BLOOSTAR, THE ENABLER FOR MORE EFFICIENT SATELLITES IN LEO

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Abstract

There is a huge boom in the number of microsatellite and nanosatellite concepts and missions in development. The mass efficiency of small satellites has increased significantly in the last decades. Nanosatellites, which used to be considered ideal for the university classroom, are now being proposed for interplanetary missions. Zero2infinity has designed a launcher to further enhance the trend of increased performance of satellites for the same amount of mass in orbit. Launching from Near Space creates a much more benign launch environment than that encountered with existing or proposed launch systems. This less shaky, gentler ride, coupled with Bloostar’s oversized fairing, allows to launch satellites that have very high surface area, with relatively low mass. Satellite designers can, for once, design satellites with geometries, materials and components, that are optimal for LEO operation, but don’t need to survive a conventional launch.

Keywords: Microsatellite, Cubesat, Launcher, Access to Space

Acronyms/Abbreviations

Zero 2 Infinity (Z2I)
International Space Station (ISS)
Low Earth Orbit (LEO)
Sun Synchronous Orbit (SSO)
Methane-Oxygen (Methalox)
Specific Impulse (Isp)
Maximum Dynamic Pressure (MaxQ)
Ultra High Performance Vessel (UHPV)
Surface Mount Technology (SMT)
Very Low Earth Orbit (VLEO)
Multi Layer Insulation (MLI)

1. Introduction

1.1 About Bloostar

Bloostar is a transportation service to LEO designed to meet the demand of frequent responsive launch for small satellites.

Z2I is looking at the problem to reach orbit as a system, of which the launch vehicle is only a small part. There are some cost drivers in a launch operation that don’t scale down well from existing or proposed aircraft and ground-based launchers. By decoupling the problem in two: first, getting above the dense layers of the atmosphere, and second, achieving orbital speed, many of those cost drivers are eliminated.

The following table shows some of the benefits of Near Space launch:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Ground</th>
<th>Aircraft</th>
<th>Near Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbo pumps</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Multiple aerodynamic regimes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Inefficient tank shapes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Rockets don’t give optimal Isp</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Loss of vehicle at start critical</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Range cost</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Vertical integration</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Expensive 3rd party liability</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Experiences weather delays</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Bloostar is not only the most affordable launcher to operate but also the one that requires the least capital to get to break even.

With our price point of €4M per individual launch, and discounts for “batch customers”, we are aiming to beat the current record of minimum cost of a primary launch into orbit ($7.9M) by SpaceX.

1.2 About Z2I

Z2I’s mission is to enable others to make their dreams come true by building a future in which access to Space is frequent, affordable and reliable for all.

The first step was developing a commercial Near Space (between 20km and 100km of altitude) access capability. That is offering clients the capability to send payloads above controlled airspace.

Z2I currently flies payloads to Near Space for a range of customers, from scientific institutions to marketing agencies.

Z2I is also working on a Near Space balloon to carry human beings, called Bloon.

2. Market demand

It’s no secret that the demand for small launch has increased faster than any other satellite segment in the industry, at a sustained pace of around 25% a year. Z2I believes that small satellites have only started to demonstrate what they can do, once networks of them, working in unison, are deployed and maintained regularly, we’ll see even greater capabilities. As foreseen in [1] it’s the combination of small satellites and small responsive on demand launchers that can really bring disruptive innovation to markets like connectivity, big data, resources monitoring, security, etc.

Several segments of the demand have been identified:

- Construction and replenishment of constellations.
- Missions requiring a low cost primary launch.
- Cluster missions with several cubesats.
- Responsive space access.
- Missions that seek to maximize surface (radiators, apertures, power, etc.).

Bloostar is unique in its value proposition offering a very wide fairing with a very gentle ride. This capability, combined with advances in electric propulsion and photovoltaics, is going to enable new classes of satellites.

3. Payload delivery capabilities

Zero 2 Infinity is enabling fast iteration of satellite designs, even before Bloostar is deployed, by offering rides on Near Space balloons where subsystems can be tested at low cost.

Fig. 1. Customer satellite being tested in Near Space

Prior to developing Bloostar, extensive conversations were held with stakeholders in the small satellite community to identify the “sweet spot” in terms of mass to orbit both for primary launches and for clusters of multiple cubesats.
3.1 Mass

In its first version Booster will be able to take 75 kg to SSO orbit. Larger masses can be delivered to other orbits as seen on Fig. 2.

![Payload capability launched from the Canary Islands](image)

Fig. 2. Payload capability launched from the Canary Islands

3.2 Volume

The volume, and particularly the diameter, available for payloads is larger than for any of the planned small satellite launchers.

![Bloostar standard Payload Fairing](image)

Fig. 3. Bloostar standard Payload Fairing

3.3 Launch Environment

The altitude from where Bloostar is ignited has been selected so that MaxQ is no longer a constraining parameter in the design. This provides a gentler and more predictable ride for satellites.

The acoustic and random vibration loads are greatly diminished compared to conventional ground based launches, because of the following:

- No aerodynamic buffeting, since flight takes place in highly rarefied air.
- Very little engine vibrations, since the engines lack turbo pumps.
- No reflection from the ground, since the ground is more than 20km away from the launcher at ignition.

Satellite configurations with lower natural frequencies than so far possible with “missile-based” launchers are an option now for satellites.

4. Example of new type of payload

Being true to its mission of enabling others to do what was so far not possible, up in Space, Z2I is providing a new, more benign, set of constraints to satellite designers. More information about it can be found in Bloostar’s payload users guide [4]

One example of such system would be a satellite designed to operate in VLEO, defined an orbit with an altitude below 450km, as proposed in [2]. Recent progress in the miniaturization of electric thrusters has opened up the prospect of stabilising satellites at orbits, that have lower altitudes than usual, using propulsion. This would have several benefits for small satellites, among others: higher resolution, increased radiometric performance, no de-orbit system needed and, for the same launcher, more mass delivered into orbit. Without moving parts or deployable wings, a disk shaped
satellite could orbit at very low altitude providing a large aperture looking down (possibly for an array of sensors) and a large area for solar arrays and radiating elements. On the periphery of the disk, novel electric propulsion devices, for instance bipolar colloid thrusters, see [3], would provide enough thrust to compensate the drag experienced. On polar, or SSO orbits, the Earth’s magnetic field could be used to control the “pitch” of the satellite taking advantage of the large magnetic dipole that a spire of current could generate around a coil placed on the outer rim of the craft.

Fig. 4. Bloostar-launched VLEO satellite (artist conception)

5. Bloostar vehicle description

5.1 Demonstrators

A series of demonstrators are being developed and built at Zero 2 Infinity. First Near Space trials are expected before the end of 2016.

Fig. 5. Bloostar scaled prototype under construction

5.2 Propulsion

The propellant combination of liquid oxygen and liquid methane is one of the greenest, easiest to handle and efficient. It’s not only one of the most mature combinations in aerospace, but also the availability of components, compatible materials and expertise from the natural gas industry and the medical domain is a great advantage.

Only 2 types of engines are required, one for the first stage and another one for the second and third stage. They share common injector elements, production methods and materials. They are lightweight and can be transported by hand, doing away with the need for cranes and complex tooling.

The thermodynamic cycle is very simple, all pressure-fed, this significantly reduces the number of parts that need to be designed.
and the number of moving parts in operation, enhancing reliability at lower cost. Since Bloostar’s exhaust plume and nozzle expand the gas to very rarefied air at high altitude, engines can have high efficiency without expensive, and prone-to-failure, turbo pumps, or heavy tanks.

5.3 Structures and Tanks

All tanks carry a certain amount of external MLI to limit the boil-off, which has been estimated to be 5kg of liquid methane and 15kg of liquid oxygen for a 2-hour cruise to altitude. These small amounts don’t justify carrying an extra tank on the balloon gondola to top off the tanks on the rocket, but that could be an option in any case.

Toroidal tanks have been used extensively for upper stages of Russian launchers. They are highly mass efficient pressure vessels and can act as load carrying members. The great amount of progress in the use of composite materials in Spain is being advantage of in the structural development of bloostar. The first and second stages are toroidal carbon fibre filament wound tanks. They are kept at pressure and provide structural rigidity to the rocket. They are made in one piece by filament winding, and they are equipped with an internal liner to avoid micro cracking in the composite walls. T1000G fibres provide the right strength to weight ratio for this application. Internal baffles have been added to prevent low frequency sloshing modes. Several axial reinforcements made by hand lay-up will be placed at the attachment points between the stages, tanks and fairing.

For the third stage, where every kg saved in dry mass is a kg of payload, an even more optimized solution has been adopted, a UHPV, which is a light and flexible cryogenic tank that stores the liquid methane and oxygen in separate tanks, with a common bulkhead, through the use of a multilayer leak-proof isotensoid. Propellant is injected to the rocket engines using a pressure fed system with pressure in the tanks maintained by helium gas. As well as providing pressure for the feed system, the helium pressurant gas also helps to maintain the structural rigidity of the tanks as propellant is used. Using UHPVs results in a significant mass saving while also reducing costs.

![Fig. 6. UHPV tested in Near Space by Z2I](image)

Bloostar’s fairing protects the payload during the balloon ascent and prevents damage of the sensitive parts of the payload because of the aero heating from the first phase of the rocket-propelled flight.

Ground or aircraft-launched vehicle’s fairings also need to withstand significant structural and acoustic loads; this is not the case for Bloostar.

A flexible, retractable fairing, with rigid ribs and a multilayer canvas, mostly made of betacloth (Teflon covered fiberglass), is been designed.

5.4 Avionics

Z2I is leveraging the great progress in drones, cubesats, open source code and mobile technology to develop a simple yet
reliable avionics solution. SMT will be used in all components and automated X-ray inspection will be implemented.

The development of the avionics of the balloon segment is complete and operational in Z2I suborbital missions.

6. Conclusions

In the history of Spaceflight, only two modes of reaching orbit have been successfully implemented: ground launch and aircraft launch, at Z2I we are convinced that balloon launch is ideally suited to meet the needs of the current wave of lightweight yet powerful small sats.

Fig. 7. Avionics part in development.
Fig. 8. Bloostar stages’ details.
References


