Secondary Launch Services and Payload Hosting Aboard the Falcon and Dragon Product Lines

Dustin Doud, Brian Bjelde, Christian Melbostad, Lauren Dreyer
Space Exploration Technologies Corp.
1 Rocket Road, Hawthorne, Calif.; 310-363-6000
dustin.doud@spacex.com

ABSTRACT

SpaceX is committed to revolutionizing access to space for the small-satellite community. With over 40 missions on our manifest, Falcon 9 is poised to become the industry workhorse for space launch services. The Dragon spacecraft, developed in part to resupply the International Space Station, is capable of hosting missions for up to 2 years on orbit. In short, SpaceX offers highly reliable, cost-effective launch services and payload hosting opportunities. This paper defines the company's secondary launch services and options, and how they will impact the small-satellite community.

Secondary payloads, by definition, must accompany and minimally impact the primary payload. Despite this unobtrusive position, small-satellite missions continue to demonstrate incredible capability at reasonable prices. SpaceX recognizes this tremendous asset, which is why as the company continues to reduce the time from build to launch, it is prepared to meet market demand and support future developments with Falcon and Dragon products. Establishing expectations and success criteria for secondary payloads, and making these guidelines available for future mission planning will enable sustainable space access for secondary payloads. This paper describes the SpaceX approach to secondary payloads, standardized services provided to multiple payload types, and provides a current list of secondary launch opportunities.

The small-satellite community is critical to the future of our industry, and SpaceX is committed to providing reliable, timely, and cost-effective launch services to enable current and future missions. SpaceX looks forward to offering launch services to this innovative marketplace and to continue decreasing the cost to space.

SPACEX OVERVIEW

SpaceX was founded in 2002 specifically to provide highly reliable and low-cost space transportation. Falcon 9, the current workhorse of the SpaceX fleet of launch vehicles, provides medium-lift capability. Falcon Heavy, recently unveiled and set for delivery to Vandenberg Air Force Base, is an intermediate- to heavy-lift launch vehicle. These launch vehicles can deliver spacecraft into a range of inclinations and altitudes, from low Earth orbit (LEO) and geosynchronous Earth orbit (GEO), to planetary missions. The Dragon spacecraft further enhances our services by providing transportation to and from Earth for cargo, hosted payloads, and eventually crew.

The SpaceX corporate structure is flat and our business processes are lean, a combination that yields expedited decision-making and delivery. Our products are designed to require fewer infrastructure facilities (production and launch) with low overhead for maintenance. Our vehicle design teams are co-located with Production and Quality Assurance staff to tighten the feedback loop for these critical disciplines; the result is highly producible, low-cost designs with quality embedded.

FALCON 9 OVERVIEW AND FLIGHT HERITAGE

Falcon 9 is a two-stage vehicle powered by liquid oxygen (LOX) and rocket-grade kerosene (RP-1). The launch vehicle can carry up to 13,150 kg into LEO and up to 4,850 kg into geosynchronous transfer orbit (GTO). Falcon 9 has a 17 ft (5.2-m) diameter fairing and is the result of SpaceX's goal to produce an evolved expendable launch vehicle (EELV)-class system with significant improvements in reliability, cost and responsiveness over existing vehicles. Falcon 9 offers breakthrough reliability because the nine Merlin engines that power the first stage offer engine-out redundancy. In fact, Falcon 9 is the first American launch vehicle since the Saturn V to offer such redundancy and reliability. The vehicle is designed with the goal of carrying humans into space aboard the Dragon spacecraft.

Falcon 9 has had three consecutive mission successes. On June 4, 2010, the inaugural flight of Falcon 9 and the subsequent demonstration flight on December 8, 2010 were carried out as part of NASA's Commercial Orbital Transportation Services (COTS) program. Both flights were successful, with all mission objectives met.

Following these successes, on May 22, 2012 the Falcon 9 launched for a third time and delivered the second Dragon spacecraft to orbit. All launch mission objectives were completed, from liftoff to Dragon separation. Views of Falcon 9 during liftoff for all three Falcon 9 missions are shown in Figure 1, below.

Figure 1: 3 Successful Launches of Falcon 9

A view of the Flight 3 Falcon 9 upper-stage Merlin Vacuum engine, shown firing in the eclipse of Earth, is depicted in Figure 2, below.

Figure 2: Falcon 9's Upper Stage Delivering Dragon to Orbit

SpaceX's three successful Falcon 9 launches, in addition to the success of the Dragon spacecraft missions described below, successfully complete the COTS mission objectives. SpaceX looks forward to providing cargo re-supply services to NASA using Falcon 9. We also look forward to providing launch services to the commercial and government customer with the same flight-proven heritage serving as a new foundation of modern space launch.

DRAGON OVERVIEW AND FLIGHT HERITAGE

Dragon is a fully autonomous spacecraft that contains all the structure and subsystems required for transporting pressurized and unpressurized cargo to and from the ISS or other orbital platforms. Developed in support of NASA's COTS program, Dragon can deliver at least 2,550 kg of cargo to the ISS. The Dragon spacecraft made history on December 8, 2010, when it became the first private-sector spacecraft to enter the Earth's atmosphere and be successfully recovered.

Dragon made history again in 2012 as the first commercial spacecraft in history to visit the ISS. Previously, only four governments – the United States, Russia, Japan, and the European Space Agency – have achieved this challenging technical feat. Figure 3, below, captures Dragon attached to the Shuttle Remote Manipulator System (SRMS), the ISS robotic arm that captures Dragon and then berths it with the ISS.

Figure 3: The Dragon Spacecraft Captured by the ISS SRMS

The Dragon spacecraft is comprised of 3 main elements: the Nosecone, which protects the vessel and the passive berthing mechanism during ascent; the Spacecraft, which houses pressurized cargo, and eventually crew, as well as the service section; and the Trunk, which can accommodate unpressurized cargo.

The service section forms an unpressurized torus around the base of the pressurized section and includes the main heat shield, tanks for propellant and pressurized gas, thrusters, various plumbing, parachutes, the grapple fixture and additional avionics including thermal and LIDAR imaging systems. Both the Spacecraft and service section components of Dragon are fully recoverable, as shown in Figure 7. SpaceX has successfully demonstrated the ability to de-orbit and recover the Dragon two times: a success for each recovery attempt made.

The trunk supports the capsule during ascent and remains attached to Dragon until shortly before reentry. The trunk contains a cargo carrier designed to support unpressurized cargo and flight releasable attach mechanisms (FRAMs) as well as solar arrays to power the vehicle. Another key feature of the trunk section is that it is designed to carry and deploy small spacecraft. Figure 4 below shows the usable volume of the Trunk, including accommodations for 6 containerized satellite dispensers.

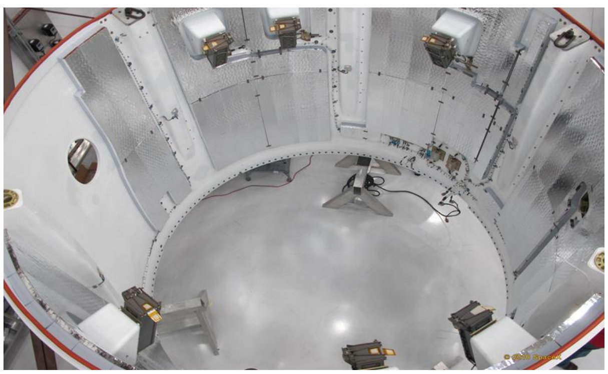

Figure 4: The Dragon Trunk with Six Small Satellite Containerized Dispensers

To ensure a rapid transition from cargo to crew capability, the cargo and crew configurations of Dragon are almost identical, with the exception of the crew escape system, the life support system and onboard controls that allow the crew to take over control from the flight computer when needed. This focus on commonality minimizes the design effort and simplifies the human rating process, allowing systems critical to Dragon crew safety and space station safety to be fully tested on unmanned demonstration flights and cargo resupply missions

For cargo launches, the inside of the spacecraft is outfitted with a modular cargo rack system designed to accommodate pressurized cargo in standard sizes and form factors. For crewed launches, the interior is outfitted with crew couches, controls with manual override capability and upgraded life-support.

Though designed to address cargo and crew requirements for the ISS, as a free-flying spacecraft Dragon also provides an excellent platform for in-space technology demonstrations and scientific instrument testing. SpaceX is currently manifesting fully commercial, non-ISS Dragon flights under the name “DragonLab”. DragonLab represents an emergent capability for in-space experimentation.

A view of the Dragon en-route to the ISS is shown, with solar arrays deployed in Figure 5.

STANDARDIZED INTERFACES AND SERVICES

Manifesting a secondary payload aboard a Falcon launch vehicle or Dragon spacecraft requires more than unused vehicle capability to be available. Secondary payloads are most easily facilitated when they are designed to public, community adopted standards. These standards can be described as two major payload categories: the containerized payload, and the ring-mounted payload.

Figure 5: Both of Dragon’s Solar Arrays Fully Deployed as seen from the ISS

Containerized payloads most typically fit the 3U form factor, which defines that any payload shall be no larger than 340.5mm x 100mm x100mm and weigh no more than 4kg, however, they may be smaller so long as they are compatible with the deployer ICD.

Ring-mounted payloads are defined by the EELV-Secondary Payload Adapter (ESPA) standard, and typically fit a volume defined by 609mm x 711mm x 965mm, have a mass no more than 180kg, and utilize a clamp-band style interface, such as the 15in (381mm) Lightband separation system.

Both classes have publically available standards via the web. To-date, SpaceX has experience performing integration and deployment of the 3U class payloads using the Poly Picosatellite Orbital Deployer (P-POD) system. In December of 2010, after separation of the Dragon spacecraft from the 2nd flight of Falcon 9, six 3U P-PODs deployed eight small satellites.

In addition to community accepted standards, clear expectations of secondary payload mission management facilitates efficient payload integration and maintains low launch prices. Labor surrounding integration of secondary payloads drives launch cost, which begins immediately after the launch services agreement is signed. This labor is required well in advance of arrival at the launch site, and to a first order includes coordinating the secondary payload with integrated spacecraft and launch vehicle analyses, coordinating with the launch range, and communicating developments to the customer. After arrival at the launch site, the payload must be integrated in a way that does not interrupt primary payload processing. Therefore, designing a payload which can be integrated without exotic requirements such as nitrogen spot purging and battery trickle charging, and then be left to itself after integration for an extended duration of time (60 days nominally), increases the likelihood of cost effective mission management and integration.

Utilization of known interfaces and clear expectations of secondary payload services enables the proliferation of a sustainable, cost-effective service to orbit.

SECONDARY LAUNCH MANIFEST

SpaceX has booked over $3.5B USD worth of business, representing more than 40 missions through 2017. This robust manifest includes many missions on which secondary payloads may be integrated. Currently, as a standard practice, if a primary mission utilizes less than 80% of particular Falcon vehicle's capability to orbit, SpaceX will reserve the right to add additional secondary payloads to the mission to utilize the capability.

In order to keep the secondary manifest up to date, SpaceX holds regular secondary payload manifest control board meetings, and publicizes the list at major conferences and to its service providers and brokers. The SpaceX Secondary Manifest, below in Figure 6, summarizes the latest secondary manifest. Each entry represents a mission which has at least several hundred kilograms of mass to orbit, ESPA class volume available within the fairing, and electrical interface margin available to the secondary marketplace.

Vehicle:	Target Date:	Orbit:	Launch Site:	LTAN/DN:
Falcon 9	Q4 2012	325 x 1500km elliptical @ 80°	VAFB	TBD
Falcon 9	Q1 2013	750 km circular orbit @ 52°	Cape	TBD
Falcon 9	Q3 2014	720km sun synch orbit	VAFB	10:00 (DN)
Falcon 9/DragonLab	Q4 2014	TBD	TBD	TBD
Falcon 9	Q4 2014	600km sun synch orbit	VAFB	06:12 (AN)
Falcon 9	Q2 2015	600km sun synch orbit	VAFB	18:12 (AN)

Figure 6: SpaceX Secondary Manifest

METHODS TO MANIFEST

For a particular mission with secondary payload capacity, supporting various payloads from multiple customers, each with potentially different interfaces and service expectations, presents a unique challenge. Secondary payloads must be coordinated efficiently, reliably and unobtrusively to the primary payload. In addition to these technical challenges, significant logistical and legal challenges may create higher barriers to entry when scaling up to larger numbers of secondary payload accommodations. Therefore, successful coordination of the secondary payload marketplace for a particular launch must be done harmoniously so that technical, logistical and legal requirements are met at a commercially sustainable price.

Motivated to increase commercial viability, SpaceX has begun to solicit for and engage payload brokers and service providers to help meet these challenges. The groups can act as agents to help develop, coordinate, and address the requirements of multiple payloads and ultimately enable more launch opportunities for secondary payloads. SpaceX envisions payload brokers and service providers leveraging their expertise, including knowledge of specific customers or product areas, to market, coordinate and develop the marketplace. We anticipate bringing together multiple brokers and their payloads, to achieve authorization to proceed (ATP) with secondary payloads on a mission with additional capability.

After ATP, service providers will begin the mission management process, acting as the single point of contact for the payloads they are coordinating throughout the mission. This delineation of contact supports commercial viability: payload customers communicate only to their service provider, and in turn they communicate solely with SpaceX. This effectively reduces the amount of interfacing for each party involved, which is a significant driver of mission cost.

With this communication structure, service providers will verify payload requirements, interfaces, and operations requirements from ATP through the final stages of integration into a consolidated payload unit. After integration, the service provider will certify that the composite payload is ready for flight, using mutually agreed-upon standards with SpaceX. During this entire process, service providers will communicate deliverables and milestones to SpaceX, remaining on track with the agreed-upon mission schedule. The final integrated composite payload will then be transported to SpaceX launch facilities, integrated into the Falcon launch vehicle, and launched.

CONCLUSION

Presently, the challenge of coordinating multiple payloads into a composite unit is a complex process, which requires specialized knowledge dependent on payload characteristics and applicable laws. Encouraging brokers and service providers to enter the marketplace and competitively leverage their relationships or technical experience to successfully coordinate payloads for launch allows SpaceX to provide commercial secondary services that can be reliably planned and budgeted for, while not disrupting the company's core goals of providing affordable commercial space access, cargo resupply services, and commercial crew developments.

As secondary payload product space continues to flourish, a designer that accommodates known, community accepted standards, and plans to minimally impact the mission integration process, can plan for a commercially sustainable launch service on a SpaceX mission. Brokers and service providers may complement the process by adding value to the marketplace as the volume of payloads looking for commercial launches begins to increase. The small satellite community is critical to the future of our industry. SpaceX is committed to providing reliable, timely, and cost-effective secondary launch services and will continue to innovate in this capacity.

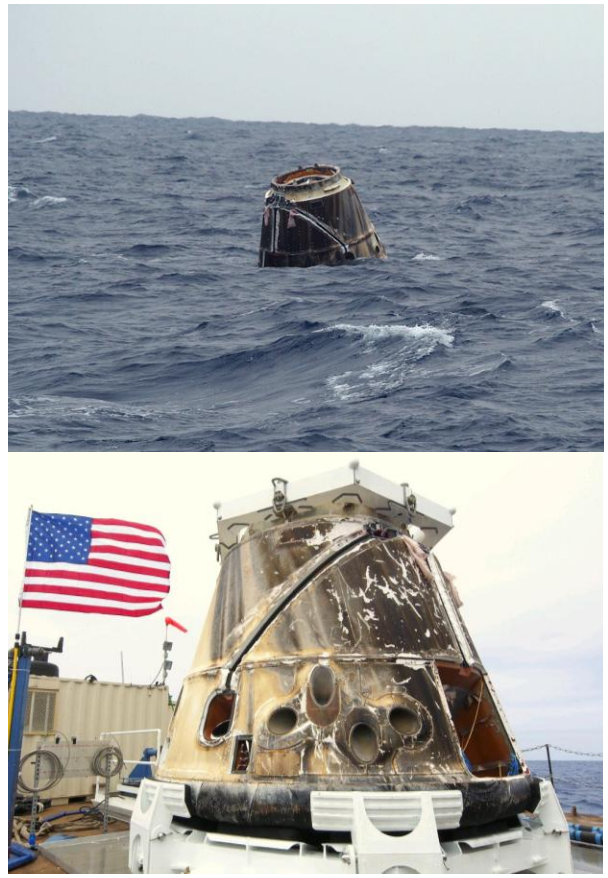

Figure 7: The Second Dragon Spacecraft after Splashdown and on the Recovery Vessel

Acknowledgments

SpaceX would like to thank the National Aeronautics and Space Administration, the United States Air Force, the Federal Aviation Administration, its commercial customers, and all its employees, without whom its achievements would not have been possible.