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# Experience Launching Smallsats with Soyuz & Vega from the Guiana Space Center

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## ABSTRACT

Arianespace pioneered dual and multiple launches of small satellites ("smallsats") since its founding over three decades ago. The experience gathered through over 200 multi-payload commercial missions has provided key insights into making smallsat launches a viable business. Recently, two new launch systems were added to the Arianespace family at the Guiana Space Center ("CSG") in South America. The legendary Soyuz and new light-weight Vega launch systems are opening up new opportunities for smallsats. Both the Soyuz and Vega carried out successful missions with smallsats including: the Pléiades mission with ASAP-S, aboard the second Soyuz flight from CSG (VS-02) in December 2011, the maiden Vega flight (VV-01) in February 2012 with LARES and a variety of smallsats and cubesats, as well as the second Vega flight with Proba V, VNREDsat-1 and ESTCube-1. Future Soyuz and Vega launches from the CSG in 2014 and beyond, will add invaluable experience for co-manifesting and orbiting smallsats. Over the past 32 years Arianespace has learned important lessons regarding scheduling, contracting, technical complexity and the need for back-up planning when launching smallsats. In the future, increasing launch rates for Soyuz and Vega in the 2014-2020 timeframe should provide critical new capacity for the smallsat sector.

## DEFINITION:

Before discussing the smallsat market, its needs and opportunities, it is important to define what constitutes a "small satellite". As the market has evolved, the definition of what is a small satellite likewise evolved. A decade or two ago, launching as an auxiliary payload aboard Ariane 4, a small satellite was considered to be in the 10-50 kilogram mass range. As the demand evolved toward more capable smallsats, along with increased launch system performance to accommodate ever larger spacecraft, the definition of a small satellite grew to 50-150 kilograms during the last decade. Nowadays, Arianespace considers "small" any satellite below 300 kilograms.

## HISTORY:

Founded in 1980, Arianespace is the world's first commercial launch company providing a wide range of space transportation services. As the industry leader in commercial space flight, Arianespace has flown numerous record-setting missions throughout its history, including the first dual satellite launch in 1982 employing a carrying structure and the first fully commercial launch in 1984 for U.S. satellite operator GTE Spacenet. Arianespace is a privately-held European company with 21 shareholders from 10 different countries. Since the first Ariane 1 launch in 1979, more than 400 payloads have been placed safely into orbit by Arianespace. Today three launch systems -- Ariane 5, Soyuz and Vega -- are operated from secure NATO-allied territory at the CSG in Kourou, French Guiana.

**Figure 1: Guiana Space Center**

Arianespace has been operating from the Guiana Space Center since its creation. Arianespace's history is tightly linked to the establishment of the Ariane launch program. Over 32 years later, Arianespace now has experience launching payloads to nearly every type of orbit – Sun-synchronous, Low Earth Orbit (“LEO”), ISS rendezvous, Earth-escape, Lagrange, Medium Earth Orbit (“MEO”) and Geostationary Transfer Orbit (“GTO”). With the combined experience of launching seven different launch systems (Ariane 1-5, Soyuz, and Vega), and the successful integration of satellite platforms from nearly every spacecraft manufacturer, Arianespace has a broad base of experience to draw on for small satellite missions. Moreover, Arianespace wrote the first commercial launch contract and understands well customer needs when it comes to launching on-time.

For over three decades Arianespace has operated the Ariane launch vehicle family, from Ariane 1 (created in the 1970s) to the current workhorse Ariane 5 ECA. The Ariane 1 was first used to put into LEO or GTO payloads weighing less than 1,850 kilograms. Although a 1,850 kilogram geostationary satellite appears relatively light today, this class of satellites was considered heavy at the time. Ariane 5’s capacity now allows it to put much heavier payloads into GTO topping over 10,500 kilograms of mass including adaptors and over 21,000 kilograms of mass into LEO-ISS transfer orbit.

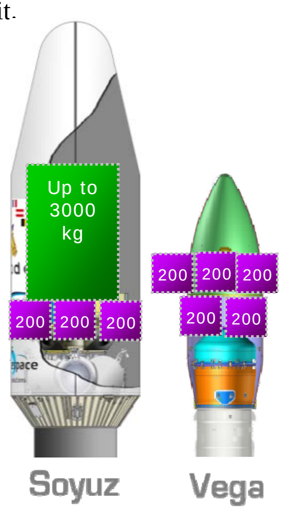


**Figure 2: Soyuz and Vega Payload Configuration**

Ariane is the first launcher family enabling the dual launch of satellites on the same vehicle as a standard. Dual launch systems were jointly developed by Arianespace and CNES on the initial Ariane-class launch systems. The SYLDA (the French acronym for Ariane Dual Launch System) was first created for Ariane 1, 2 and 3 as an internal carrying structure under the fairing. When Ariane 4 was first flown, a new system was implemented, the SPELDA, an external dual launch carrying structure for multiple payloads. For Ariane 5, the light-weight carbon fiber SYLDA is in use today for all dual launches of large satellites to GTO. Another multi-payload system was developed and flown on the early Ariane 5 flights called the SPELTRA. The SPELTRA allowed up to three potential primary satellites to be launched on the same Ariane 5. It was never used commercially.

Arianespace invented the first multiple small satellite carrying structure called the Ariane Structure for Auxiliary Payloads (“ASAP”) in 1988 to fly on the Ariane 4. The first ASAP was used during Flight V35 to launch the Spot-2 satellite for Spot Image, with six other auxiliary payloads (UoSAT-D, UoSAT-E, AMSAT Oscar 14, 15, 16 and 17). This first ASAP system was used to launch smallsats limited to 200 kg of total performance accommodated on up to six positions. The ASAP system was later adapted for use with the Ariane 5 in order to provide the same service for even heavier and more numerous (up to eight) smallsats after the Ariane 4 was retired. The main problem was that many customers with smallsats were not interested in flying to GTO, the primary market for Ariane 5 flights carrying two communications satellites.

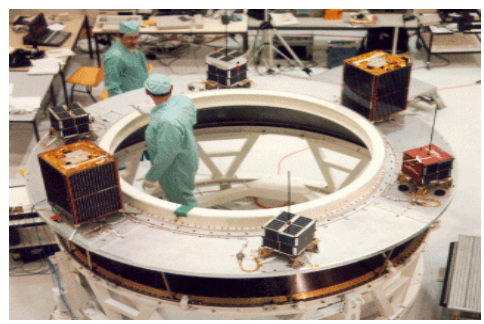

**Figure 3: ASAP System**

In recent years, Arianespace has expanded our family of launch systems to include both the medium-class Soyuz and light-weight Vega launch systems flown from CSG. The introduction of the Soyuz and Vega allows, once again, Arianespace to propose innovative launch services for smallsats.

**A FAMILY OF LAUNCHERS:**

In addition to the mainstay Ariane 5 launch system, Arianespace has invested significant resources to flying the Soyuz and Vega from new and refurbished launch pads at the CSG. Recent successful missions prove the capacity of those two launchers to meet current market expectations. For the last few years, Soyuz has shown its reliability in carrying smallsats to their desired orbit, having achieved two launches with Galileo In-Orbit-Validation (“IOV”) satellites, two launches with Pleiades, including one with the ASAP-S system (six payloads in total) and the launch of four O3b satellites in June 2013.

Vega, with a design tailored for smallsats to Low Earth Orbit ("LEO"), achieved full success in its maiden flight on February 13, 2013, placing LARES, ALMASAT-1 and multiple cubesats into LEO. This first flawless Vega launch, under the authority of the European Space Agency ("ESA") for qualification, has given Arianespace additional experience in launching different small payloads, including cubesats, on the same launch system. The second Vega launch performed on May 6, 2013, was also a complete success placing three payloads on different orbits thanks to the Vega Secondary Payload Adaptor ("VESPA") multi-satellite carrying structure and the re-ignition capability of the AVUM upperstage. The Vega with VESPA offers multiple potential configurations of several smallsats with masses ranging from 50 to 200 kilograms.

**EVOLUTION:**

Because the primary mission for Ariane 5 continues to be flights of ever larger satellites to geostationary transfer orbit – generating limited interest from the small satellite community, Arianespace has stopped flying the ASAP system on our largest launch system, the so called ASAP-5 system. However, the corresponding market can now take the opportunity to use both the Soyuz and the Vega for these types of missions using the ASAP-S ("S" for Soyuz) and the VESPA systems.

Soyuz is currently being used for energetic MEO constellations deployments such as Galileo and O3b. However, Soyuz from CSG is also slated for upcoming LEO/Sun-synchronous missions, and for high energy-escape orbits flights. The aim for Soyuz operations to LEO is to launch bigger satellites not fitting on Vega, mainly for dawn dusk SAR radar missions, or to allow a dual launch accommodation of two main Vega class satellites (1 ton class). With the ASAP-S structure, Soyuz can also carry up to five smaller auxiliary satellites with a main passenger to LEO, as demonstrated with the launch of Pléiades 1A.

Vega can provide launch opportunities for a wide range of smallsats to reach their desired orbit, using the VESPA structure, with the main passenger placed in the top position while the small satellite(s) occupies(y) the lower position beneath the VESPA. It is important to note that such dual or multiple launch missions are generally constrained by target orbits, local times, and the necessity to respect the regulations for debris on orbit (de-orbiting of the AVUM upper stage for instance). Building a launch with multiple payloads on board requires Arianespace to design the mission around these technical elements and according to the performance capabilities of the Vega launch vehicle.

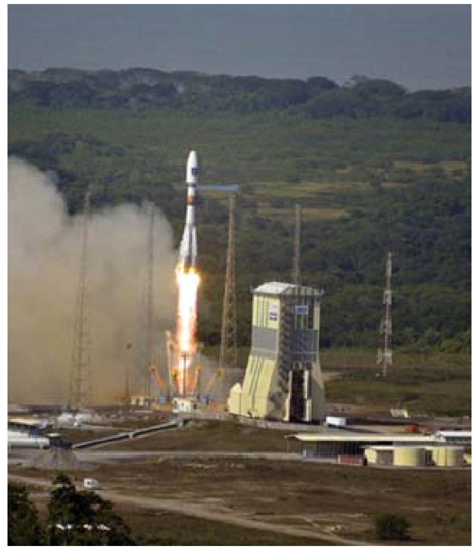

**Figure 4: Soyuz**


**Figure 5: Vega**

**RECENT MISSION EXPERIENCE:**

Soyuz with Pléiades and ASAP-S: Five small satellites (120-150 kilogram class) with Pléiades main mission. Four satellites (ELISA mission) were placed on the four external positions around the ASAP-S structure and separated two by two on almost the same orbit following the separation of Pléiades. Note that sufficient time was allocated for collision avoidance and proper distancing between all separated bodies. The fifth satellite, SSOT for Chile, was placed in the central position beneath the ASAP-S structure and separated later at a lower altitude SSO following two additional Fregat burns with ballistic phases in between. The total duration of the mission was approximately three hours, with the largest part devoted to the injection of the fifth satellite.

Soyuz VS-05: With the initial four satellites for the O3b broadband MEO constellation.

Vega VV01: Vega Maiden flight: the specific accommodation set up for this flight incorporates the central mission, LARES, representing the bigger portion of the payload with its four pod structure to carry and separate this heavy geodesic ball. A plate dispenser was implemented with a microsatellite (Almasat1), seven Cubesats in three canisters, and specific instrumentation to exhaustively monitor the mechanical and thermal environment during the flight. LARES was separated on a high altitude circular inclined orbit (above 1450 kilometers) following two ignitions of the AVUM upper stage. All the other satellites were released on an elliptical orbit with a low perigee, obtained after a third ignition of the AVUM stage (note that the second VEGA flight, VERTA 1, included five upper stage firings).


**Figure 6: Vega's Second Launch Proba-V atop of the VESPA**

**Table 1: Vega's first Flight (VV01) Time Line**

| Mission Events | Rebuilt (s) | Measured (s) | Delta (s) |
|---|---|---|---|
| **P80 Ignition** | 0.0 | 0.0 | 0.0 |
| **P80 Separation** | 114.5 | 112.5 | - 1.9 |
| **Z23 Ignition** | 115.1 | 113.5 | - 1.6 |
| **Z23 Separation** | 201.9 | 200.3 | - 1.6 |
| **Z9 Ignition** | 218.5 | 216.5 | - 2.0 |
| **Fairing Jettison** | 223.5 | 221.5 | - 2.0 |
| **Z9 Separation** | 347.0 | 349.2 | + 2.3 |
| **First AVUM Boost** | From 354 for 180.9 s | From 357 for 185.4 s | + 4.5 |
| **Second AVUM Boost** | From 2,889 for 242.4 s | From 2,888 for 231.9 s | - 10.5 |
| **LARES Separation** | 3,299.0 | 3,293.2 | - 5.8 |
| **Third AVUM Boost** | From 4,092 for 138 s | From 4,091 for 134.8 s | - 3.2 |
| **CubeSats & ALMASat1 Separation Sequence** | From 4,231.0 | From 4,225.3 | - 5.7 |

Vega VV02: VERTA-1 flight with Proba V in the upper position, VNREDSat-1A and ESTCube-1 inside the VESPA carrying structure. This second Vega was successfully launched from Kourou on May 6, 2013 at 23 h 06 mn 31 s Kourou time (02 h 06 mn 31 s UTC on 7th May).

The first evaluations of the Launch Vehicle orbital parameters, just after the AVUM burns cut-offs, are the following:

**See Tables 2 & 3 on the following page**

**Table 2 & 3: Vega's second Flight (VV02) Orbital Parameters**

| Orbital parameters at the end of the second AVUM boost (Before Proba-V separation) | 1st Evaluation | Predicted Min | Predicted Nominal | Predicted Max |
|---|---|---|---|---|
| Semi-major axis (km) | 7198.2 | 7179.3 | 7197.9 | 7216.5 |
| Eccentricity | 0.00112 | 0.00000 | 0.00118 | 0.00268 |
| Inclination (°) | 98.73 | 98.69 | 98.73 | 98.77 |

| Orbital parameters at the end of the fourth AVUM boost (before VNREDSat-1 and ESTCube-1 separation) | 1st Evaluation | Predicted Min | Predicted Nominal | Predicted Max |
|---|---|---|---|---|
| Semi-major axis (km) | 7044.9 | 7014.8 | 7044.8 | 7074.8 |
| Eccentricity | 0.00120 | 0.00000 | 0.00116 | 0.00716 |
| Inclination (°) | 98.14 | 97.75 | 98.14 | 98.53 |

***Lessons learned:***

1. Be ready for launch before the main passenger
2. Understand the contractual elements, commitments of the launch provider and your priority
3. Adapt to the complexity of different altitudes, local time and disposal constraints
4. Employ mass simulators to ensure that multiple mission analysis is not needed

## FUTURE MISSIONS:

Arianespace believes the small satellite market is evolving rapidly as technical gains have made smaller platforms more capable and flexible. Arianespace sees a range of smallsats looking at LEO opportunities orbits in the 50-300 kilogram mass range to serve a wide range of present and new applications. Arianespace is working to tailor the ASAP-S and VESPA configurations to accommodate those missions on two to four flights per year. Vega is optimized for these missions with secondary payloads mostly in the lower position on VESPA.

## CUBESAT CONCERNS:

Launch services providers cannot easily and efficiently use scarce resources and engineering capabilities for a cubesat treated as an independent payload. Arianespace is looking to aggregators that can package multiple cubesats into dispensers that represent a more conventional 50-300 kilogram small payload as an efficient way to fly on Vega with VESPA or on Soyuz with ASAP-S. Cubesat launch aggregators can more efficiently work to ensure for on-time launches of multiple units and ensure that mass simulators are available to conform to the primary coupled loads analysis prepared for each mission.

## CONCLUSION:

Arianespace provides tailored solutions for small satellite launches aboard Soyuz with the ASAP-S and Vega with the VESPA structure. Arianespace invented commercial dual / multiple launch and continues to refine the concept for launch systems that will fly regularly to orbits preferred by small satellite operators. In order to make multiple launches profitable on a commercial launch system, Arianespace requires flexibility from small satellite operators so that ride sharing makes sense for all parties involved.

Small satellite operators need to understand and respect the constraints posed by pairing multiple missions on a single launch system. Understanding the limits posed by launch date, orbit/altitude and local time is the first step to working towards an effective launch solution. Contractual rights and launch priority are the next main consideration for small satellite operators. Finally, small satellite and cubesat payloads must have mass simulators available to ensure that they do not delay the primary mission.

Increasing launch rates for Soyuz and Vega at CSG will provide ample opportunities for small satellite launches in the 2015 to 2020 timeframe and beyond. Small satellite operators eager to place their payloads into orbit must prepare for the scheduling, contractual and technical challenges if they are to access space successfully.