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SETTING THE STANDARD: LAUNCH UNITS FOR THE SMALLSAT ERA

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Abstract

Over the next ten years, more than 6,000 smallsats are expected to launch, an over six-fold increase from the previous decade. As the smallsat market grows, launch remains the main bottleneck to timely and affordable access to space. Currently, most smallsats are launched as secondary payloads when there is excess space in a launch vehicle. In addition, every deployment must be specifically designed for each smallsat. The capabilities and agility of the smallsat industry would be greatly enhanced by the implementation of a smallsat launch standard. This standard would address the physical properties of the smallsat (size, volume, vibrational modes) as well as the mechanical and electrical connections to the launch vehicle. This paper explores the benefits of defining a launch standard for medium-class (25-200 kilogram) smallsats and provides options for its development.

Introduction

In recent years, small satellites (or smallsats) having masses between 25 and 200 kilograms (and occasionally up to 500 kg) have proven to be invaluable in the space domain. Providing new capabilities and benefits to industry, academia, and government agencies alike, the smallsat has encouraged the space community to reframe its ambitious mission objectives. However, the overwhelming variety of smallsats in orbit and on the market may diminish the promise of rapid access to space – one of the primary justifications for the emergence of smallsats in the first place. Now, users have begun to advocate for smallsat standards, driven by trends in average satellite size and the push for low-cost and responsive access to space.

This paper explores these trends and discusses how the implementation of a smallsat standard will benefit smallsat manufacturers, launch providers, government satellite acquisition programs, and other stakeholders. A coalition of industry leaders aims to select a smallsat standard, called a Launch Unit, by the end of 2018.

Trends in Satellite Size

Since the beginning of the Space Age, the average satellite form factor has changed drastically. After the launch of early missions that were mostly experimental (e.g., the 80-kg Sputnik[1]), satellites tended to be heavy and large. Mission designs were motivated by satellite capacity and capability, and not necessarily by cost or schedule. Over time, increasing emphasis was placed on rapid and low-cost development of spacecraft.[2] Satellite components miniaturized and became cheaper and more efficient, eventually leading to the CubeSat boom in the early 2000s.[3] This boom was in part due to the standardized CubeSat form factor (10 cm x 10 cm x 10 cm = 1.33 kg = 3 lbs). Altogether, these drivers lowered the barrier to entry for newcomers, both financially and technologically.

Now, designers have run into obstacles when they desire their CubeSats to have even more capabilities (for example, orbit maintenance or high-precision pointing) to achieve more complicated mission objectives. A smallsat is loosely defined as a satellite between 25 and 200 kilograms (in some definitions, up to 600 kilograms), and is more conducive to opportunistic missions than a CubeSat.

Compared to larger satellites, smallsats have lower overall launch costs. Smallsats can reduce manufacturing costs by incorporating commercial off-the-shelf parts and providing appropriate size, weight, and power required for a mission's goals.[4] They have shorter design cycles, allowing for more frequent technology insertion and faster innovation.[5] In fact, smallsats are so popular that a six-fold increase in the number of smallsat launches is expected in the next decade.[6]

Today, the variety of smallsat sizes and shapes is dizzying.[7] There is little guidance on the form factor of the many medium-size smallsats in the pipeline. This is in contrast to the CubeSat form factor and some effort to standardize the larger satellites (e.g., via the ESPA-ring, or the EELV Secondary Payload Adapter-ring).[8]

Trends in Access to Space

As smallsats have increased in popularity, many stakeholders (launch providers, satellite manufacturers, governments) have advocated for low-cost access to space (LCAS), not only as an avenue to reduced costs and time-to-launch, but also to encourage resilient architectures in orbit and on the ground. A "freight-train-to-space" would provide a standard schedule, standard configurations, and known pricing, while ferrying a variety of cargo.[9] High-launch availability and flexibility are critical aspects of achieving low-cost access to space. The ability to swap out launchers and payloads on short notice is key for resiliency and addresses some of the shortcomings of modern launchers.

The Promise of a Smallsat

Smallsats have found success in many mission areas, owing to their price points and capabilities. Notably, much of smallsat demand is driven by constellations for communications and Earth observation.[a] Constellations can provide constant 100% global coverage in low Earth orbit. They can be reconstituted; if a single node of the constellation is lost the constellation can continue to function in its absence and, if necessary, the cost of a replacement node is relatively low. Here, we list a few examples of applications.

Communication: SpaceX plans to launch a constellation of over 4,000 smallsats over five years that will bring Internet to every corner of the globe. Launches are planned to begin in the early 2020s.[b]

Earth observation: In 2017, Planet launched 88 Dove satellites. By May 2018, Planet has over 150 Dove, SkySat, and RapidEye satellites on orbit. This puts Planet well on track to its goal of imaging the entire Earth daily.[c]

Planetary science: LunaH-Map (Lunar Polar Hydrogen Mapper) will launch as a secondary payload on the Space Launch System in 2020. LunaH-Map will determine hydrogen abundances on the surface of the moon and learn about the nature of the moon's permanently shadowed regions.[d]

Technology development: Smallsats provide an opportunity to move a particular technology across technology readiness levels. The CubeSat Proximity Operations Demonstration (CPOD) project is one such example. The flight will characterize miniature low-power proximity operations with applications to future on-orbit servicing and assembly missions.[e]

[a] Euroconsult, "Prospect for the Small Satellite Market," (Jul. 2017); http://www.euroconsult-ec.com/shop/space-industry/95-smallsats.html.
[b] C. Henry, "SpaceX, OneWeb detail constellation plans to Congress," Space News (Oct. 2017); http://spacenews.com/spacex-oneweb-detail-constellation-plans-to-congress/.
[c] S. Erwin, "With six new satellites and more coming planet looks to disrupt high res imagery market," Space News (May 2018); http://spacenews.com/with-six-new-satellites-and-more-coming-planet-looks-to-disrupt-high-res-imagery-market.
[d] "LunaH-Map spacecraft," ASU (2016); http://lunahmap.asu.edu/.
[e] "Cubesat Proximity Operation Demonstration Fact Sheet," NASA (2015); https://www.nasa.gov/sites/default/files/ atoms/files/cpod_fact_sheet-19apr2017-508.pdf.

Part of the solution is to more efficiently use launch capacity. In 2013, 47 of 82 attempted launches had excess payload mass capacity.[10] This excess mass capacity and unused volume could be used to carry secondary or "rideshare" spacecraft. The ESPA-ring, first launched in 2007, fits underneath a primary spacecraft, can hold and deploy multiple secondary payloads, and has spawned a class of 180-kilogram small satellites colloquially called “ESPA-class” satellites. Another example is the Aft Bulkhead Carrier, which occupies the excess space behind an Atlas V launch vehicle’s upper stage. For CubeSats, there is an array of launchers and carriers such as the P-POD (Poly Picosatellite Orbital Deployer) and the Naval Postgraduate School Cubesat Launcher (NPSCul), which can fit into both an ESPA ring port and onto an Aft Bulkhead Carrier.[11]

Even if launch volume is efficiently utilized, secondary payload owners still face a host of challenges. Smallsats generally lack propulsion (though the technology evolves every day) since a fueled secondary payload on board may pose unnecessary risks to the primary payload. As a result, ridesharing satellites are often confined to the orbit of the primary payload on board. Furthermore, launch vehicle failures and delayed schedules have a significant effect on the missions of all the payloads slated to fly on that vehicle. In fact, an AIAA Conference on Small Satellites survey reported that half of the 300 conference attendees saw space access as a bigger concern than payload/bus capability and advancements in ground architecture.[12]

Some companies have developed smaller launch vehicles that could be launched more frequently (on the order of 100 times a year), thereby providing more launch opportunities for smaller satellites.[13] This approach has been advocated for many years by the Satellite Industry Association’s State of the Industry reports as the number of satellites seeking launch opportunities has outpaced launch rates.[14] However, the engineering and design of a small launcher is more complicated than scaling down that of a large launcher, and the cost of a dedicated launch vehicle can still outstrip the resources of smallsat developers.[15] Even if small launch vehicles become more prevalent and less expensive, smallsat developers still benefit from designing to standards that make them easily interchangeable between launch opportunities.

The Need for a Standard

The development of a standard smallsat form factor, or Launch Unit, can play a pivotal role in achieving high-launch availability and flexibility.

Many studies have concluded that standards can effectively coalesce an emerging market like the smallsat market. As discussed in Piskorz & Jones (2018),[16] standards encourage compatibility and interoperability and avoid lock-in of old technology by allowing simultaneous use of evolving components. Standards enable product variety and competition and build cohesion and critical mass in markets. Finally, standards lower the barriers to entry and lower risk associated with new enterprises. Examples of successful standard adoption include the Universal Serial Bus (USB), intermodal shipping containers, and the CubeSat form factor itself.

The Development of the CubeSat Standard[a]

The CubeSat standard (10 cm x 10 cm x 10 cm = 1.33 kg = 3 lbs) began development in 1999, early enough that the market had not yet matured and it was easy for a standard to take hold. Developers, including Stanford University and California Polytechnic State University, saw a distinct community need for cheaper satellites with shorter design cycles. The CubeSat program essentially chose the CubeSat form factor for the industry, “drew the bull’s eye around it,” and strongly encouraged the community to conform. The CubeSat’s popularity was aided by the availability of commercial off-the-shelf parts and a path to launch facilitated by California Polytechnic State University, The Aerospace Corporation, and others. The P-POD (Poly Pico-satellite Orbital Deployer) played and continues to play a critical role in hosting CubeSats within various launch vehicles and maintaining low launch costs.

[a] J. Puig-Sauri, C. Turner, and R.J. Twiggs, “CubeSat: The Development and Launch Support Infrastructure for Eighteen Different Satellite Customers on One Launch,” 15th Annual AIAA/USU Conference on Small Satellites (Aug. 2001).

The CubeSat standard not only paves a clear path for satellite manufacturers but also eases the delivery of satellites into space by various launch vehicles (Figure 1). For example, CubeSat dispensers can be stacked as payloads in small satellite launchers or co-manifested with other primary payloads. Every deployment does not have to be specifically designed for each CubeSat. Since CubeSats are modular, they can be added to a manifest fairly late in the launch campaign or swapped out as necessary.

Similar to the CubeSat standard, a smallsat standard can positively influence the industry by reducing integration costs, maximizing launch fairing efficiency, and decreasing time to launch. A "rising tide lifts all boats," and straightforward access to launch vehicles, cargo, and satellites benefits launchers, satellite manufacturers and end users alike.

Previous and Current Standard Work

In 2013, the Express Class was proposed, a class of satellite having a mass between 20 and 50 kg and a size of 88,000 cubic centimeters.[17] Bounding load cases, electrical interfaces, separation protocols, electromagnetic interference, and a timeline for mission integration, safety, and compatibility were considered in choosing this configuration of mass, volume, and center of mass. However, enthusiasm for the standard fizzled when it failed to garner sufficient buy-in from industry partners.

The Aerospace Corporation is currently leading a team of government officials, satellite manufacturers, launch vehicle manufacturers, launch brokers, launch range operators, and other stakeholders to foster an industry consensus on the first official smallsat form factor, called a Launch Unit (Figure 2). In doing so, Aerospace, a non-profit organization, is not vested in any design standard that interfaces with a specific launch vehicle, adaptor system, or satellite. Kicked off at the Small Sat Conference in Logan, Utah, in August 2017, the group's recommendation will be announced at the same Small Sat Conference in August 2018.

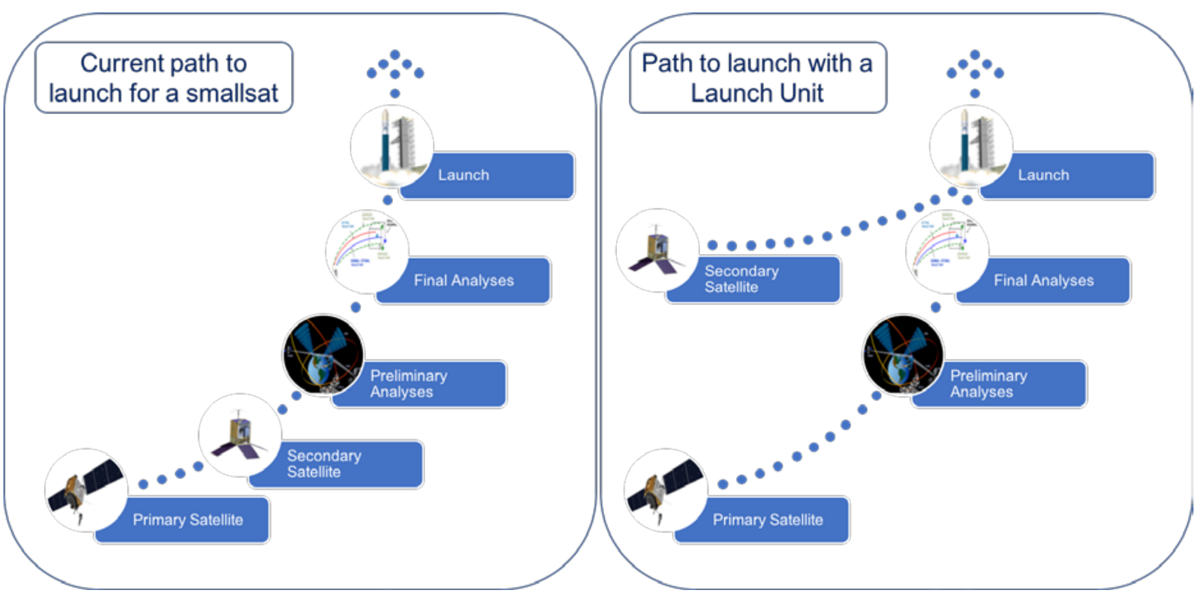

Figure 1: Current and future launch paradigms. Ideally, a standard smallsat form factor would allow a smallsat to be designed and built without knowledge of its launch vehicle.

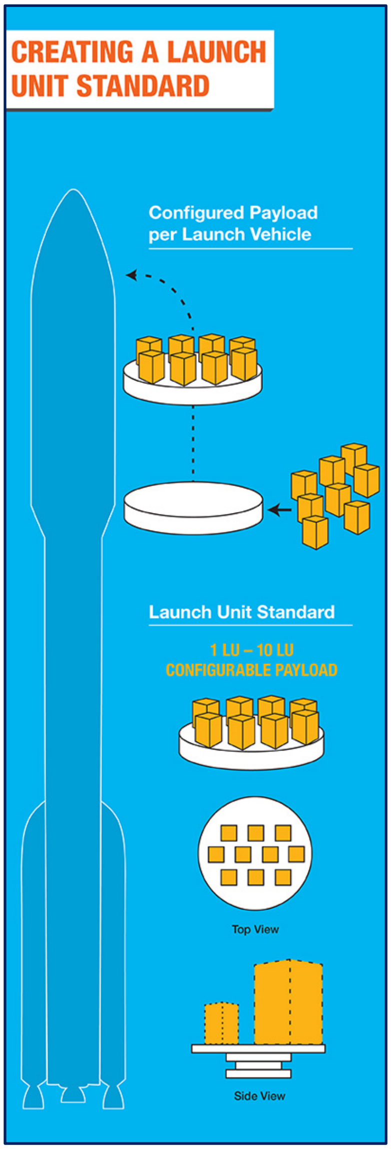

Figure 2: Launch Unit concept.

Policy Obstacles

There are obstacles that may hinder widespread acceptance of the Launch Unit standard. A few examples follow.

Standard Implementation. There are multiple avenues to standardization: standards development organizations, consortia, or *de facto* industry standards. (See Piskorz & Jones 2018 for further discussion.) The Launch Unit initiative is best described as a consortium, an association of private and public stakeholders in the smallsat ecosystem discussing best practices and factors to consider while selecting a standard.

However, Aerospace will not necessarily manage or enforce adoption of the Launch Unit in the same way that the CubeSat standard is maintained by Cal Poly. An option might be to turn to the American Institute for Aeronautics and Astronautics (AIAA), which is accredited by the American National Standards Institute (ANSI) and efficiently manages many aerospace industry standards. In the best-case scenario, the Launch Unit standard would be disseminated and used internationally by all small satellite manufacturers and launches.

Standard Acceptance. Many satellite manufacturers are already invested in their own smallsat designs. Piskorz & Jones (2018) emphasized that the timing of standard implementation is crucial. Space Universal Modular Architecture (SUMO) and the CubeSat form factor are two examples of this point. SUMO sought to standardize satellite buses when the satellite market was very mature and has failed to gain widespread adoption. Conversely, the CubeSat form factor was implemented when the CubeSat field was still green. Therefore, it is critical that the smallsat form factor be developed and adopted quickly, before the smallsat field itself becomes too diverse. That point is rapidly approaching, and it may be difficult for the Launch Unit to take hold, especially given previous experience with the Express Class. The need for standardization could decline if diversification of the launch market results in more smallsat missions being flown on dedicated launchers rather than as rideshares. However, this iteration of a smallsat standard is different in that it is supported by many different facets of the smallsat community.

Export Control. National policy and export control regulations state that sensitive satellite components cannot be launched on foreign launch vehicles (or foreign launch ranges) without a license and that

U.S. government satellites must use U.S. launchers unless they obtain a White House-level waiver.[18] These regulations would hinder foreign entities' willingness to adapt to the standard and prevent widespread *international* acceptance of the Launch Unit. If only the U.S. adopts the Launch Unit and U.S. satellites must use U.S. launch vehicles, there is little incentive for foreign launch vehicles to adapt to the Launch Unit for the sake of drawing business from U.S. satellites alone. This could put U.S. satellites at a great disadvantage.

Government Buy-In. Just as important as commercial buy-in is government buy-in. A Launch Unit furthers the industry's ability to rapidly prototype and fly design concepts. This capability is at the fore of the "freight-train-to-space" concept and could help enable the U.S. government's objective of more resilient space systems.

Space Congestion. It is possible that a smallsat standard will lead to more demand for smallsats on orbit. This increases opportunities and profits for launchers, satellite manufacturers, government customers, and commercial users alike. However, more satellites on orbit will inevitably lead to more congestion on orbit, in terms of both spectrum allocation and orbital debris.

Rideshare Policy. The emergence of a Launch Unit for smallsats will increase the number of rideshares to orbit. Rideshare plays a key role in keeping launch costs low, and a core tenet of rideshare policy is that secondary payloads shall do no harm to primary payloads.

Excess Launch Volume Ownership. A key question that has not been widely addressed is who owns excess launch capacity? Arguments could be made for either the launch vehicle owner or the primary payload owner. The success of the rideshare paradigm hinges on clarity in this regard. There has been movement in the Air Force recently to establish a multi-manifest organization, which would own all launch capacity, and thus be able to make launch assignments for both primary and rideshare missions. Such an organization would "own" the excess launch capacity, rather than either the launch vehicle or the primary mission.

Transparency in Regulatory Regimes. As discussed in Sims & Braun (2017),[19] many aspects of the path to launch and policy compliance for smallsats, even aside from interfacing with the launch vehicle, are vague. This includes current regulation of orbital debris, spectrum allocation, cybersecurity, and imaging. Clear regulations are especially critical in a Launch Unit era, where one expects smallsat launches to increase significantly. In fact, standardization of the smallsat form factor could contribute to streamlining the regulatory process.

Conclusion

Based on trends in satellite sizes and the push for low-cost access to space, The Aerospace Corporation has taken on a key role in the development of a standard smallsat form factor, or Launch Unit. The Launch Unit pushes the smallsat community toward an ecosystem where one could build a satellite without knowing its launch vehicle or where one could swap out launch vehicles or payloads on launch day. The implementation of the Launch Unit would seriously impact the development and success of the smallsat industry.

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