INFLATE: INFlate Landing Apparatus Technology

Vsevolod V. Koryanov[1] and Victoria Da-Poian[2], [1]Department of Dynamics and Flight Control of Rockets and Spacecraft, Bauman Moscow Stete Technical University, 5, b1, 2nd Baumanskaya Street, Moscow, Russian Federation, 105005, vkoryanov@mail.ru , [2]ISAE-Supaero (French aerospace engineering school, Toulouse France), and Bauman Moscow State Technical University, da-poian.victoria@hotmail.com.

Introduction: « The objectives of the LM landing planning strategy are to anticipate the lunar environmental problems and to plan the landing approach so that the combined spacecraft systems, including the crew, will most effectively improve the probability of attaining a safe landing. » (From *Cheatham 1966*)

Space exploration missions are very complex scientific projects. One of the greatest challenges during such missions is the spacecraft's landing on the surface of the targeted planetary body. The vehicle has to be decelerated in a very short period of time from its orbital entry velocity to a complete rest on the surface. This mission phase is hardly fault tolerant. Moreover narrow targets for the vehicles position, velocity and attitude have to be met for a controlled landing within the vehicle's functional capabilities. Furthermore, each mission is highly constrained by the planetary environment, such as the gravity field, the atmosphere, the illumination conditions and also the surface properties. For instance, Viking (NASA ,1975) and Luna (Soviet Union, 1973) landings on the Moon relied on luck not to strike a large boulder or to be stuck into a large crater.

According to Adler et al (2012), "Entry, Descent and Landing (EDL) is defined to encompass the components, systems, qualification and operation to safely and usefully bring a vehicle from approach conditions to contact with the surface of a solar system body". Safely and Usefully are the main keywords of this definition. The scientific goals characterize not only the design of the spacecraft, but also the landing site in order to land in an area where the science objectives will be met. The site has to be « useful » to make the mission successful, and the landing must be « safe » to avoid fatal consequence in case of failure of such costly missions. The mission design deals with a high degree of uncertainty in the apriori knowledge of the environment.

Objectives: Our project, named INFLATE (INFlatable Landing Apparatus TEchnology) aims at reducing space landing risks and constraints and so optimizing space missions (reducing cost, mass and risk and in the same time improving performance). Inflatable braking systems are now the subjects of many researchers, but what about an inflatable landing system?

As the future space exploration projects are focusing on the installation of a Moon Village and then on an exploration of Mars, landing operations must be safe. In order to land on a celestial body surface, the lander's kinetic energy must be entirely safely removed, while traveling before the entry phase at high speeds (about 4 to 7 km/s). Re-entry friction with atmosphere is used to slow down from orbital speed (aerodynamic braking operations). For instance, with Earth's thick atmosphere, the only use of parachutes provides a gentle decent. The martian atmosphere is so thin that it cannot provide enough resistance to slow a spacecraft to a safe landing speed only thanks to a heat shield and parachutes. And on the Moon, as there is no atmosphere, only rockets are used all the way down to ensure a soft landing. Nevertheless, all these landings have ont thing in common: the touchdown which is also a very critical phase.

Mars exploration proved that it is not the fall that kills the mission but the landing. Remember the landing crashes of Mars Polar Lander, (NASA, 1999), Mars Express, (ESA, 2003, with Beagle 2 technology), and more recently ExoMars Schiaparelli lander, (ESA, 2017)
Nevertheless, in the last 50 years, landing technology has evolved and each generation of landing technology has attempted to resolve the challenges posed by the previous generation.

Equipment facilities required: Our INFLATE lander vehicle would be designed with inflatable lander system to avoid many of the previous landers uncertainty.

The INFLATE lander will be composed both by an inflatable landing structure and by a penetrator system based on the landing devices, it will be like an inflatable mattress with a reliable and safe anchorage system to avoid rebounds on the surface. As the first step of future lunar missions will be to build a safe and livable moon base, this considerable construction will need a great lander composed of inflatable braking device (IBD), system of inflation, shock absorption system, payloads, on-board equipment…

This lander will have the advantage to be composed of inflatable braking system with special thermal protection material that will absorb the heat flux when lander enters Moon vicinity or future Mars atmosphere. The advantage of this selected concept is that the lander physical size and the overall mass of the lander are much smaller than in case of the traditional landers with rigid heat shield and rigid landing system.

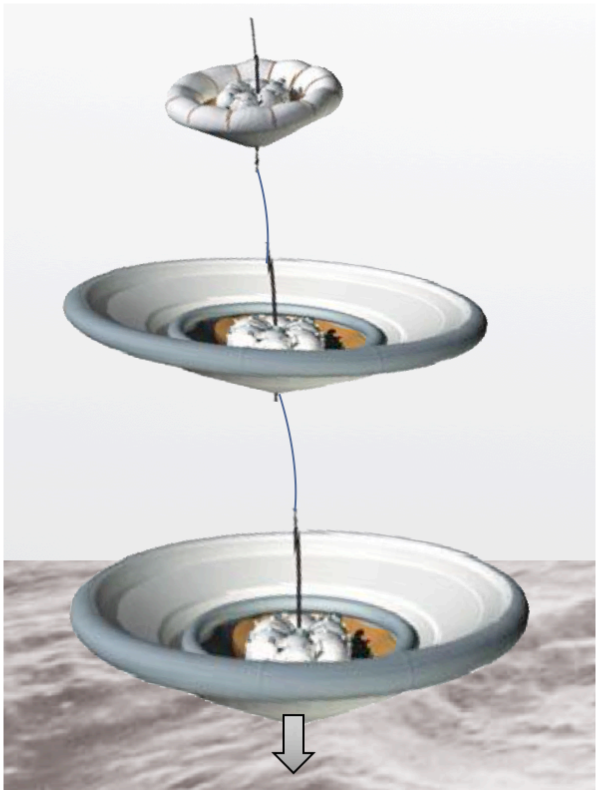

Figure 1: Inflatable structure deployment for Lunar landing

Moreover this innovative lander would also be equipped of various payload assuring science on the target surface (Mars, Moon, other celestial bodies…). This lander will :

- take panoramic pictures,
- perform observations of pressure, temperature, humidity, magnetism, wind speed and direction
- for bodies with atmosphere: atmospheric dynamics, interactions between the surface and the atmosphere, as well as atmospheric optical depth.
- analyze the surface (dust raising mechanisms, seismology seismometer)
- cycles of CO2, H20…

The main advantages of the inflatable lander concept, the compact size and mass compared to the conventional rigid heat shield landers, are even more significant when pursuing landing on other celestial body or planets (The Moon, Mars, Titan…). To conclude, INFLATE project aims to developing the safest landing system, using inflatable devices and anchorage system. Not only this project is a low cost and low mass project but also this is a simple construction that will revolutionize landing operations.

References: Use the brief numbered style common in many abstracts, e.g., [1], [2], etc. References should then appear in numerical order in the reference list, and should use the following abbreviated style:

[1] Mark Adler and Michael Wright (2010) *DRAFT Entry, Descent and Landing Roadmap.*

[2] Vsevolod V Koryanov and Victor P. Kazakovtsev (2017) *The technology applying of inflatable devices to access adaptation, movement and landing descent vehicle from Martian environment to the Earth conditions, AIP Conference Proceedings*.

[3] Prof. H. Dittus and Prof. J. Oberst. (2015) *Touchdown Dynamics and the Probability of Terrain Related Failure of Planetary Landing Systems.*