Deploying 87 Satellites in One Launch: Design trades completed for the 2015 SHERPA flight hardware

Kaitlyn Kelley, Mitch Elson, Jason Andrews
Spaceflight Services
3415 S 116th St #123, Tukwila, WA 98168; (801) 618-7223
kkelley@spaceflightindustries.com

ABSTRACT

Launch remains an obstacle for small satellites, which are often limited to small platforms, aft bulkheads, and accommodations for a single P-Pod. While launch vehicles have expanded the space available to small satellites, the largest number of satellites deployed in a single launch stands at thirty-seven. Spaceflight has secured a single launch opportunity in 2015 for no less than 87 small satellites. The ability to support so many satellites stems from tactical design decisions. This paper focuses on the design trades for the payload adapters developed for the 2015 SHERPA launch. Three unique payload adapters were designed to interface to the Moog ESPA Grande ring, the core of the SHERPA spacecraft. Each is an aluminum plate that interfaces to the 24” bolt-hole pattern on the five ESPA Grande ports. For these adapters, a balance was struck between designing to the unique payload in the flight configuration and developing a reusable system. The paper discusses the initial design trades regarding the adapter plate capabilities and how these trades have affected the plates’ utility on later SHERPA missions.

INTRODUCTION

Spaceflight Services is poised to break the record for the most satellites launched on a single launch vehicle, doubling the number previously launched.

As more small satellites clamor for launch, many organizations have begun filling excess capacity with small satellites and nanosatellites. Innovative Solutions in Space B.V. and Tyvak Nanosatellite Systems have been launching nanosatellites as secondary payloads for years. Nanosatellite deployment has even begun from the International Space Station, through the commercial company NanoRacks.

NASA and the U.S. government also launched large numbers of small satellites in the past. The Operationally Responsive Space office recently launched 29 CubeSats on a Minotaur launch vehicle. Roscosmos, a Russian agency, develops cluster missions around a few main payloads and fills the remaining space with small satellites and nanosatellites.

There is an upward trend in the number of satellites deployed during each launch. Moving from one satellite to nearly forty is a huge advance. Spaceflight Services is poised to take the next leap; from forty to nearly ninety satellites deployed in a single launch. Unlike the other commercial companies mentioned, which focus primarily on CubeSats, Spaceflight integrates microsatellites as well. This ability opens up new opportunities for small satellite integration on larger vehicles. These larger launch vehicles have more capacity for adapter equipment and offer more options for creative integration. With this additional volume and capacity, the record number of satellites in a single launch is primed to be broken.

2015 SHERPA MISSION

The 2015 SHERPA mission addresses the limitations of current launch configurations by maximizing the number of payloads integrated to the structure. It is an ESPA Grande-derived satellite deployment system intended for launch on any Evolved Expendable Launch Vehicle (EELV). The SHERPA is a free-flier auxiliary payload deployment system capable of deploying up to 1500 kg. Secondary payloads are integrated to each port of the SHERPA and the primary payload can be safely integrated to the top of SHERPA.

Flight Configuration

While the high number of satellites on this mission is in part due to CubeSat constellations, the SHERPA concept is well suited to support small spacecraft that range from CubeSats to 300kg. By developing unique adapters for the standard ports, Spaceflight has enabled many different sizes of spacecraft to deploy from SHERPA, including the DARPA eXCITe microsatellite, built by NovaWurks, and two BlackSky Global Pathfinder satellites. Future planned configurations involve multiple SHERPA rings on a single launch as well as support for much larger spacecraft on the forward section of the SHERPA ring.

For the 2015 SHERPA mission the final configuration incorporates three microsatellites and 84 CubeSats of which the majority are 3Us. The microsatellites represent two different spectrums with regard to mass and interfaces. This demonstrates the capabilities of using the modular approach Spaceflight took in the design and implementation of its adapter hardware.

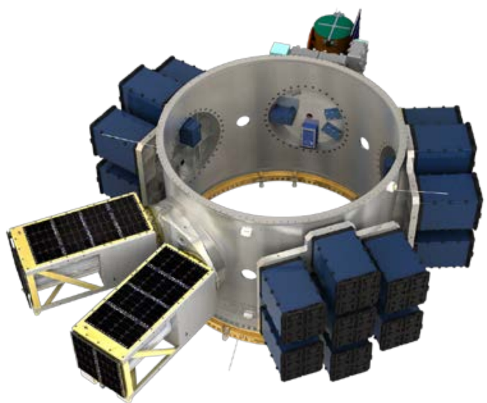

Figure 1: 2015 SHERPA Flight Configuration

One of the innovative microsatellites included on the manifest is a 160kg system, developed and flown by NovaWurks. Based on our current customer inputs, this 125kg to 250kg spacecraft class will be an area of high demand. Spaceflight has concluded that this is one of the worst served markets in terms of access to space. Historically, this category was served by foreign launch service providers and the U.S. Government. As technology advances, this class of spacecraft has begun to catch the interest of commercial satellite providers. This new group of customers does not have access to the Government small launch vehicles, and, to date, commercial small launch vehicles are too expensive for the secondary market. While there are efforts underway to develop lower cost commercial small launch vehicles, the efficiencies in cost provided by the SHERPA concept will remain a competitive means to access popular orbits.

Two microsatellites on the 2015 SHERPA mission support the early phases of a constellation build out. With numerous spacecraft manifested on this mission Spaceflight has had to consider not only the mass to orbit, but also the volume consumed by any given spacecraft. By developing an adapter system that places two spacecraft on a single port, Spaceflight is able to maintain its Internet advertised pricing. Customers can recognize the benefit of this pricing by designing to industry and SHERPA published standards. This will increase the number of rideshare opportunities available and keep the cost per kg low.

For microsatellite deployments, Spaceflight has selected the Planetary Systems Corporations Motorized LightBand as our preferred separation system. Planetary Systems has developed and published standards for mechanical and electrical interfaces. Spaceflight offers our services at fixed prices, so known technical specifications and cost allow Spaceflight to have a high degree of confidence in its pricing. With extensive flight heritage, the Motorized LightBands provides confidence in its mission assurance. That is further enhanced by the amount of testing that Planetary Systems has completed. The company provides the related data in their published documentation.

Finally, the Motorized LightBands have compiled a great deal of data on their deployment characteristics based on their extensive flight heritage. This supports another part of overall mission assurance, and provides the customer with the knowledge that their spacecraft will have minimal tip-off rates. This is an important factor in our post-deployment system stabilization and allows Spaceflight to deploy spacecraft as soon as possible after launch.

In addition to the microsatellites, there are 84 CubeSats manifested on the 2015 SHERPA. Spaceflight chose to use the QuadPack, a CubeSat deployment system procured from Innovative Solution in Space of the Netherlands, to deploy the CubeSats. The “Quad” in QuadPack refers to the baseline configuration to support four 3U CubeSats. This can be configured to support any number of CubeSats that can be divided into that space. For the 2015 SHERPA mission Spaceflight is utilizing the modularity to fly a number of 6U CubeSats.

Not only do the QuadPacks provide modularity in the CubeSat configuration, the ability to integrate the system through multiple bolt hole patterns enables additional integration options. Spaceflight has designed an adapter plate that integrates the aft end to the plate. This design allows Spaceflight to place seven QuadPacks per SHERPA port.

The QuadPacks are compatible with CubeSats developed to the Cal Poly CubeSat Standards. This system also offers options to support some of the emerging trends in the CubeSat world; such as “tuna can” extrusion, and volumegrowth around the rail system.

Mission Concept of Operations

A significant driver for the requirements of the 2015 SHERPA mission is the overriding concept of avoiding any additional risk to the primary spacecraft or the launch vehicle. Secondary payload mechanical and electrical designs have been addressed over the years at the Small Satellite Conference; therefore it will not be discussed in this paper.

The SHERPA is to be separated from the launch vehicle prior to any deployments. This operation enables Spaceflight to minimize the risk to the launch service provider because it is responsible for all deployments after SHERPA separation.

This separation requirement drove Spaceflight to develop a robust avionics system at a competitive price. The avionics system had to be compatible with Spaceflight's advertised launch pricing. In the end, we determined that developing our own system was the best solution.

The avionics incorporated into the 2015 SHERPA mission were kept as simple as possible and still meet mission requirements: battery, computer/sequencer, GPS and transmitter. The SHERPA system is powered off throughout the launch ascent phase (as a secondary payload itself) and activated via the separation event from the upper stage of the launch vehicle. Once initiated, the avionics perform the separation sequencing based on a timing script.

Timing the separation events was an important trade analysis. The first consideration was to avoid spacecraft re-contact. The second was to manage the forces imparted on the SHERPA because there is no system to maintain and control attitude. The third requirement was to deploy all the satellites and confirm the deployments prior to the end of battery life. Our analyses and lessons learned are documented for use in future mission planning. We have developed a separation plan that minimizes risk of contact and does so without control authority on the SHERPA.

Spaceflight also included a GPS for position knowledge and a radio to transmit telemetry as part of the SHERPA. Avionics will capture the GPS location of each separation event, and confirm deployment. The avionics provide the telemetry data to customers within 30 minutes of successful ground station pass.

The overall mission timeline is as follows:

- Separation from the upper stage of the launch vehicle
- Avionic system initiated and mission sequence timing begins
- 30 minute coast – no SHERPA activity
- Enter payload deployment sequence
- 45 minute payload deployment time
- Continue to relay telemetry over selected ground sites until end of battery life approximately 10 hours post SHERPA separation.

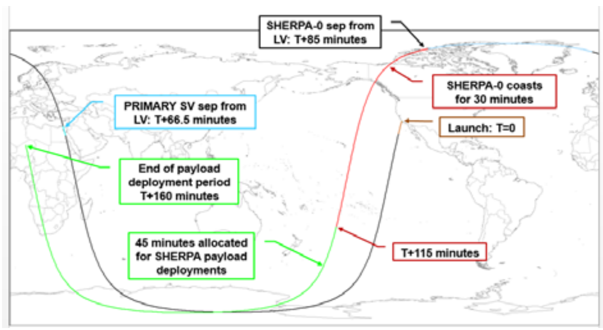

Figure 2: 2015 SHERPA Event Timeline

FLIGHT HARDWARE DESIGN TRADES

Deployment Electronics

A common challenge in aerospace is defining a set of requirements that can be met through "off the shelf" solutions. In the case of the SHERPA, Spaceflight developed electronics capable of meeting mission requirements. Requirements included the electrical inhibits required by the launch service provider to ensure no inadvertent deployments.

Figure 3: Internal view of SHERPA showing electronics

Power is a considerable challenge when there are 87 spacecraft being deployed. Both the GPS and radio must be powered, for up to 10 hours. The design solution Spaceflight selected was the CORTEX Avionics Suite. The CORTEX battery is a Spaceflight COTS unit based on lithium-ion cells purchased from Yardney.

Spaceflight also chose to keep the flight computer, or sequencer, in house. The CORTEX 160 flight computer performs the computing, command and storage functions needed for the mission.

Figure 4: CORTEX 160

Spaceflight's final piece of in-house capability is the newly developed Spaceflight Ground Station Network. Communications between the SHERPA and ground station are primarily accomplished using Spaceflight Networks. The system will be a global ground station network developed to support commercial and government satellites. It is available to Spaceflight customers on a pay per-minute basis. The network has a "bent-pipe" architecture: all ground stations are unmanned and controlled by the central network operations center located in Seattle, WA. The ground stations are connected via terrestrial fiber, and customers are given direct access (via TCP/IP) to communicate with their spacecraft during the designated communications window. Spaceflight Networks currently support communications in UHF, S, and X-bands. For commercial spacecraft, S-band uplink and X-band downlinks are used. For the 2015 SHERPA mission, Spaceflight will use three of the ground stations as well as support from NASA Wallops Flight Facility to downlink the mission telemetry.

Microsatellite Adapters

Spaceflight developed two requirements that defined the final design of the adapter plates; modular and minimal mass. Overall mass is a significant concern in the business of purchasing excess launch capacity and then selling that capacity to satellite providers. The final designs are machined aluminum plates with the minimal mass required to support the flight configuration payloads under the anticipated launch load.

For the 2015 SHERPA mission, Spaceflight is using 3 different plates and in total allows for 6 different satellite, separation or dispenser configurations. These plates are estimated to support 80% of the current customer base Spaceflight tracks.

The radial port adapter is a flat plate for microsatellites greater than 50kgs. It bolts directly to the SHERPA 24 inch port interface and can provide separation diameter interfaces of either 11.732 inches or the 15 inch Motorized LightBand. It is also capable of supporting a total mass of up to 150kg.

The plate itself is machined from one piece of aluminum alloy. The diameter is just slightly wider than the 24-inch bolt pattern at 25.75 inches; it has a total mass of 13.3kg. In addition to supporting the spacecraft, the backside of the plate is used to mount the various avionics components required for the 2015 SHERPA mission. The plate has accommodations for cable pass through.

The dual port adapter enables Spaceflight to fully utilize the volume available on a port and supports two spacecraft, each with a mass of up to 85kg. This adapter is machined from a single piece of aluminum and has a mass of 21.7kg. It attaches to the ESPA Grande ring via the 24 inch bolt hole pattern and has accommodations for both the 11.732 inch and 8 inch Motorized LightBands.

Figure 5: Dual Port Adapter

CubeSat Adapters

To date Spaceflight has flown over 76 CubeSats across a range of launch systems using a variety of different dispensers. With no slowdown in upcoming cubesat deployments forecast the QuadPack Plate was developed. It supports 7 QuadPacks per plate.

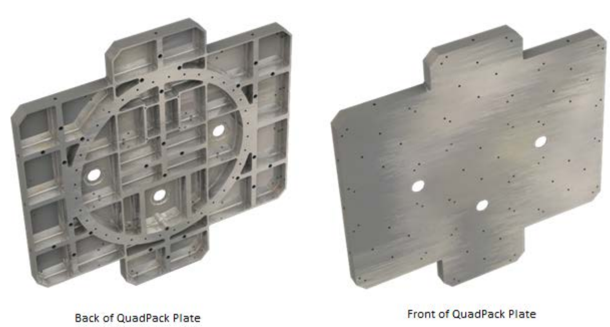

Figure 6: QuadPack Plate

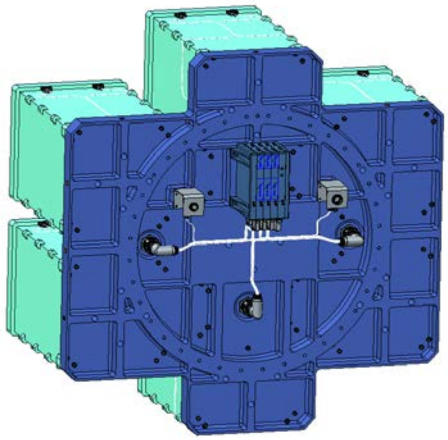

Figure 7: QuadPack Plate integrated with dispensers and electronics

The initial SHERPA is based on the ESPA Grande ring, along with a number of adapters, which are paired with Spaceflight Systems electronics. The concept behind SHERPA is to make the configuration modular. With this set of adapters and electronics Spaceflight can mix and match components to suit most any set of payloads.

HARDWARE DELIVERY AND INTEGRATION

The paper will close with a status report on the 2015 SHERPA mission. As of the paper submittal date,. Spaceflight is preparing for final integration, which will begin late this summer. Integration will cover a 45-day period and will consist of completing final integration of the payloads, shipping to the launch site and final launch vehicle integration.

Integration Facilities

Spaceflight defined a new approach to assembling an integrated payload stack such as SHERPA. Being a scrappy start up drives an innovative approach to engineering.

Spaceflight was founded on the concept of providing a service to an underserved market: small satellite launch. Spaceflight has developed the hardware, processes, and overall CONOPs within a small budget.

This small budget had to support use or the development of an integration facility for SHERPA. Typically, integration activities take place at the launch site, either at the launch service providers' facility or other launch base facilities. There were two limiting factors for Spaceflight. First, the launch service provider has a primary customer, with full access to their payload processing facility, severely limiting the time available for any secondary payloads. Second, commercial facilities located at or near the launch are extremely expensive; costs can exceed $500,000.00 for the minimum time allowed..

Spaceflight solved these issues using a different, yet pragmatic and efficient approach. Spaceflight will integrate the SHERPA into the integrated payload stack, at the Spaceflight facility near Seattle Washington.

One challenge to this approach is the logistics and cost of shipping to the launch site. While our approach is no different than that of shipping individual satellites overland, the most difficult aspect of this approach has turned out to be the Department of Transportation requirements with respect to shipment of hazardous materials. In this case, the identified hazards are the multitude of lithium ion batteries and several pressurized vessels. Although working through the hazards is time-consuming, Spaceflight will save a significant amount when compared to the cost of renting a facility at the launch site.

Our facility, created on a tight budget, complies with the basic needs of our customers and launch service provider. Our facility is Class 100K. We've also invested in hardware that supports our customer's integration logistics. In the past two months, Spaceflight completed a 725 square foot integration area for about the price of a car. This area is Class 100K compliant and includes a gantry crane. This demonstrates what can be accomplished when you solve the requirement instead of implementing the most commonly aerospace solution.

Figure 8: Newly completed Class 100K processing room

Finally, a point on how hardware is handled during integration CONOPs. Spaceflight started with a clean slate and worked with our partner LoadPath to develop a simple system of handling equipment capable of supporting not only the 2015 SHERPA mission, but also an estimated 90% of the payloads that may fly on a SHERPA system in the future.

The ground support equipment is configured in such a way that Spaceflight is able to handle adapter integration to payloads in both a horizontal and vertical configuration. This provides a great deal of versatility for our customers for their own spacecraft checkout and final preparations.

On our upcoming 2015 SHERPA mission, the QuadPacks will be integrated to the adapter while in the horizontal configuration. Once complete, the adapter plate with the QuadPacks will be mounted to the SHERPA and the CubeSats will be loaded. This reduces the number of operations where loaded QuadPacks will be handled, lowering risk of damage to the individual CubeSats.

This same flexibility is used in the CONOPs for handling and integrating the microsatellites.

Focusing on simple solutions to solve complex integration challenges led to the development of CONOPs that minimize risk and cost. This approach is now the standard that Spaceflight uses in the development of subsequent missions maintaining the ability to provide cost effective launch service support to our customers.

Fit Check

One of the first major milestones we completed was the mechanical fit check between the SHERPA, the upper stage of the launch vehicle, and the interface to the primary space vehicle. The fit check was also used as an opportunity to test out the processes and handling equipment, further reducing mission risk.

The mechanical fit check was a success. Spaceflight demonstrated that the hardware fit and the handling equipment was built appropriately. Additionally, a set of volume simulators was produced. These volume simulators allowed the team to assess the access, or lack thereof, to the SHERPA when fully integrated with payloads. While it seems simple, the addition of the volume simulators helped refine procedures, consequently avoiding time loss during the launch campaign.

Figure 9: SHERPA fit check with volumetric models

Schedule

When utilizing a mix of in-house and commercial off the shelf components, organizing the delivery schedule can be a complex task. Some items have been available for years. In house products have EDU's available for testing. Other flight hardware is delivered just in time for the launch, in order to minimize time spent in storage.

The ESPA Grande ring has been on site for quite some time. As of June 1, 2015, all of the adapter plates have arrived and been verified for fit. Planetary Systems has delivered the 3 Motorized LightBands for the microsatellites.

Figure 10: Flight QuadPack Plate

Figure 11: Flight dual payload adapter

Figure 12: Flight radial plate adapter

Avionics and software are going through test. They have already demonstrated their capability to send deployment signals to the QuadPacks.

All that remains are a few ground support items and the QuadPacks. These are all scheduled to arrive by August, leaving Spaceflight with a comfortable schedule margin prior to the first spacecraft arriving at the end of October for integration.

FUTURE SHERPAS

There are several future SHERPA missions in the works, one in 2017 and two more in 2018. While Spaceflight is maintaining adherence to the standards adopted from industry, there are expected upgrades.

Propulsion is a key enabler for the SHERPA concept. Spaceflight is developing a plan to implement a series of SHERPAs with increasing delta V capability to support missions requiring altitude change and long-term orbit maintenance.

In addition, the SHERPA serves as the perfect platform for hosted payloads. It is unique in its hosting capability, as the hosted payload essentially gets a dedicated spacecraft bus following secondary payload deployment. This means that the hosted payload is actually the primary payload with full access to power, pointing and communication.

SHERPA is based on the ESPA Grande ring, but the concept is tailorable to any number of adapter concepts. In 2015, Spaceflight began to explore adapters that provide additional configurations and mass saving features that will only enhance Spaceflight's ability to successfully manifest secondary payloads, taking advantage of the wealth of excess lift capacity that has gone unused for years. Time will tell what the future capabilities of SHERPA will be after its historical first launch in 2015.