Combined Launch System: a new concept to reduce the launch costs for Micro (Cube) Satellites and Debris' hunting probes

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ABSTRACT

This paper introduces a simple approach to a cheap, reliable and conventional concept for launching projects to the outer space like Micro-Scaled Satellites, To provide the students and young researchers the chance to launch their own projects and experiments and see it actually functioning in space through the simplicity of launch procedure, assembly, mission tracking and systems engineering, The main theme for this project is to serve both educational and commercial sides of space exploration using the scientific bases and experiments of Control and Aerodynamics on lighter than air dirigibles, Rocket Propulsion and Flight dynamics stability to increase the efficiency of all systems and decrease both complexity and cost by integrating simple designed systems and fine tuning of their objectives to reach the desired mission aspects, Using a relatively small rocket to the ones used from a ground launch and a high altitude balloon with very simple tuning and additions trying to increase their efficiency and reliability in this specific mission as a launch system, also the variety of missions the Combined Launch System could be used in, besides lifting the Micro satellites into orbits, debris hunting which results to be an essential threat to most of the space related projects nowadays, the paper details theoretically with all the concepts however the future working plan involves all the testing phases to proof the concept and finalize it hoping to introduce something to make space an easier and less complex reach.

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1 NOMENCLATURE

Rockoon	Balloon launched rocket
CubeSat	Cube Satellite
HAB	High Altitude Balloon
CLS	Combined Launch System

Table 1: Nomenclature

2 INTRODUCTION

Launching and getting to orbit has always been a sophisticated stage in any project relative to space that need to be practically performed, such projects like small space probes, micro scaled satellites or any experiment that need to be performed in the outer space either by companies, research laboratories or by university or school students has always been a huge difficulty either because of lack of the capabilities, the required amount of knowledge or the funds to afford building the launch vehicle to reach the attitudes their projects are meant to be tested or operate at.

This issue forced many promising theories and experiments to be held in their theoretical phases and passionate student projects not to see the lights or even been tested. The amount of complexity to get something to space either for taking too long to organize and to have a place in a launch vehicle or the cost to do so.

In the 1950's, Rockoons (Balloon launched rockets) were developed to provide a cheap and easy way to access the space environment for scientific studies and researches. These early Rockoons consisted of surplus military rockets from world war two launched from below meteorological high altitude balloons, the Rockoon concept seems to have been originated by Lt. M. L. Lewis during a conversation with S. F. Singer and George Halvorson during the Aerobee firing cruise of the U.S.S. Norton Sound in March 1949. The basic idea is to lift a small sounding rocket high above the dense atmosphere with a large balloon in the Skyhook class. Once enough altitude is attained, the rocket is fired by radio signal straight up through the balloon. The rocket will reach much higher altitudes than it could from the ground. The Rockoon has turned out to be a simple, cheap way of getting high-altitude data and reaching the outer space easily without special facilities and complex procedures.

As follows this paper will introduce the design of systems and all the mission theoretically as this is the very first stages of this project, its planned to have more physical work and studies aside with some experiments to make sure we reach the best know how to serve our goals and aims.

3 MISSION DESIGN

3.1 Segment A: HAB

A theoretical study of a complete mission design study was made to introduce the steps needed to be performed for the launch system to reach the desired altitude and finish the required mission with the best performance, taking into account some of the main failures and scenarios that could be faced and the way to avoid or to solve those problems.

First of all, filling the balloon with the lifting gas - helium – slowly it will be released to start the ascent phase.

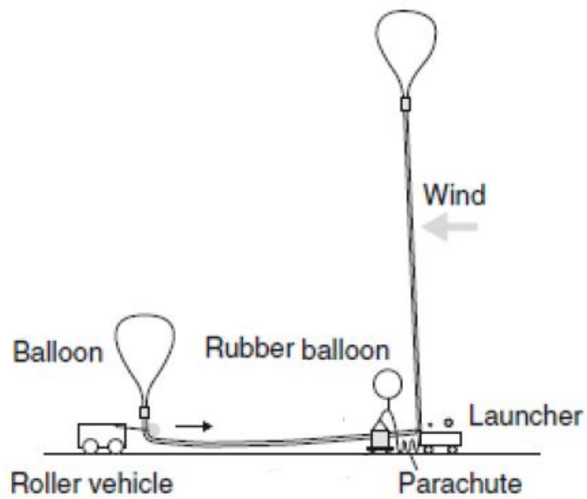

Figure 1: illustration of static launch method.

The balloon must be in a downwind position, so when the balloon is released it is moored to the ground until all slack is removed from the system.

In order to having accurate detailed information about the forecast, wind turbulence and conditions of flights, a simple weather rubber balloon will be sent prior to the main balloon launch, this method is performed by mostly all the launching companies and space agencies to ensure having accurate data for the balloon launch.

Depending on the feedback reading from the system of sensors & weather forecast, heating of the helium will start and stop in order to control the acceleration of the balloon to avoid the turbulences and side winds that may affect the balloon's stability.

After reaching the primary altitude - which is the same altitude where the helium only with no additional heating can put the balloon up in the atmosphere - the heating mechanism will start working heating the helium raising the balloon to reach up to an altitude of a range about 25 to 40 km depending on the required mission or experiment, the heating mechanism idea will be discussed later in the balloon design section.

On reaching the desired altitude, the heating mechanism completely stops working allowing the helium to cool down again, though losing altitude and therefore starting the decent phase to the primary altitude – which is mainly controlled by the amount of helium in the balloon following the equations discussed later in the balloon design - the same manoeuvring strategies and techniques will be performed to insure precise decent of the balloon.

Venting the helium will starts as soon as the balloon reaches the primary altitude, venting the lifting gas will force the balloon to fall down slowly back to earth with the effect of the gravitational force, venting can be precisely controlled through valves and regulators. After venting nearly all the helium inside the balloon, a simple recover system using parachutes will open to land the platform with the balloon back safe to earth.

Detecting where the balloon landed can be configured using the ground positioning system GPS mounted on board of the balloon navigation system, though recovering the balloon back to the ground station, checking it then filling it back again with helium then equipping it with the experiment hardware will make it ready for another flight in no time.

The balloon design depends on introducing a platform that will be able to use the previous theories to allow the balloon to maintain its function and reach its goal with the new techniques, certain aspects were monitored for the balloon design in order to serve that purpose;

Payload Weight	50 kg
Target Apogee Altitude prior to heating	10 km
Target Apogee Altitude after heating	40 km
Balloon's max. Height	8 m
Balloon's max width	3.5 m
Balloon's material	Mylar
Lifting gas	Helium

Table 2: Balloon design example inputs

Heating the lifting gas:

Using a heating mechanism that depends on induction heating of a metallic coil by electromagnetic induction, heat will be generated in the metal through eddy currents though the heat generated is inside the metal itself then transferred to the helium following the basics of heat transfer through convection and radiation.

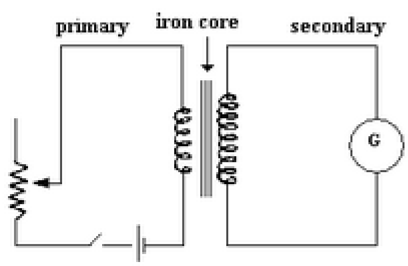

Figure 2: Electromagnetic Induction Circuit

Induction coils are recommended as Induction heating relies on the unique characteristics of radio frequency (RF) energy - that portion of the electromagnetic spectrum below infrared and microwave energy. Since heat is transferred to the product via electromagnetic waves, the part never comes into direct contact with any flame or the balloon's boundaries, the inductor itself does not get hot and there is no product contamination. When properly set up, the process becomes very repeatable and controllable which is an essential part in our design as it depends on heating the coil during different phases of flight to serve manoeuvring and control strategies.

Heat transfer through convection and radiation, an electric coil heats up warming the helium gas, though raising its temperature, Therefore as shown previously, increasing the helium's temperature results in increasing the lifting force for the balloon.

This idea was illustrated and discussed in details in the reference number [1].

3.2 Segment B: Rocket Booster

After reaching the highest apogee for the balloon, a separations system consisting of a simple ignition charge connected to an altimeter will separate the rocket booster from the Balloon.

The problem that let the Rockoon program down so fast was mainly the stability, the rocket firing from its position when being deployed from the balloon makes it so hard on the rocket to adjust itself back then to ascent in a correct way, however using new technologies of adaptive controllers with thrust gambling and movable control fins connected to the fins, the rocket will waste a lot of fuel to adjust itself into orbit.

In order to encounter this problem, the addition of gliding wings was introduced to the rocket booster - as shown in Figure 2 – those wings will allow a free fall stage - Performing the "Boost-glider: drop and pull-up Manoeuvre" - once the separation mechanism separates the booster from the balloon, this will allow the rocket to glide gently through the thin layers of the atmosphere with enough time to adjust its orientation directing itself towards its orbit.

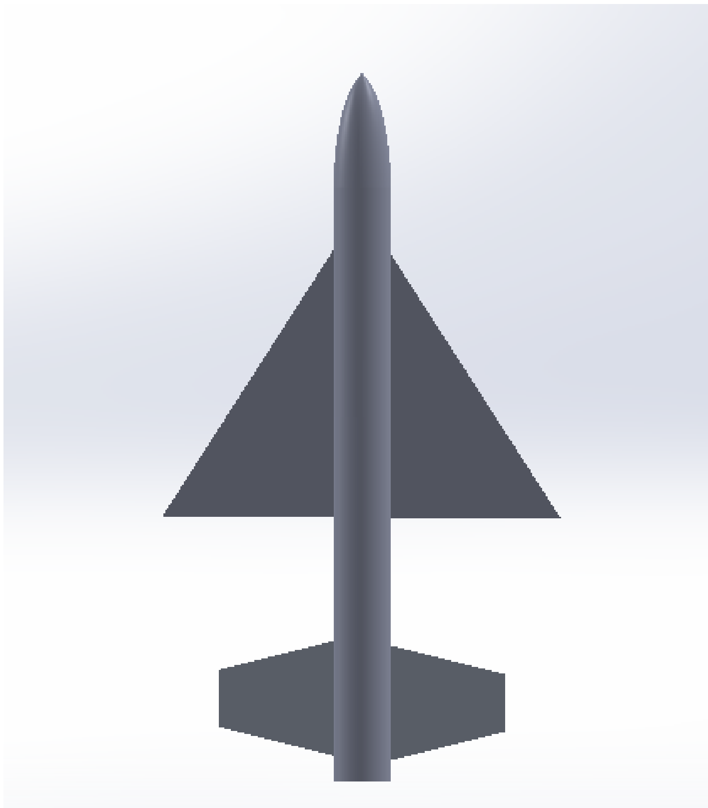

Figure 3: Primary design for the Rocket Booster with the gliding wings

When a glider is dropped vertically from a high altitude balloon. The ensuing pull-up manoeuvre from vertical plummet into a near-horizontal glide is pretty-much a quarter of a circle, and for the same reasons this can be an enormous circle at high altitudes.

The manoeuvre starts with a drop from the balloon, where the glider falls vertically (and hopefully nose-first) until it reaches a high enough airspeed to perform the pull-up.

As mentioned in reference [2], through detailed calculations the size of the circle is inversely proportional to the density at altitude, Also during the drop and pull-up manoeuvre, the glider is combatting drag all of the time, so energy (height and speed) is continually being lost. Pulling a tighter circle requires combatting higher centrifugal 'force' so more lift is required which causes higher induced drag. Pulling a larger circle causes the circumference of the circle to get large, so more energy is lost to profile drag and the height loss is large. Either way, a drop followed by a pull-up is an inefficient manoeuvre at very high altitude: a lot of energy is lost to drag.

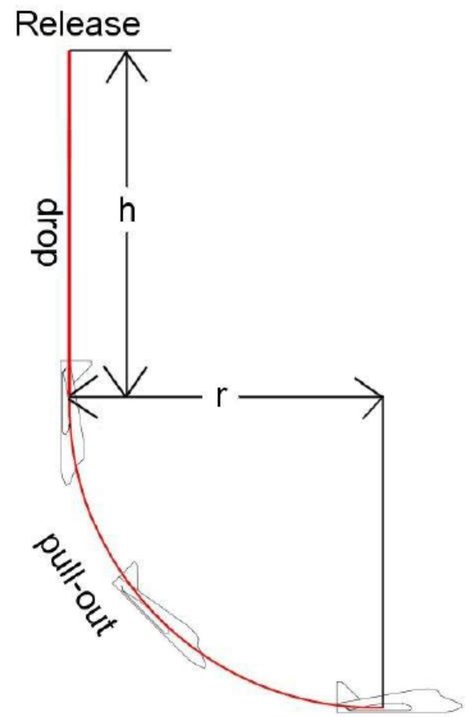

Figure 4: "Boost-glider: drop and pull-up Manoeuvre" as illustrated in reference [2]

To build up airspeed as quickly as possible, the glider should be trimmed for minimum drag which means reducing induced drag to zero by trimming for zero lift from the wings during the drop.
Arriving to the desired orbit, the booster will end up his mission and the payload will be thrown into orbit and at this point the rocket booster's role will be over.

The additional wings will have an essential role in reusability, in order to save expenses and avoid the condemnation of space debris, the booster will be guided to glide again back to earth using the gravitational force, free falling till the aerodynamic force grew enough to allow the control surfaces to guide the rocket back to earth, multiple firing from the small thrusters will be done to ensure a successful recovery of the rocket.

The rocket's recovery system which will be a system of dual deployment parachutes – as illustrated in Figure 3 - will have a safe decent rate to bring the rocket down to earth safety and precisely, this will allow us to re-load the rocket motor and make the rocket ready for another launch.

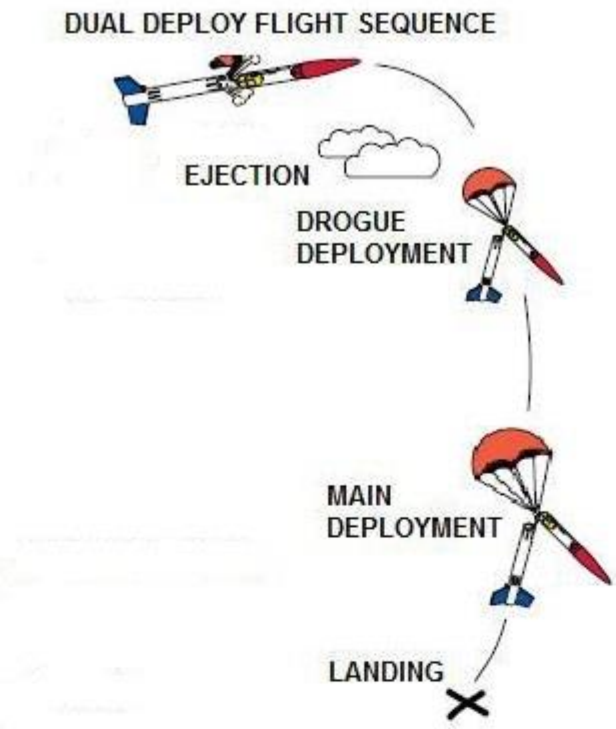

Figure 5: Recovery's Dual Deployment system

4 THE COMBINED LAUNCH SYSTEM DESIGN

The main theme of the CLS is to serve the experimental science and research, fitting in any university or space lab working area is a must, the concept is built not to exceed the area of half of a football field, as mostly every University had a one so it can use it for this kind of launches, also it won't affect the structure or the environment.

4.1 Specifications of the CLS

- Reliability

Reaching the desired altitude with precision and with the least risks to the flying payload or experiment, avoiding all the possibilities for shifting for the balloon is one of the main focus points of the design.

For the conventional balloons, several precautions to be provided to make sure the balloon don't intercept a plane or even flying birds which could harm the birds or cause problems for the flight. Rather than the conventional uncontrolled high altitude balloons, Using a guidance system through the heating mechanism offers a better control on the ascent and decent of the balloon.

Using a simple designed one staged rocket engine limits the percentage of failures and malfunctions of the propulsive system used.

- Handy size

Introducing the combined launch system from the very beginning aims to offer the maximum usage of the technologies used during all the flight phases, the CLS volume on starting the ascent phase should fit into a football/baseball field, This condition is because every University or High school has its own or even a free access to such type of fields, though the process of setting the test field and getting the experiment done will cost nothing as it's already a reachable facility.

- Cost

The CLS total cost of launch per time should not reach a 40% of the price of the cheapest platform that can conduct the same sort of testing experiment (reaching the same altitude with the same capabilities), though 40% is considered a high percentage, further plans and modifications are to be added to guarantee introducing the cheapest design preserving all the quality & performance to ensure an easier approach to space.

- Reusability

As reusability is one of the main aspects of this design for keeping the cost as low as possible compared to the qualities and performance introduced, using the same hardware multiple times is so essential as losing the heating mechanism and balloon structure would cost, therefore getting the balloon back safe to the ground is an important phase to be considered.

- Safety

Precautions of the launch site is much easier and more to be sure no accidents can happen due to the simplicity of the flight however many aspects is to be mentioned during the preparations like having an exact plan for the failure flights, a specified safe area during the launches that have the ground station and of course the detailed inspections before flight, which is believed that can be done easily in the case of the CLS.

5 APPLICATIONS

5.1 Launching Micro Scaled Satellites (Cube Satellites)

Implementing the suggested technologies and concepts with the nowadays applications is so important as the base for any new engineering concept & design is to serve a new purpose or a certain need, on the small scale the first thing to consider is the University students and young researchers' small Micro-scaled satellites or the so called Cube Satellites!

Cube Satellites are used by universities for many research or training purposes, also they are an essential step to let the engineering students and researchers to have the real Space based projects flavour, Taking Pictures from space, Sending radio communications, Performing Atmospheric Researches, Doing Biological Experiments or as a test platform for future technologies are some applications that can be performed by a CubeSat.

Using a CubeSat as the payload of the CLS is one of the main goals of this project, in order to offer an alternate cheap and reliable launching platform for experimenting those satellites in the actual environment they were meant to be.

5.2 Launching Debris Hunting Probes

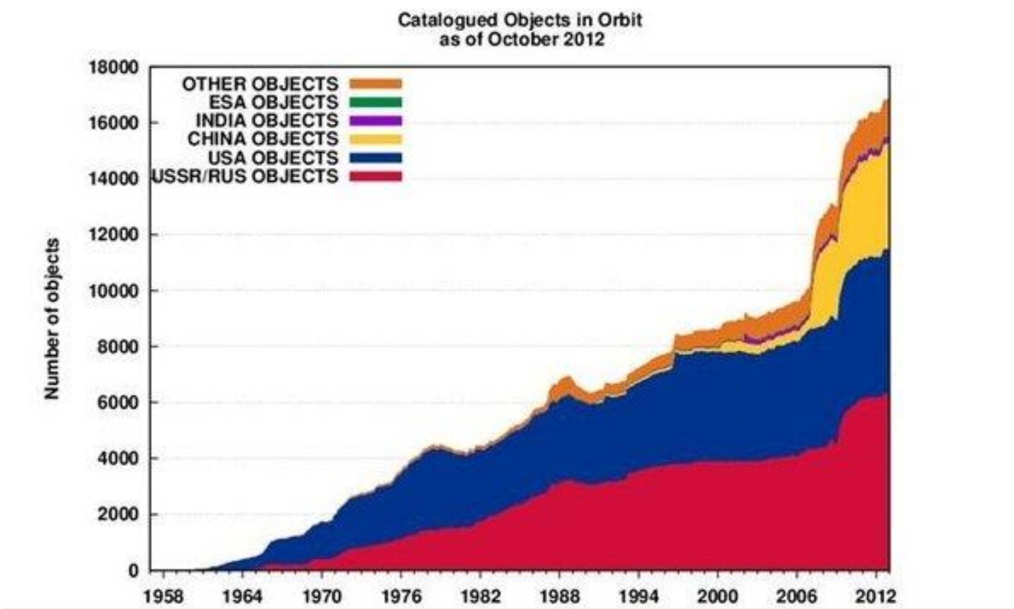

Figure 6: Evolution of the tracked space debris population made by European Space Agency ESA

Hunting the space junk or the space debris was something that attracts the attention of mostly all the space community around the world, According to a study made by the European Space Agency, in almost 50 years of space activities, more than 4900 launches have placed some 6600 satellites into orbit, of which about 3600 remain in space; only a small fraction - about 1000 - are still operational today.

With a total mass of more than 6 300 tones. Not all objects are still intact. More than 23 000 space objects Earth orbits in total are regularly tracked by the US Space Surveillance Network and maintained in their catalogue in order to make it safe for the nowadays operational satellite to function, this covers objects larger than approximately 5 to 10 cm in low Earth orbit (LEO) and 30cm to 1m at geostationary altitudes (GEO).

Over time, the harsh space environment can deteriorate the mechanical integrity of external and internal parts, leading to leaks and/or mixing of fuel components, which could trigger self-ignition. The resulting explosion can destroy the object and spread its mass across numerous fragments with a wide spectrum of masses and imparted velocities, the main cause of in-orbit explosions is related to residual fuel that remains in tanks or fuel lines once a rocket stage or satellite is discarded in Earth orbit.

On using the CLS, simple platforms of hunting probes could be launched towards the essential debris that may affect a future mission or a functioning satellite, also forcing an old satellite to enter the decay orbit, the usage of the CLS will be so easy as it can be operated at high levels and the payload carried varies from the mission.

6 CONCLUSION & FUTURE WORK

Implementing these ideas discussed should encountering most of the problems that faced the Rockoon concept before and of better using of High Altitude balloons, this will offer a variety of new applications. With keeping an eye on maintaining the cost, reaching the near space will be also much easier rather than using sophisticated launch platforms.

Also in the meantime testing on the rocket booster and recovery system is being performed, in addition to a study on using the feather gliding concept for stabilizing the glide before ignition, CFD data is being compared to experimental data from the wind tunnel testing aiming to reach the desired know how to reach our main goals and introduce an effective cheap platform to reach space.

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