# How Fulton's surface-to-air recovery system works

A. Eremenko

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This system was proposed during WW II for lifting the loads from the ground by an airplane. The load is attached to a long wire which is lifted to the vertical position by a balloon. The airplane flies horizontally at a constant speed and at the moment of meeting the wire clamps it. This system was actually used to lift the people, not only dead loads. The most famous use was during the operation Coldfeed when CIA recovered from the polar ice the leftovers of a Soviet Polar drift station. Humans who did the recovery work were lifted by an airplane from drifting ice.

When I first read about this (in 1960-s, when I was a child), I was surprised that such a system can lift a human without harming him. Especially from a rough terrain like ice or rocks. But it actually works, and in fact it lifts the person almost vertically in the beginning. Below is a simple mathematical reason for this.

The airplane flies horizontally left to right with speed $v$, on height $h$. At time $t = 0$ it engages the vertical wire to the lower end of which a load is attached. The load is at rest at until the time 0. The wire is rigid (its length is constant). Describe the motion of the load for small times.

Let us place ourselves to the airplane. Let $\phi(t)$ be the angle of the wire from vertical direction, as seen from the airplane, counted anticlockwise, so that $\phi(0) = 0$, and $\phi(t) < 0$ for $t > 0$. Then the system is an ordinary pendulum with initial condition $\phi(0) = 0$, $\phi'(0) = -v/h$. Using linear approximation for the pendulum we obtain

$$\phi'' + k^2\phi = 0, \quad k = \sqrt{g/h},$$

$$\phi(t) = -vh^{-1}k^{-1}\sin kt.$$

So the motion of the load with respect to the earth is:

$$x(t) = vt - h \sin\left(vh^{-1}k^{-1} \sin kt\right) \sim \frac{t^3}{6}(vk^2 - v^3/h^2),$$

and

$$y(t) = h - h \cos\left(vh^{-1}k^{-1} \sin kt\right) \sim \frac{v^2t^2}{2h}.$$

So we see that:

1. *The trajectory of the load near the origin is a semi-cubic parabola* $y = cx^{2/3}$ *whose tangent at the origin in vertical.*

2. *The velocity at small times is* $Ct$ *so there is no jump of the velocity at time* 0. *The acceleration the load experiences at the initial moment is*

$$C = v^2/h.$$

For example, if $v = 180km/h = 50m/sec$ and $h = 100m$, then acceleration is $25m/sec^2 \approx 2.6g$, which is bearable even if applied suddenly.

3. *Elasticity of the rope and additional amortizer at the airplane will certainly smoothen this sudden acceleration, but even the idealized problem shows that the project is very realistic.*

In [3] which is extracted from a James Bond movie, the lifting procedure is real.

[4] is a documentary about operation Coldfeet.

# References


[1] Fulton surface-to-air recovery system, Wikipedia.

[2] https://www.youtube.com/watch?v=u4xlYpKrCnU

[3] https://www.youtube.com/watch?v=dekJ2Ip7koo

[4] https://www.youtube.com/watch?v=dXmRYYjyKfE