



DoubleSSHOT De-Spin solution preliminary draft.

Rev. 2010/08/22

Background

The doubleSShot vehicle is made up with a payload capsule on its head. After the soar, the capsule is released, normally at 33km, and has a free fall period before the opening of the parachute.

During the soar, the rocket has a roll around his axis, so the capsule undergoes this effect after the release.

It could cause many problems, such as motion in embedded video, danger for the opening of the parachute, lack of stability etc...

This preliminary draft has to quote several solutions which exist to stop the capsule spin, and then to choose one of them to make a deepened study, in order to design and build this solution.

Spin causes

Firstly, let's have a look on the spin causes of the rocket. I will quote Richard Nakka's explanation about this phenomenon:

"The spin (roll) is a natural result of the fins not being perfectly aligned to the long axis of the rocket, or some other aerodynamic imbalance such as the fins not being exactly the same profile. It does not take much to start a roll, since the angular mass moment of inertia of a rocket is small. Trying to eliminate roll by perfect balance would not be realistic. Often roll is intentionally induced, to aid stability and improve the trueness of trajectory. This may be done by fins tabs or asymmetric fins."

This explanation means that stopping the spin while the capsule and the rocket are still flying together is not possible and not desirable.

So, the only way is to act when the capsule is alone, thing which happens at 33km above the ground. We could notice that at this altitude, it remains only 1% of the atmosphere at the sea level, so we can neglect it (in other words, the aerodynamic effects are almost the same that on a satellite).

Review of available solutions

There are many solutions to manage this problem. I selected 3 solutions, I will enumerate them here. We will approximate for the moment the capsule as a cylinder of 165mm diameter and a weight of 10kg.

Guidance parachute

Developed by the NASA during the 60' this system is used to stabilize a load which returns to the earth. It proceeds on two steps:

-First, the load is in a free fall phase, a first and small parachute is deployed. His goal is to stabilize the load's attitude and to give a good trajectory.

-Then, this parachute is released and a second, the final parachute which slows down the load until it grounds is deployed.

For example, this system is used on the Orion's rescue tower.

This solution is old and reliable, but actually more adapted for heavy load. Then as explained before, the atmosphere is not very dense at the releasing altitude, so the parachute couldn't be deployed easily soon. We would have to wait a moment to have a denser atmosphere, but we have to stop the spin as soon as possible, so this solution is not the best.

A pair of micro jets

A solution to stop the spin is simply to apply a reversed couple of the rotation movement. It could be easily done by using two opposite-micro jets.

This principle is viable but poses several questions:

-Firstly, how to feed the jets? Using little tanks? Why not but we could have a weight problem. If we just have to do one or two pushes and the spin is really stop, this solutions could be possible, but if we have to do other corrections later during the fall, the tanks could be quickly empty.

-Secondly, the control. In order to design this system, we've to make an upgrade of the software. What we have to think about is: will this software be complex? What effects will it have on the main software? Then, is this device very precise and profitable with this solution?

-The latest point about the micro jets deals about the design of the capsule. There was not a such system on the MiniSShot, so what modification this system imply on the capsule? And what are the effects?

For me, we could build this solution and it'll probably work well, but we can make better, in a design of a simpler solution. That's the subject of the third solution.

The yoyo de-spin

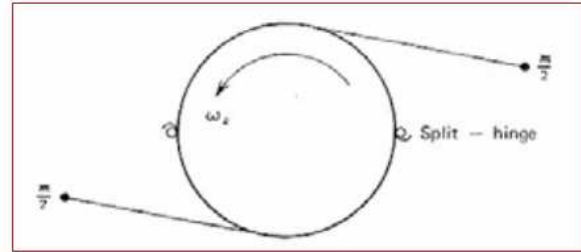
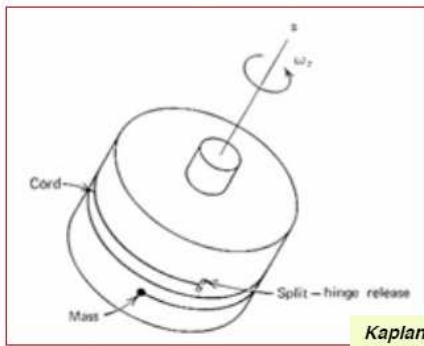
There is a solution which uses less energy that the micro-jets and if well designed, stops the spin once for all. This solution was imagined by the NASA in the 60', it's called the "yoyo".

Based on the principle of momentum angular conservation, this system consists of two weights fixed to the capsule by two tethers.

When the tethers are released, the weights move away and a part of the kinetic energy of the capsule is transferred outward through the weights, the own capsule weight decreases, the inertia moment increases, and finally the spin slows down. If the dimensions of the tethers and the weights are well though, it can stop the spin

There is an illustration:

(extracted from the lecture document of Robert Stengel, Princeton University:
<http://www.princeton.edu/~stengel/MAE342.html>)



That's for the principle. Actually, there are some studies about this system, but we won't quote them all here, you could have a look in the annex if you are interested, but we'll use their results.

This solution seems to be the best because if well designed, it could be efficiency and stops the spin rate quickly, wouldn't be heavy in term of weight and wouldn't load the computer.

We can now have a look to the equations of this system. I'll present you these equations which come from the same document quote just above: (from Robert Stengel, Princeton university)

$$\omega_{final} = \omega_{initial} \left(\frac{cR^2 - l^2}{cR^2 + l^2} \right)$$

$$= 0 \quad \text{if} \quad l = R\sqrt{c}$$

where

R = spacecraft radius

l = tether length

$$c = \frac{mR^2 + I_{zz}}{mR^2}$$

m = mass of 2 weights

I_{zz} = satellite moment of inertia

ϕ = angle between split hinge and tangent point

Practical study

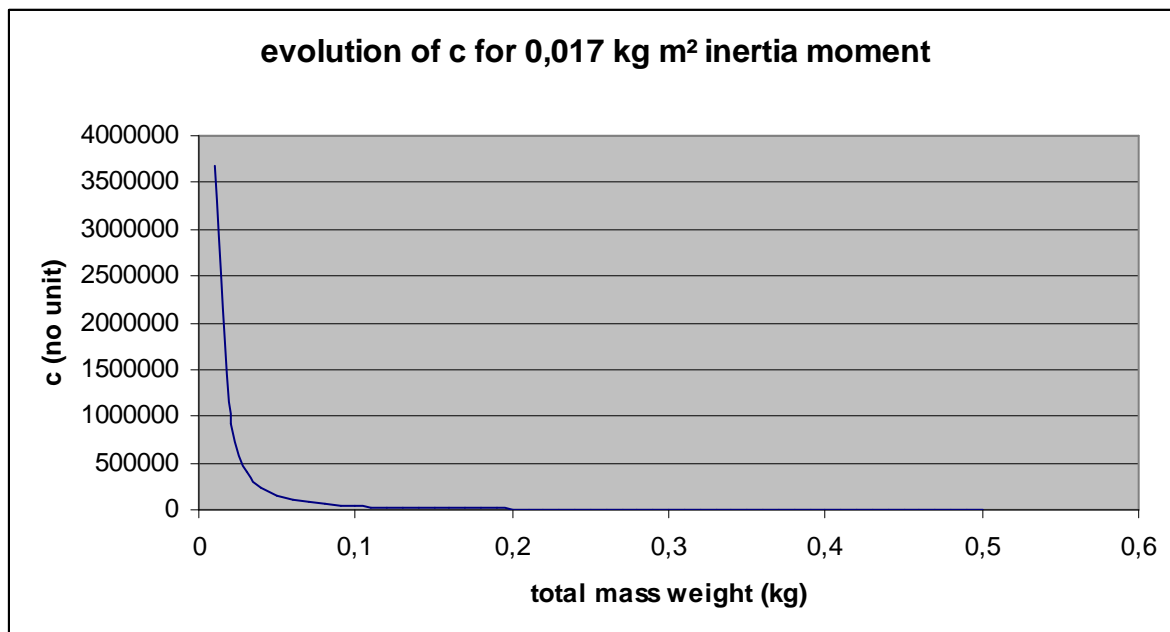
Firstly, we'll get the moment of inertia (I_{zz}):

$$J_{\Delta} = \int_0^R r^2 (\rho 2\pi r h dr) = \frac{1}{2} \rho \pi R^4 h = \frac{1}{2} M R^2$$

Where M is the total weight (kg) and R the radius (m).

We'll admit a weight range of 5-10 kg for the capsule, and a radius of 0.0825 m.
So the inertia moment is include between: 0.017-0.034 kg.m²

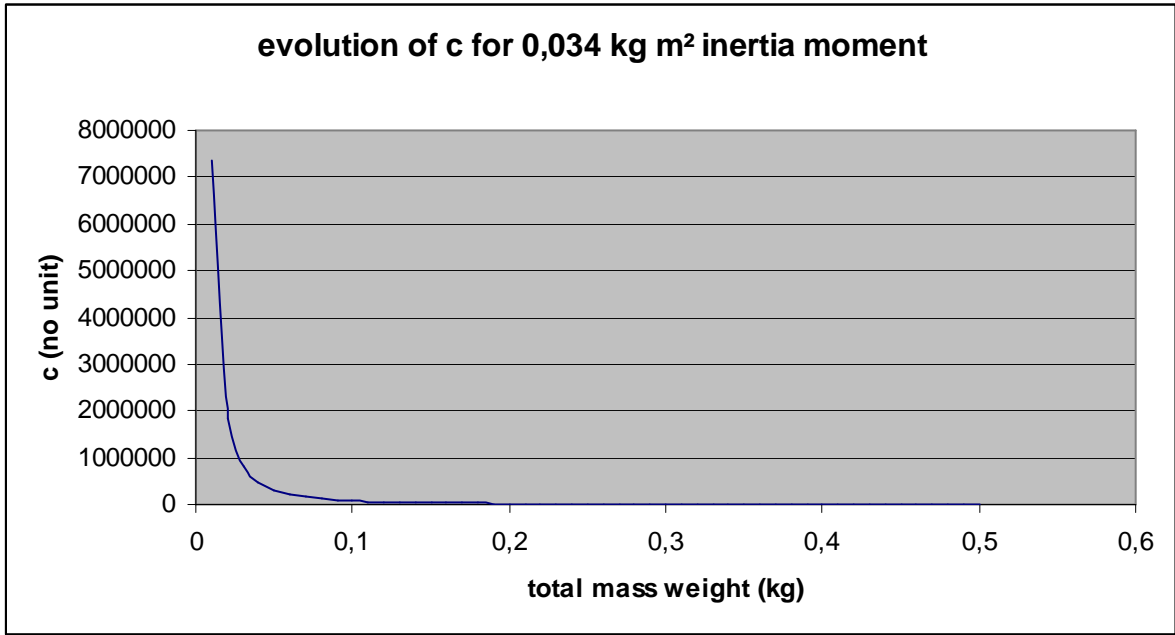
Then, we'll compute the next data with these 2 limit values.
Let's have a look on the evolution of c for these values:



Extreme values:

Minimum: weight: 0.01 kg => C: 3684414,05

Maximum: weight: 0.5 kg => C: 1761,73624

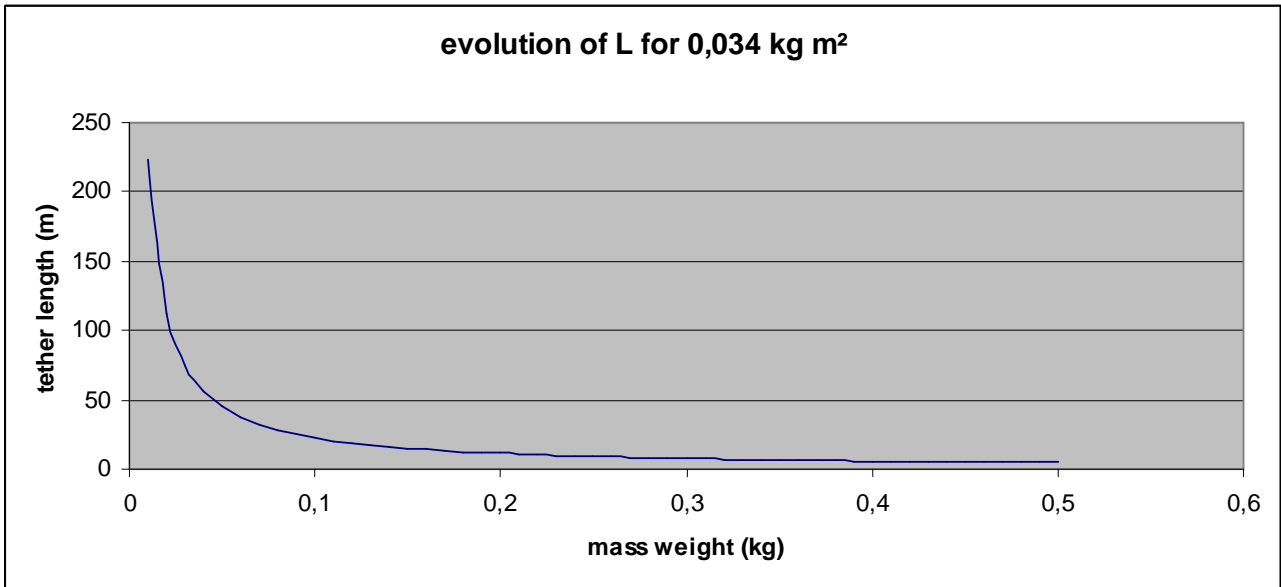


Extreme values:

Minimum: weight: 0.01 kg => C: 7354135,73

Maximum: weight: 0.5 kg => C: 3229,62491

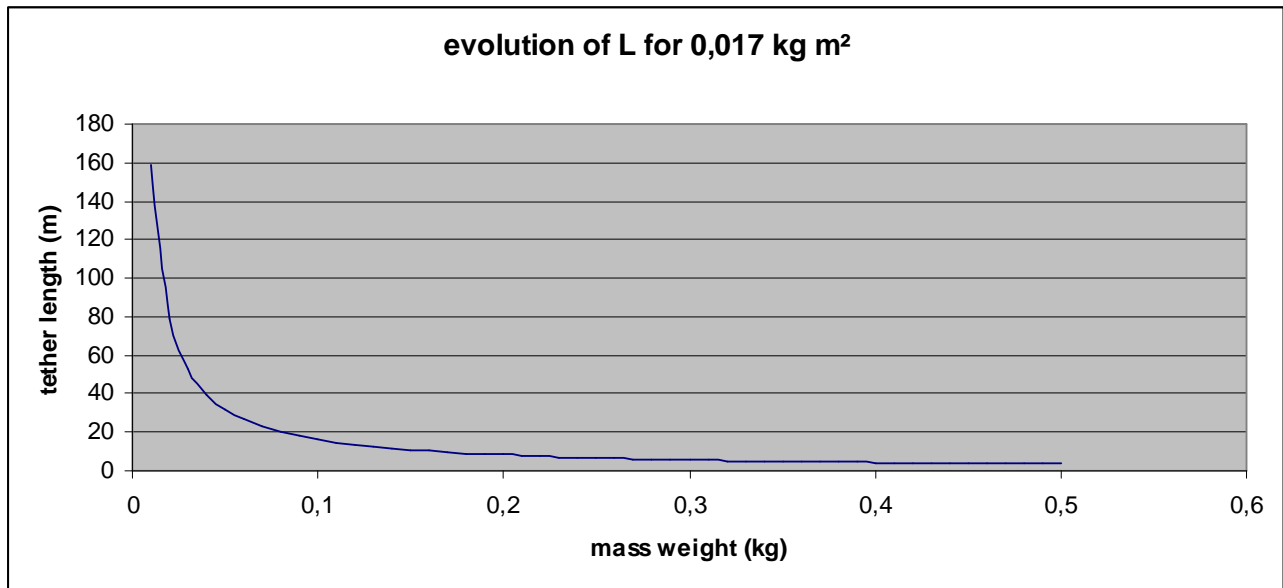
Knowing that the radius is constant, we can draw the evolution of the tethers length according to c, which gives directly the values linked to the mass weight for the 2 limits of inertia moment:



Extreme values:

Minimum: weight= 0.01 kg => tether length= 223.73 m

Maximum: weight= 0.5 kg => tether length= 4.69 m



Extreme values:

Minimum: weight= 0.01 kg => tether length= 158.36 m

Maximum: weight= 0.5 kg => tether length= 3.47 m

For information, in the case of 0.034 kg m² inertia moment and for a 0.5 kg weight, it means that the tether has to do 6.7 laps around the capsule.

The calculus sheet is available in the annex.

Results

We know with these data and the evidences of efficiency by space's agencies about this system that its realization is possible.

Nevertheless, we could inspect the other solutions more; if the yoyo is hold, more studies will be needed, in order to make a better approximation, to affine this first design and to set up a design and realization plan including ground tests and if possible dynamic tests.

Annex

Lecture document of the Princeton University:

<http://www.princeton.edu/~stengel/MAE342Lecture14.pdf>

Nasa's reports about the yoyo:

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19620006811_1962006811.pdf

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19630004528_1963004528.pdf

Sheet used to draw the graphs:

See attached files.