Environmental Monitoring of the Amazon Basin with a Low Cost Small Satellite Constellation in Equatorial LEO

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ABSTRACT

A low cost satellite constellation is presented for environmental monitoring of the Amazon region with unprecedented performance-to-cost ratio. The constellation design is based on the unique characteristics of the small Brazilian launcher VLM-1. Launched from the near-equatorial Alcantara base, the vehicle allows for direct injection of small payloads in equatorial LEO (E-LEO), i.e. a low Earth orbit with zero (or near-zero) inclination. Such orbital configuration is actually used very seldom because of its limited ground coverage, which is restricted to equatorial regions only, while near-polar configurations (inclination close to 90 deg) allow for ample coverage of most of the planet surface. Almost all Earth Observation (EO) missions are therefore placed in polar orbits.

Countries in the tropical regions are not well served by a conventional, high inclination LEO satellite, due to the less-than-optimal coverage and residency period over the equator. Satellites in the geostationary orbit (GEO) are also non optimal for EO, because of the heavy bandwidth congestion due to the large telecom traffic, not to mention the limited optical resolution that can be achieved from GEO.

The use of the equatorial LEO orbit, instead, can provide excellent coverage for geographical areas around the equator. One satellite in E-LEO can provide about 14 passes a day over any location on the equator, with every pass being essentially an overhead pass lasting several minutes. With a constellation of 6 or more satellites, continuous service could be provided for countries lying between the Tropic of Cancer and the Tropic of Capricorn. The regions to benefit are ASEAN countries (Singapore, Malaysia, Thailand, Philippines, and Indonesia), Southern India, North Africa, Central America, Pacific basin countries and Northern Australia.

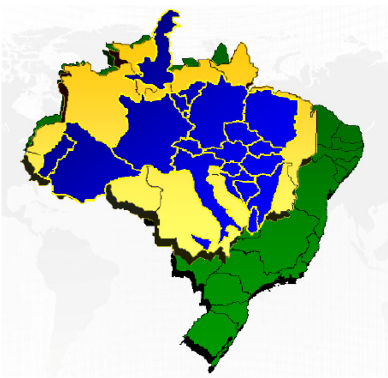

Fig. 1. Legal Amazon (in yellow. A map of western and central Europe is shown for size comparison)

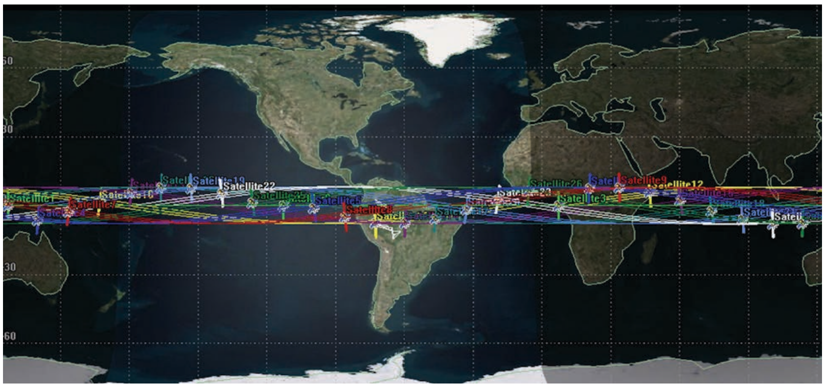

Fig. 2. One of the possible constellation configurations studied.

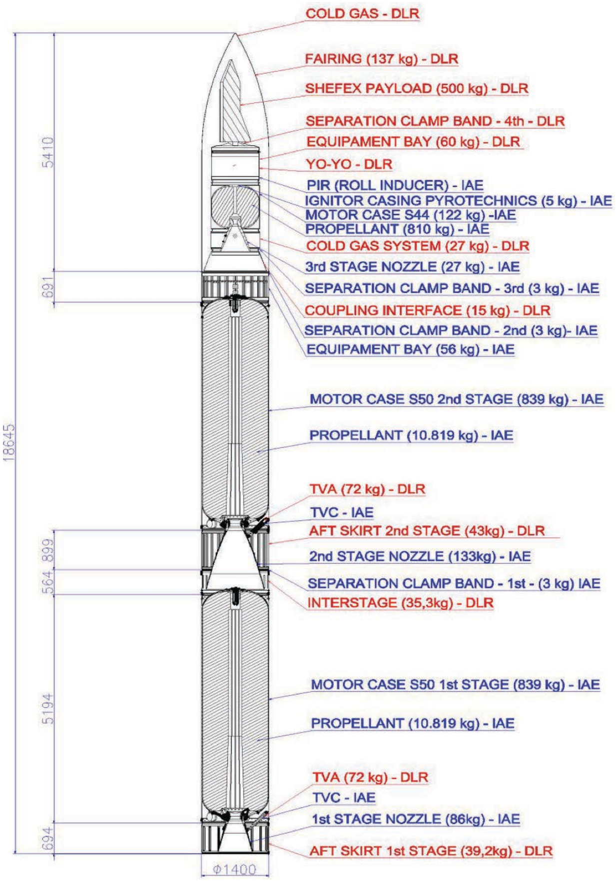

Fig. 3. VLM-1 with the SHEFEX III payload.

The Legal Amazon region extends over 9 Brazilian states has an area of 5.200.000 km^2, i.e. 61% of the Brazilian territory and half of the whole Europe, yet with a population of only about 24 million (Fig. 1). The sheer extension of the territory, and its prevalent wild forest nature, makes it quite difficult to monitor; the coverage area needed is approximately 2500 x 2000 km, at latitudes between 5° N and 15° S.

Several space assets provide EO services to the Brazilian governmental bodies in charge of environmental protection, such as the Canadian RADARSAT and the Japanese JERS-1 (SAR coverage), the U.S. LANDSAT-7 and the French SPOT-4 (optical imagery). The China-Brazil Earth Resources Satellites (CBERS-1, 2 and 4) provide dedicated support through the Coherent Change Detection camera with a resolution of 20 m, the Infrared Multispectral Scanner (IR-MSS) with a resolution of 8 m and the Wide Field Imager camera (WFI) with a resolution of 260 m. They are, however, in sun-synchronous polar orbits, so that coverage of the equatorial zones is nevertheless limited in terms of revisit frequency.

The E-LEO solution is enabled by the planned introduction of a new Brazilian small launcher.The Veículo Lançador de Microssatélite 1 (VLM-1) is a small carrier originally developed for DLR's SHEFEX III re-entry payload by the Brazilian Instituto de Aeronáutica e Espaço - Departamento de Ciência e Tecnologia Aeroespacial (IAE/DCTA). VLM-1 is a three-stage, solid-fuel powered rocket (Fig. 3). Altough primarily intended for sub-orbital flight, VLM-1 is powerful enough to put as much as 260 kg in LEO. Being operated from the Alcantara Launch Center, the launcher is mostly suited for E-LEO, being any large change of inclination too expensive in terms of delta-V.

Taking into account the altitude/inclination/mass performance and fairing constraints of VLM-1, we considered several possible constellation architectures based on a state-of-the-art compact hyperspectral instrument. In order to guarantee coverage over a large area with frequent passes, as well as allowing for the smallest possible number of launches, constellations including a small number of satellites (2 to 6) on slightly inclined orbits (5 to 8 deg), with satellites evenly distributed in RAAN, were analyzed (Fig. 2). The correct choice of orbital altitude is critical to guarantee sufficient lifetime, with higher altitude resulting in reduced residual atmospheric drag. A trade-off was made between better ground resolution and extended orbital lifetime, with an altitude in between 550 and 600 km being the optimal outcome.

In addition to environmental monitoring, a VLM-1 launched microsatellite mission has interesting potential applications for maritime and airspace surveillance. With such application in mind, the possibility to embark a small SAR instrument, alongside or instead of the optical payload, was also addressed.

As a result of our study, we show that a full functional, near-continuous monitoring of the Amazon region is within the capability of the small, low cost launcher VLM-1, with substantial cost reduction with respect to traditional EO missions. This is made possible by leveraging on present microsatellite technology advancements, namely power production with high efficiency solar cells and compact optical instrument design.