Whether a Soyuz Spacecraft really needs a parachute or is there an alternative?

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Abstract - This paper presents an alternative to the parachute braking system in use presently in the Soyuz Capsule Reentry Module. Possibilities including the addition of a heat resistant nose cone as well as propellants and rocket engines have been discussed. A model hydro-rocket was used to conduct all experiments observed. The approximate force required to bring the module to a halt is found and balanced. The parachute while effective is not fail-safe and thus the addition of a rocket engine is found to be not only perfectly stable, but also essential for increased safety as well as additional braking force necessary to reduce acceleration of the module from the time it enters the earth's atmosphere to its final landing moment.

Keywords - Breaking Force, International Space Station (ISS), Landing Craft, Pilot Parachute, Propellant, Propulsion, Reentry Module, Reverse Exhaust, Soyuz Capsule, Upward Viscous Force.

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1 INTRODUCTION

Astrophysics or Rocket Science has since times immemorial been one of the most complicated subject of study. It has taken centuries to perfect the art of flying in the sky and an infinite amount of data, to actually enable a manned aircraft to explore outer-space. The very first aircraft sent to the moon, Apollo 11 is still cited as one of the greatest achievements of the human civilization. The mission was indeed perfectly described by astronaut Neil Armstrong when he explained his setting foot on the moon as a small step for man, but a giant leap for mankind. Astrophysics has always been not just an interest, but a career goal which is why I present to the reader, this research paper.

Rockets have evolved greatly over the decades. The Columbia Space Shuttle tragedy opened the eyes of engineers and researchers alike to the hazard of imperfections in design and execution. NASA launched its last Atlantis Space Shuttle on the 8th of July, 2011 and with it ended its ability to launch any rockets for the next 3 to 4 years. The prominent Space Shuttle Program of the decade has indeed been the Russian Soyuz Capsule Space Shuttle Program which has caught the attention of all worldwide space agencies and has been the rocket used by NASA when sending astronauts, supplies and other material to the International Space Station (ISS).

The landing mechanism of the Soyuz spacecraft entails the ejection of a braking parachute and at a later stage, the main parachute. This is kind of landing gear is almost unique and is in contrast to the traditional detached ‘Landing Craft’ which has one main rocket engine and various other side boosters. On having seen various rocket landings, I wondered why the Russians used the parachute system of landing and whether there was an alternative method to land the Soyuz spacecraft, which is why I conducted a few experiments and wrote this paper.

2 MATERIALS, METHODS AND EQUATIONS

In order to explore various alternatives, I used a hydro-rocket as an experimentation tool.

Thus Materials:

1. Paper
2. Rubber Nose Cone
3. Hand Pump
4. Rocket launcher with thin channel
5. Water

1st Alternative- A Nose Cone:

I built a hydro-rocket with no parachute, but instead attached a Nose-Cone at the end. The nose cone was an ordinary rubber and cork cap that acted as a shock absorber due to the elasticity of the material used. The Soyuz Reentry Module already has a heat-resistant coating over the bottom which counters the frictional force or air drag that the capsule comes across, once it enters the Earth’s surface. The nose-cone, made of heat-resistant material could replace this, thereby acting as both a lubricant as well as a source of a greater braking force.

2nd alternative- Upward propulsion

In the hydro-rocket containing the nose cone, I added a hole through which the contents of an underlying vessel could be sprayed out. The contents below only touched the contents stuck to the top when the rocket was coming down due to gravitational force. When the rocket started to descend, Mentos and Diet-Coke led to the formation of foam due to reaction of potassium benzoate, aspartame, and CO_2 gas with gelatin and gum. This created an upward force acting against gravitational force. The result was a great reduction in the velocity of the rocket as it approached ground level.

As a Soyuz Spacecraft approaches the Earth, 10 km above sea-level, the pilot parachutes are deployed which reduce the velocity of the Reentry Module of the Capsule. The reduction is from 230 m/s to 80 m/s in 16 seconds and a subsequent reduction to 7.2 m/s with the deployment of the main parachute. At the end of its journey, when the module is barely 10 m from the ground, it fires up a rocket engine to provide a final up thrust force that brings it to rest. I believe that that the engine would find better use if used as the primary braking force source. For the Reentry Module:

Force of gravitation at such a height:

$$F = M_{rm}g$$

$$g = g_o\left(\frac{r_e}{r_e + h}\right)^2$$

$$F = M_{rm}g_o\left(\frac{r_e}{r_e + h}\right)^2$$

Where M_{rm} is the mass of the Reentry Module of the Soyuz Capsule (including added propellant mass, which is recommended in this paper) and g_o is the approximate value of g on the surface of the Earth.

$$M_{rm} = 2900kg \qquad and \qquad g_o = \frac{9.8m}{s^2}$$

$$r_e = 6\,378km \qquad and \qquad h = 10km$$

$$F = \frac{2900 \times 9.8 \times 6378^2}{(6378 + 10)^2}\ N$$

F =1156093883280 N / 40806544 = 28331.1 N which is practically more than the actual braking force required as when the Capsule enters the atmosphere, other forces such as viscous force, etc. also act on it, thereby considerably reducing acceleration. Let us take the Capsule to be approximately spherical as the landing module has a length of 2.1 m and a diameter of 2.2 m, thereby making the radius approx. 1.1 m.

Therefore, By Stoke's Law:

$$Upward\ Viscous\ Force = F_v = 6\pi\mu R v_{air} = \frac{1}{2}\rho v^2 A c_d$$

$$F_v = 0.5 \times 0.4135 \times 230^2 \times 2.1 \times 2.2 \times 0.0604\ N$$

$$\rho, v^2\ and\ A\ are\ values\ as\ seen\ experimentally\ in\ air.$$

Where value of c_d is a minimum of 0.0604 for a prototype space shuttle and can go up to 0.75 for a model rocket

$$F_v = 3051.9689046\ N = 3052\ N\ (approx.)$$

Therefore, total force to overcome: $Downward\ F = 28331.1 - 3052 = 25280\ N\ (approx.)$

In order to overcome this force, the capsule would require a specific exhaust velocity. Assuming that the exhaust is only used in the final landing stage, say when it is 100m from the surface,

$$Fd = \frac{1}{2}mv^2 = 25280 \times 100\ J$$

$$Thus, \qquad v_{required} = -41.75m/s$$

According to data available, present propellants can easily provide this upward force in order bring down the downward force to almost zero. Propellants used in rocket engines typically provide impulses ranging from 200 seconds to a theoretical maximum of 400 seconds.

As exhaust velocity is approximately equal to 9.8 times the impulse value of the propellant, a negligible amount of propellant as compared to the mass of the reentry module will be able to provide the necessary braking force through the reverse acceleration engine already present in the same.

A nose cone made of highly compliant material would indeed go a long way in ensuring a safer landing.

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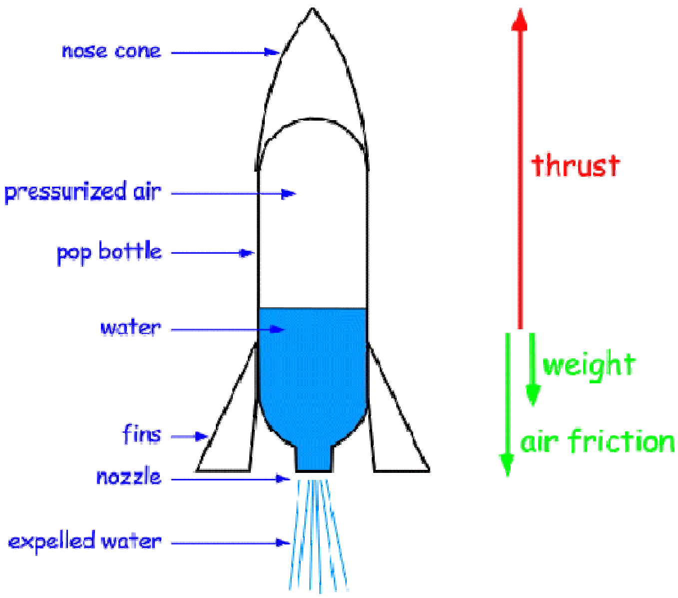

3 RESULTS

1. The first alternative, i.e. the usage of just a nose-cone was most certainly not enough to provide enough force to make the rocket land safely. The shock-wave produced will destroy the Soyuz Capsule if this alternative were to be put into use.
2. The second alternative was perfect in its combination of a braking force as well as a nose cone. The braking force greatly reduced the velocity of the rocket and the elasticity of the nose cone completely absorbed the resulting shock wave when the rocket reached ground level. This is indeed an efficient and effective way to land a Soyuz Capsule.

   NOTE: A Parachute may be used along with this in order offer a greater braking force, thereby increasing landing safety.

4 DISCUSSION

The parachute, made of extremely strong fabric is still prone to extremely disastrous scenarios. Parachutes can malfunction in several ways. Malfunctions can range from minor problems that can be corrected in-flight and still be landed, to catastrophic malfunctions that require the main parachute to be cut away using a modern 3-ring release system, and the reserve be deployed.

The use of a propellant is in many ways better to the usage of a parachute in stopping the reentry module. A propellant which is extremely light in weight can easily provide a force much greater than the braking force required, or provided by a parachute with the same purpose. Another disadvantage is most certainly, the vulnerability of a parachute which unless checked at every point may give in to atmospheric pressure, high wind speeds or any such ongoing environmental susceptibilities such as a storm, hurricane, etc. The same is however not true with the usage of a propellant, which may just be used through the exhaust engine already fitted in the reentry module.

A propellant however, may also create other complications such as multitude of inflammable material aboard the Capsule. Apart from safety issues, the weight of the propellant may also be a contributing factor in not using it as it may influence precise calculations, made both during take-off, travel and landing. Storage of the same may create another issue.

The advantages of using reverse propulsion however do indeed overweigh the disadvantages. Its usage along with a heat resistant nose-cone and a safety parachute may indeed revolutionize the way we look at landing gear when looking at aerospace travel.

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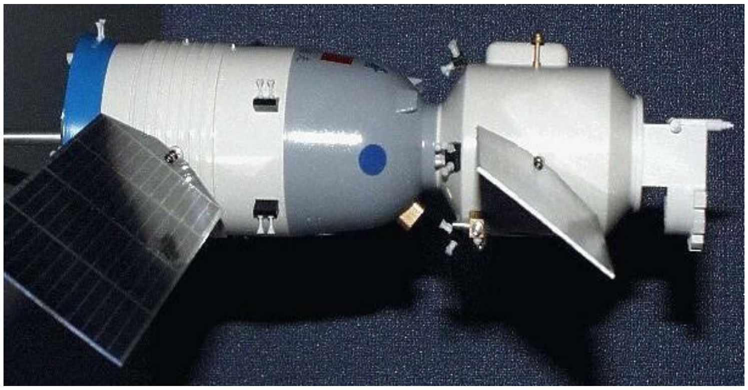

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