Routine Scheduled Space Access For Secondary Payloads

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ABSTRACT

Commercial launch vehicles often launch with primary payloads that do not max-out launch capacity to the destination orbit. To take advantage of this excess capability, secondary payloads can be launched with the primary payload, providing an economical means to get small spacecraft to orbit, as well as providing additional revenue to the launch provider. Up until now, these secondary payload opportunities have been limited and sporadic, with payloads waiting for rides due to mismatched orbit destinations, availability of launch vehicle capacity, and prohibitive cost. With the advent of new U.S. commercial launch services, the opportunities for launch of small secondary spacecraft are expected to increase. Secondary payload customers can take full advantage of these opportunities with standard interfaces and processes to enable routine launch at competitive commercial prices. To provide routine low cost access to space, Spaceflight Services has partnered with SpaceX to provide secondary payload flight services on its Falcon 9 launches using available capacity or in Falcon 9 Dragon launches using volume in the Dragon Trunk. Spaceflight Services provides standard interfaces for a range of small spacecraft, ranging from CubeSat-class to ESPA-class payloads. This paper explores the effects of implementing standard payload accommodations and streamlined launch integration processes in establishing routine launch of secondary payloads at commercial prices.

BACKGROUND

This paper explores the effects of implementing standard payload accommodations and streamlined launch integration processes to establish a pipeline for the routine launch of small and secondary payloads at affordable commercial prices.

Spaceflight Services, Inc. (Spaceflight) was spun off from Andrews Space in 2009 to serve as a space access service provider for fixed and deployable cargo and spacecraft to address the following markets:

- Small spacecraft launch
- Hardware qualification
- Biotechnology and space research
- Earth observation and monitoring

Spaceflight provides two types of services: deployable secondary payloads ranging from CubeSats (<4 kg) up to ESPA-class spacecraft (<190 kg); and fixed secondary payloads. Spaceflight has an agreement with SpaceX to manifest and fly payloads on dedicated DragonLab missions. Spaceflight is working with other launch vehicle service providers to manifest payloads on a range of flight opportunities. In addition, Spaceflight has recently expanded to include suborbital platforms.

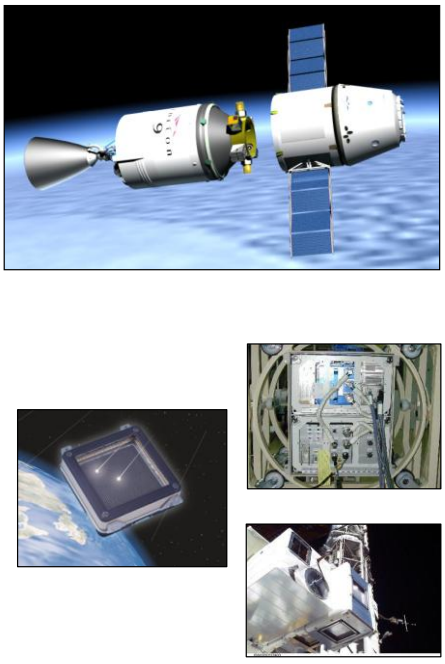

Figure 1. Spaceflight was spun off from Andrews Space in 2009 to serve as a space access service provider for fixed and deployable cargo and spacecraft.

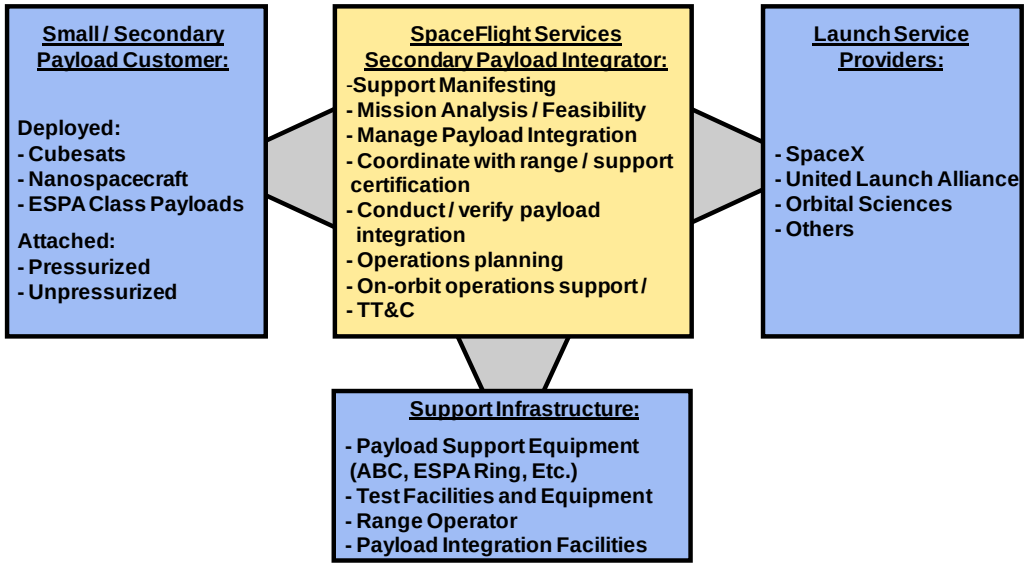

Figure 2 Spaceflight Services is a Secondary Payload Integrator.

SERVICE STRUCTURE

Spaceflight works as a small payload integrator (Figure 2), working with the small / secondary payload customer and the launch customer to manifest and integrate payloads for launch. In this manner the customer buys space launch and flight services from Spaceflight.

- The launch vehicle provider acts as a wholesaler of Secondary Payload Services
- Spaceflight Services has agreements with the launch vehicle providers to market and contract for flight services at approved pricing
- Spaceflight is responsible for analytically and physically integrating multiple payloads into a package that is treated as a major discreet payload for manifesting purposes.

In addition, the customer pays Spaceflight to bring payloads onto manifest while conforming to all launch vehicle technical and safety requirements. In this manner Spaceflight works with the payload customer to provide / conduct:

- Flight service,
- Safety audit,
- Review and approval of flight documentation,
- Coordination of launch and on-orbit services,
- Customer manifest planning

Spaceflight Services provides additional services (Pricing TBD) including but not limited to:

- Integration support to customer developed payloads: analytic and physical integration, testing or other verification services, and design review.
- Customer payload development services: take customer's core concept or instrument and build, test, and integrate into an assembled secondary payload.

DEPLOYED PAYLOAD INTERFACES

To simplify spacecraft integration time and cost, Spaceflight has developed a range of standard payload interfaces leveraging industry proven approaches such as the 15-inch lightband adapter and CalPoly P-POD. Depending on the manifest and launch vehicle, multiple spacecraft can be integrated into a single discrete unit, leveraging items such as the ESPA ring, for easy integration with the launch vehicle (Figure 3).

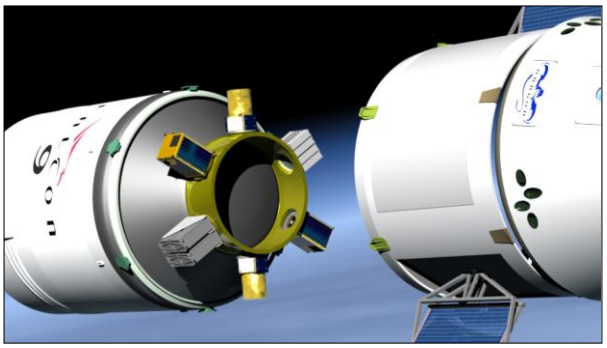

Figure 3 Falcon 9 Secondary Payload Interfaces

	Containerized Payloads					Lightband Adapter	
Payload Type	1U	3U	6U	12U	24U	Microsat	ESPA
Length (max) cm	10.0	34.0	36.6	36.6	68.0	70.0	98.0
Height (max) cm	10.0	10.0	10.0	22.6	22.6	30.0	60.0
Width (max) cm	10.0	10.0	22.6	22.6	22.6	30.0	60.0
Mass (max) kg	1.0	4.0	10.0	20.0	40.0	70.0	190.0
Price ($1,000 USD)	$160	$320	$615	$1,190	$1,650	$2,850	$5,850

Note: For planning purposes only

Figure 4 Spaceflight Services Standard Interfaces

Deployed spacecraft can use the following standard interfaces or dispensers offered by Spaceflight Services. These are explained in further detail in the subsequent text.

- 3U Cal Poly P-POD (1U – 3U CubeSats)
- 6U NanoBox dispenser
- 12U NanoBox dispenser
- 24U NanoBox Dispenser
- 8-inch (20.3 cm) diameter Lightband interface
- 15-inch (38.1 cm) diameter Lightband interface

A summary of these system dimensions, and ROM pricing, is shown in Figure 4.

CubeSat Interfaces

The P-POD has a tubular design (Figure 5) and can hold up to 34cm x 10cm x 10cm of deployable spacecraft. Multiple CubeSats of different lengths can be accommodated in the same P-POD, up to a total length of 34 cm.

Figure 5 Cal Poly 3U CubeSat Dispenser (Ref: P-POD Mk III ICD)

CubeSat P-PODs can be attached singly or in multiple sets to a secondary payload adapter similar to an EELV Secondary Payload Adapter (ESPA) mounted between the launch adapter and primary payload.

Nanosatellite-class Interfaces

Andrews Space, Inc. as well as other companies are developing containerized dispensers for NanoSats larger than the 1U to 3U standard CubeSat size. Spaceflight Services can accommodate these dispensers with three standard options. Spaceflight Services can provide the customer with NanoBox dispenser hardware, or accommodate third party hardware as well. Interface details for the standard hardware is summarized below in Figure 6, Figure 7, and Figure 8. In each case, the interface and deployment method is similar to the smaller 3U P-POD, in that the spacecraft is supported in the canister by corner rails, and is pushed from the NanoBox by a spring deployment system.

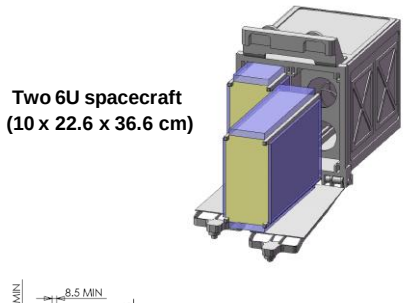

Figure 6 NanoBox dual 6U interface

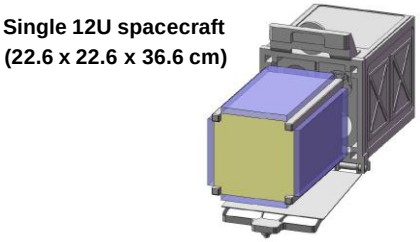

Figure 7 NanoBox 12U interface

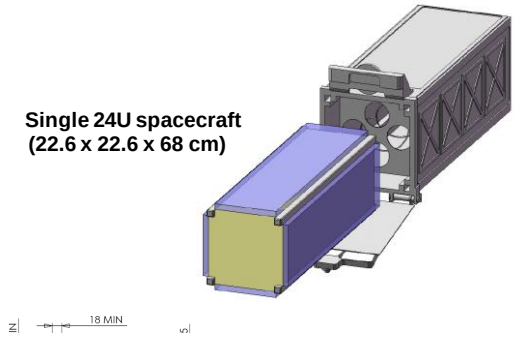

Figure 8 NanoBox 24U interface

MicroSat and ESPA-class Spacecraft Interfaces

Spaceflight Services also provides for the integration of larger spacecraft that attach to an 8-inch (20-cm) or 15-inch (38-cm) mechanical interface within a standard Microsat (30 cm x 30 cm x 68 cm) or ESPA-class (60 cm x 60 cm x 98 cm) payload volume.

The Microsat-class secondary payload interface is for small spacecraft (70 kg or less) that are designed to be separated using a base-mounted separation ring. The interface is a forged aluminum flange on a secondary payload adapter with a bolt-pattern diameter of 8-inches (20-cm).

Figure 9 ESPA Ring Model
(Ref. ESPA User's Guide)

The ESPA-class secondary payload interface is for larger spacecraft (190 kg or less) that are designed to be separated using a base-mounted 15-in (38-cm) separation ring. The interface is a forged aluminum flange on a secondary payload adapter with a bolt-pattern diameter of 15-inches (38-cm). The bolt pattern consists of twenty-four 0.64-cm holes spaced every 15 degrees around the ring.

SpaceX Dragon Interfaces

DragonBox is an offering of Spaceflight Services that attaches to the Dragon trunk cargo carrier and provides a mechanical and services interface for secondary payloads (Figure 10). The trunk is a composite cylinder that serves as the adapter between the Dragon capsule and the Falcon 9 launch vehicle. In addition to the unpressurized cargo, it supports the Dragon solar arrays and the radiator. A cargo carrier spans the inside of the trunk and may interface with the cargo through FRAMs or other separable fittings, or through non-separable fittings for payloads that will remain attached in the trunk during orbit operations.

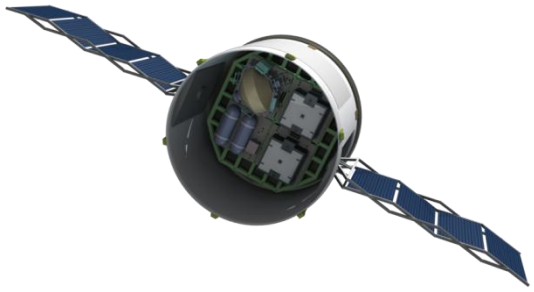

Figure 10: Cargo Mounted on Cargo Carrier in Dragon Trunk

A unique offering of the SpaceX Falcon commercial launch system will be the availability of an orbital free-flyer in the form of the SpaceX DragonLab vehicle. For free-flying DragonLab missions, the Dragon capsule with trunk will remain in orbit as a free-flying spacecraft for a period of time specified by the DragonLab customer, up to a period of 2 years. For these missions, unpressurized payloads may be deployed from the trunk or may remain attached to the trunk cargo carrier for the period of the mission. As with ISS operations, the trunk will be separated from the pressurized capsule prior to reentry from orbit, and will burn up during reentry.

Secondary Payload Environments

Secondary payload pre-launch and launch environments will be specific to the manifested launch vehicle. For example, quasi-static load factors expected on the primary payload are shown in Figure 12. This is an envelope of expected load factors for the Falcon 1e, Falcon 9, Falcon Dragon, Taurus II, and Minotaur IV launch vehicles.

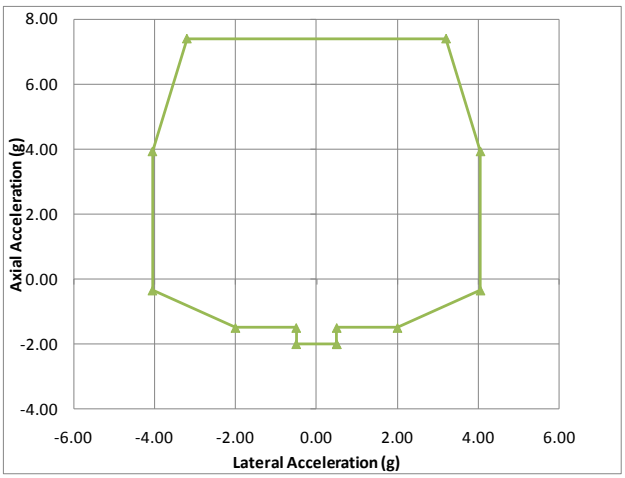

Figure 12 Launch vehicle Design Load Factors

Standard Integration Processes

Commercial launch operations are designed for minimal complexity and time at the pad. Once integrated, the launch vehicle is typically moved quickly to the pad and erected for launch. Launch readiness approval is received via a Launch Readiness Review (LRR) held 24 hours before launch.

For most launch vehicles, integration and encapsulation of the primary and secondary payloads takes place off-line in an integration facility, followed by mating with the launch vehicle and transport to the launch pad. Secondary Payload integration to the Payload Adapter will be performed by Spaceflight Services prior to integration of the primary payload and encapsulation at the Launch vehicle facility (Figure 11). For this reason, Secondary Payloads must arrive at the Spaceflight Services facility up to 8 weeks prior to launch to allow enough time for Payload Adapter integration, test, and delivery to the launch vehicle provider facility. Standardizing the integration process removes uncertainty from the integration schedule, and keeps the secondary payload integration from driving the overall launch vehicle integration. If a particular spacecraft is known to be behind schedule, an alternate spacecraft or mass simulator can be substituted, depending on the integration timeline.

The first step in the secondary payload integration process is the integration of the Secondary Payloads to the Payload Adapter within Spaceflight Service facilities near the launch site. Secondary payloads will be accepted at this facility up to 4-1/2 months prior to launch, at which time they will be inspected and readied for integration with the Payload Adapter. Limited payload processing, including hazardous operations, may be conducted as a non-standard service. Any kitted parts will be assembled, and then the payloads and assemblies will be sent to the Payload Adapter integration facility for integration in a clean (<100k cleanliness) temperature-controlled environment prior to integration with the launch vehicle.

Launch vehicle providers will encapsulate primary payloads in either a vertical or horizontal orientation,

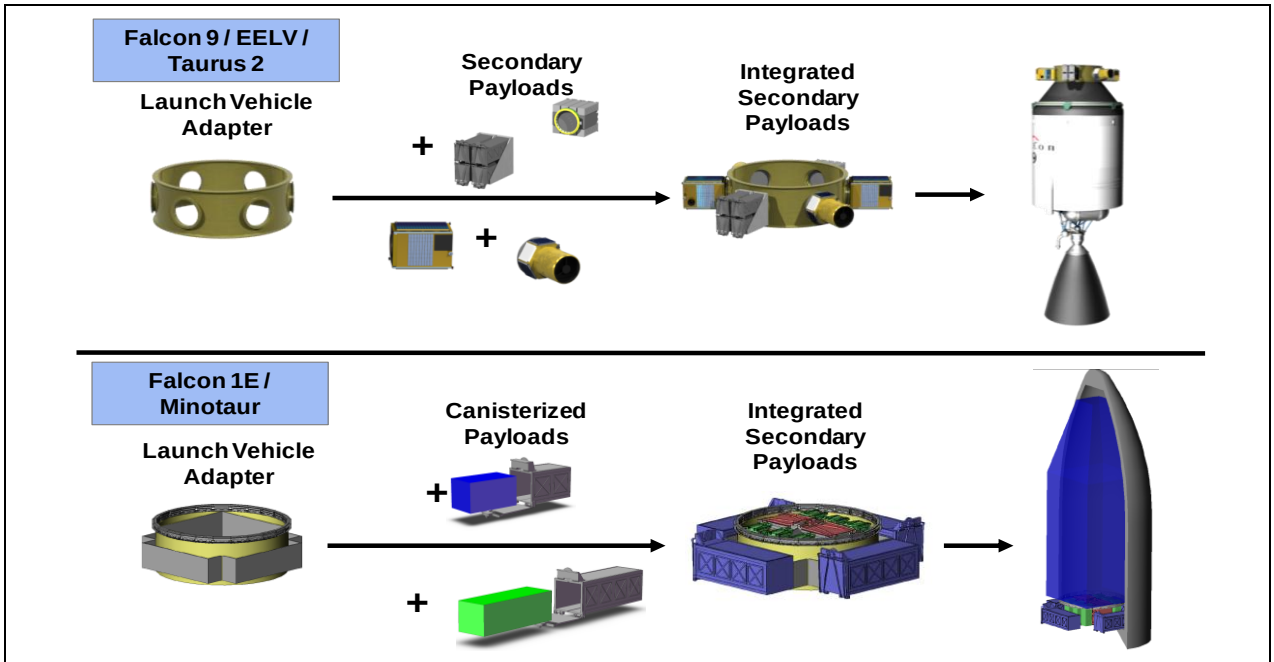

Figure 11 Secondary Payload Integration Flow

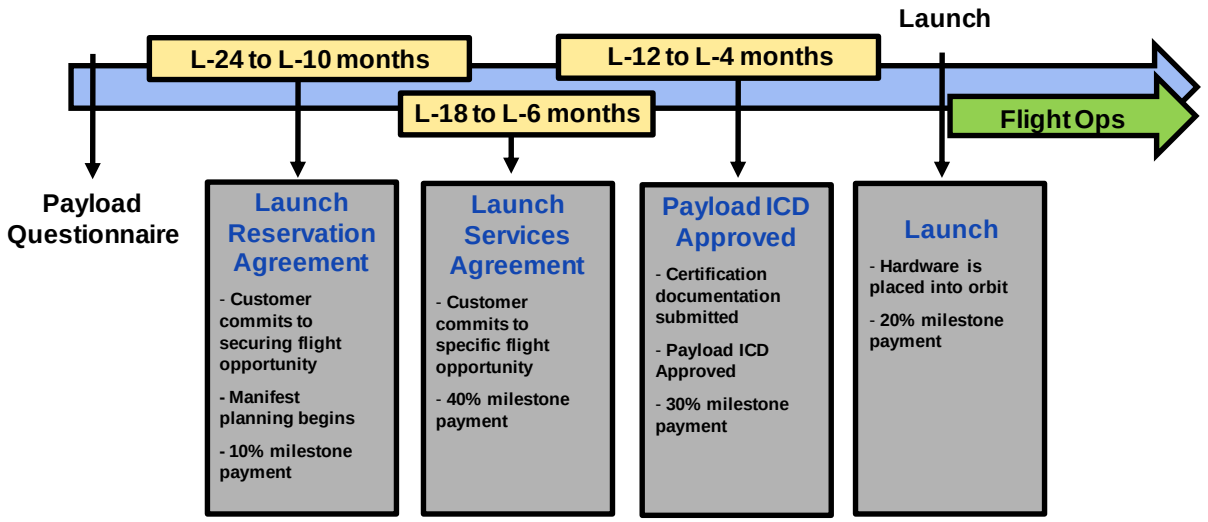

Figure 13 Secondary Payload Integration Schedule

depending on the integration and operational flow. Secondary payloads integrated with the Payload Adapter will be transported from the Spaceflight Services integration facility to the launch vehicle integration facility to be integrated with the launch vehicle. Typically, the integrated Payload Adapter will be mounted to the launch vehicle adapter in a vertical orientation, then the primary payload will be mated to the Payload Adapter. The entire payload assembly will then be encapsulated vertically, or encapsulated horizontally using a break-over fixture.

Once encapsulated, the Environmental Control System (ECS) will be connected, and the encapsulated paylaod will be integrated to the launch vehicle. Post-mate checkouts will be conducted and followed by a Flight Readiness Review (FRR).

With completion of the FRR, the launch vehicle is readied for transport to the launch pad. Once weather and safety clearance are received, the vehicle is rolled out and erected on the launch pad. Environmental control of the vehicle and payload during rollout is maintained by a portable ECS. After arrival at the pad, ECS function is transitioned to the pad ECS, which supplies environmental control until launch. Once the launch vehicle is erected at the pad, a series of operational and functional tests are performed to ensure operational capability and launch readiness. Twenty-four hours prior to launch, a launch readiness review (LRR) is held with the range to confirm final readiness for launch.

SERVICE SCHEDULING

Spaceflight has established a standard payload integration process and milestone payment structure. The contracting process begins with filling out a Payload Questionnaire to provide payload information. This questionnaire can be found on the www.spaceflightservices.com website. Once a payload customer decides to contract for launch services, they sign a Launch Reservation Agreement and put down a 10% non-refundable payment. This starts the payload manifesting and mission planning process. Once a specific flight opportunity has been identified, the customer signs a Launch Reservation Agreement and pays 40% of the contracted price. The payload manifesting / integration process proceeds with a third payment required at finalization of the payload ICD. The final payment is made upon launch.

CONCLUSION

With the advent of multiple low-cost U.S. commercial launch vehicles in recent years, the opportunities for launching secondary payloads have increased. Spaceflight Services, Inc. has teamed with SpaceX to offer secondary payload services aboard the Falcon 9 Dragon system. Future opportunities aboard domestic, and potentially foreign, launch vehicles are expected as well. Spaceflight Services will offer standard payload interfaces and streamlined integration processes in order to reduce costs to the customer. Payloads from Cubesats up through ESPA-class payloads are expected to be accommodated, increasing availability to orbit for a wide range of spacecraft and experiment developers.