Mass Loss
TTL .... Transistor–Transistor Logic
US .... United States

