Entry, Descent and Landing using Ballutes

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The In Space Propulsion Program is funding a team lead by Kevin Miller at Ball Aerospace. This team of Industry, NASA, and Academic researchers is actively pursuing ballute technology development, with very promising results.

The focus of that study has been to maximize the payload that is put into <u>orbit</u> (around Titan, Neptune, and Mars).

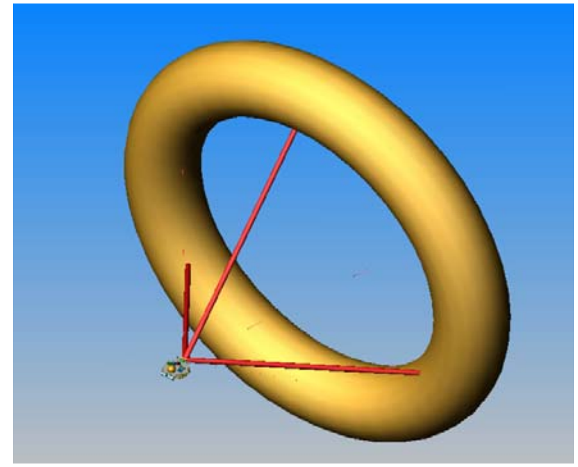
So far the mass associated with the ballute has been minimized, because it was being thrown away.

If an instrument package is attached to the Ballute, it will eventually land on the surface. Thus, the Ballute can do <u>double duty</u>: Aerocapture the Orbiter and Soft-land a set of instruments on the surface.

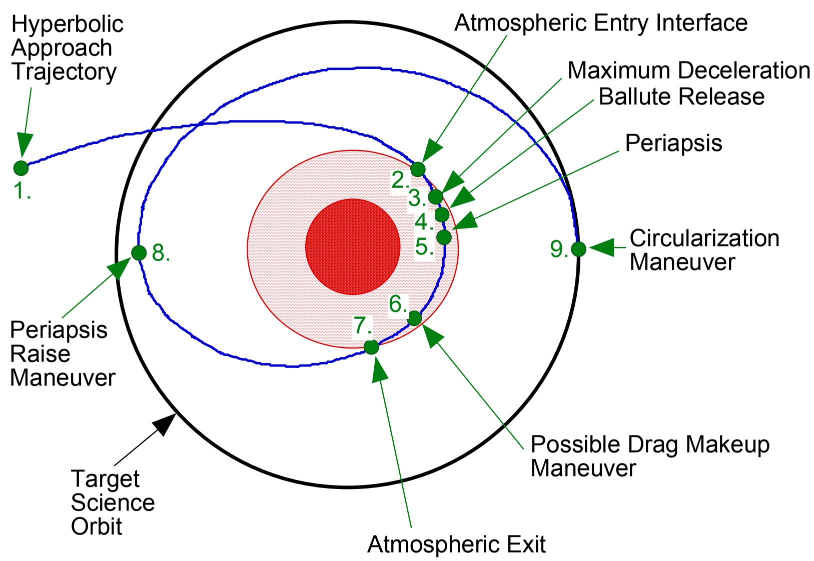
Ballute Basics:

Large Inflated “Ballute” Provides Large Drag for Low Mass, Low Heating.

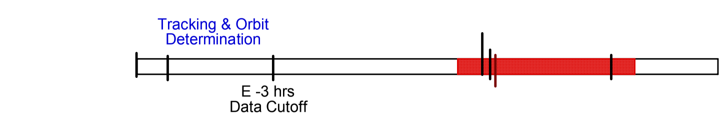
Primary Control: “Let go”
(Once you have enough ΔV.)



Trailing Ballute Configuration



Orbiter Trajectory



Sequence of Events
Adapted from Aeroshell Baseline

Titan Example

An example trajectory taken from the Titan Ballute Aerocapture Study that was funded by the In Space Propulsion Program is used to illustrate three trajectories:

1. The trajectory of the Orbiter through the Atmosphere.
2. The trajectory of the Ballute+Lander after Orbiter release.
3. The trajectory of a pure lander. (No ballute release.)

Simulated Parameters

Entry Speed: 6.5 km/sec (Specified by ISP study.)

Entry Mass: 500 kg (400 kg Orbiter, 100 kg Ballute+Lander)

Ballute Area: 750 m^2

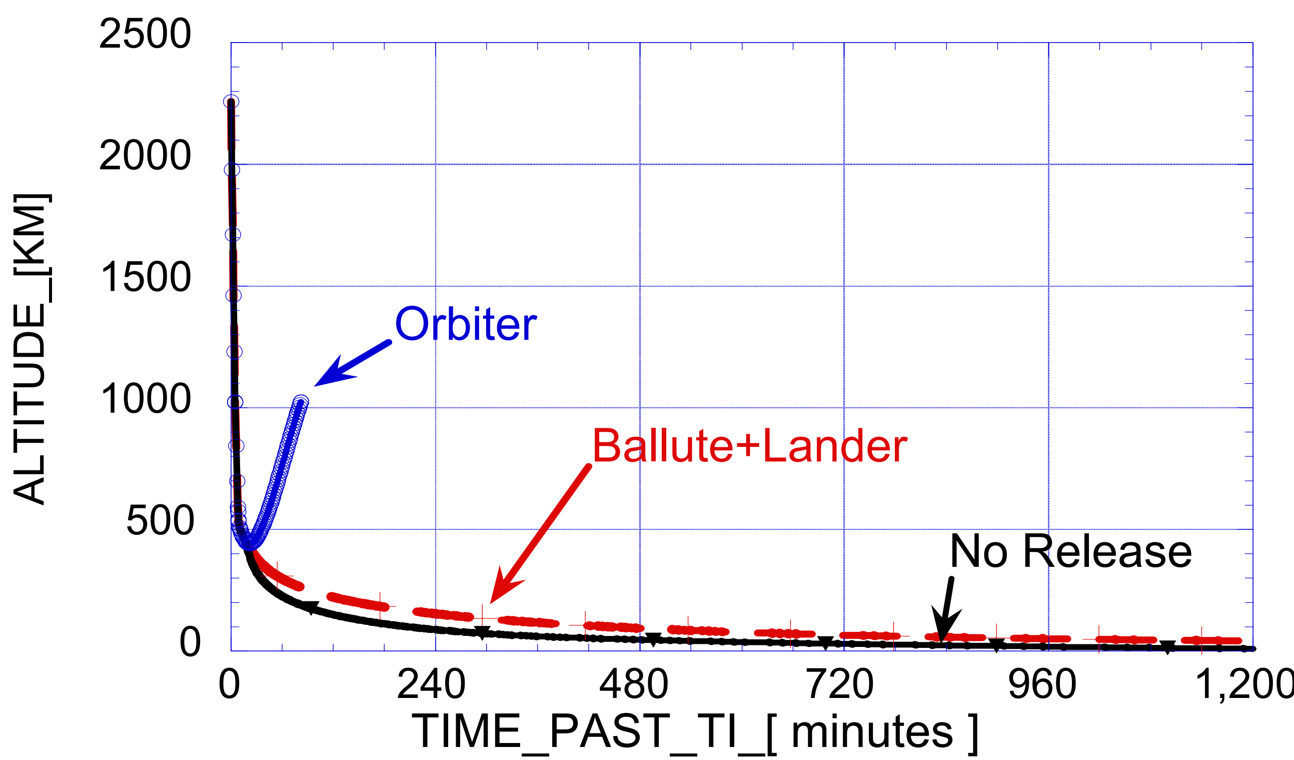
Orbiter Area: 2 m^2

Drag Coef. 1.37 (constant)

Atmospheric Density from TitanGRAM (NASA Marshall).

Target Ballute release for 1700 km Orbiter Apoapsis.

The orbiter altitude is decreasing while the ballute is attached. The ballute is normally released before periapsis to accommodate navigation and atmospheric uncertainties. The orbiter has enough speed to escape the atmosphere, while the ballute and anything still attached to it will always end up on the surface of the planet (or moon in this case).

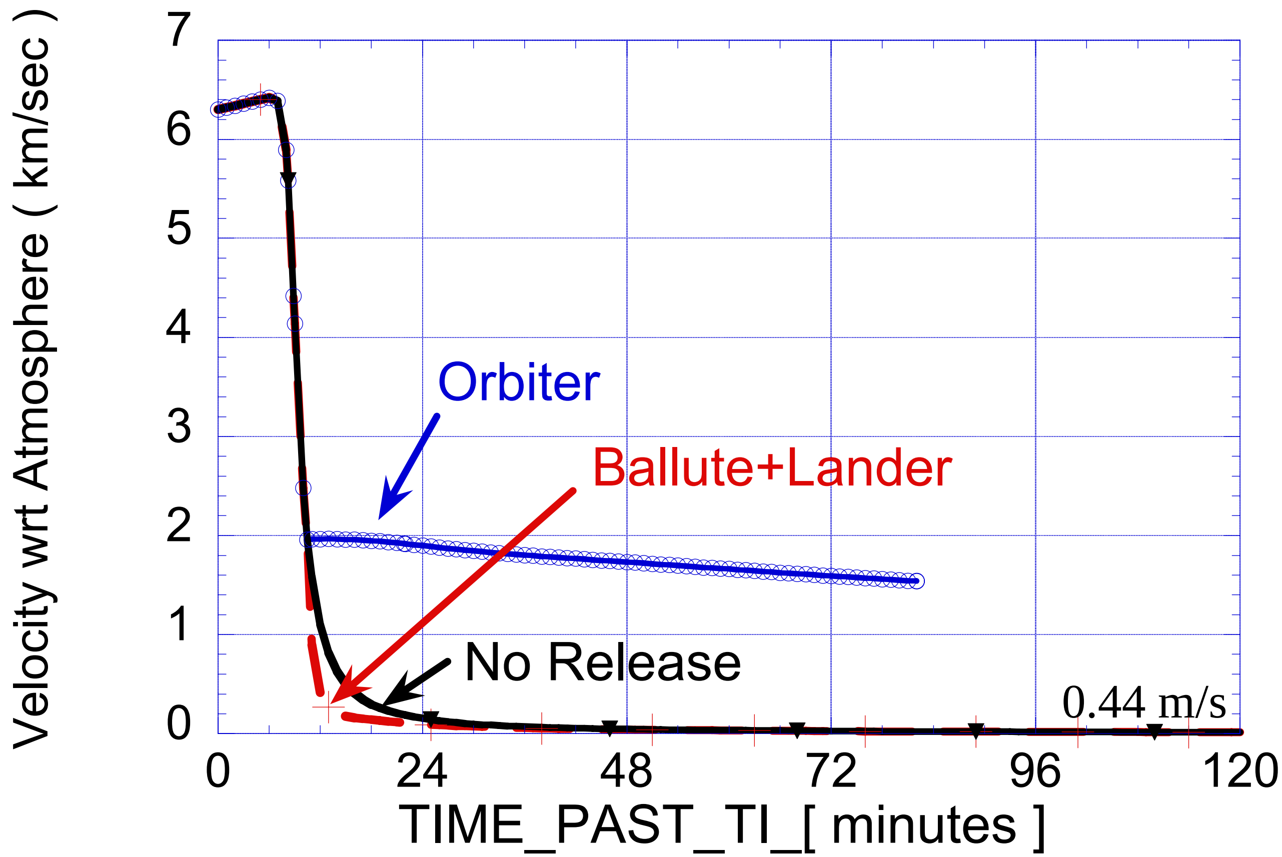


@Entry + 1 Day

"No Release" Reaches the surface, but

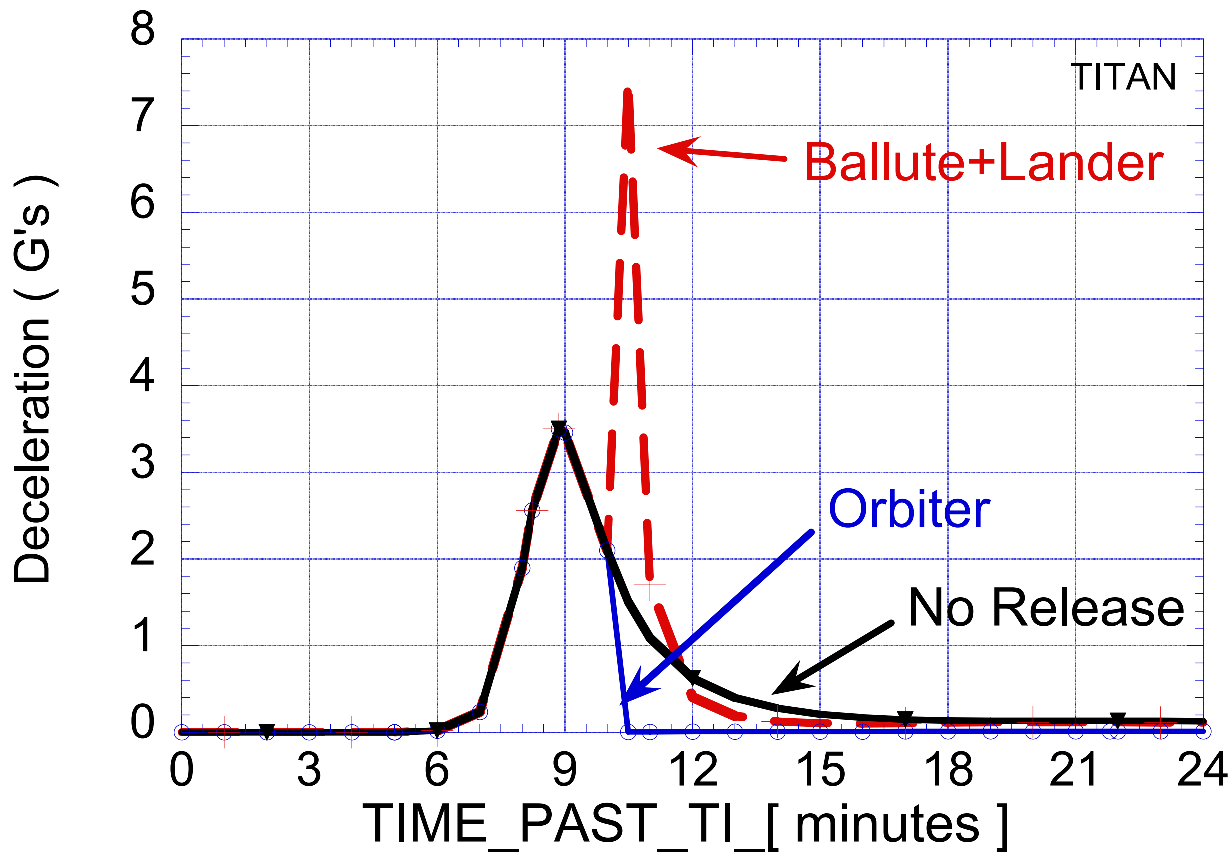
Ballute+Lander is still 34 km above surface!

Velocity relative to the Atmosphere decreases rapidly from drag acting on the ballute. After release, the orbiter speed decreases as altitude increases, while the ballute+lander speed decreases rapidly until terminal velocity is achieved.



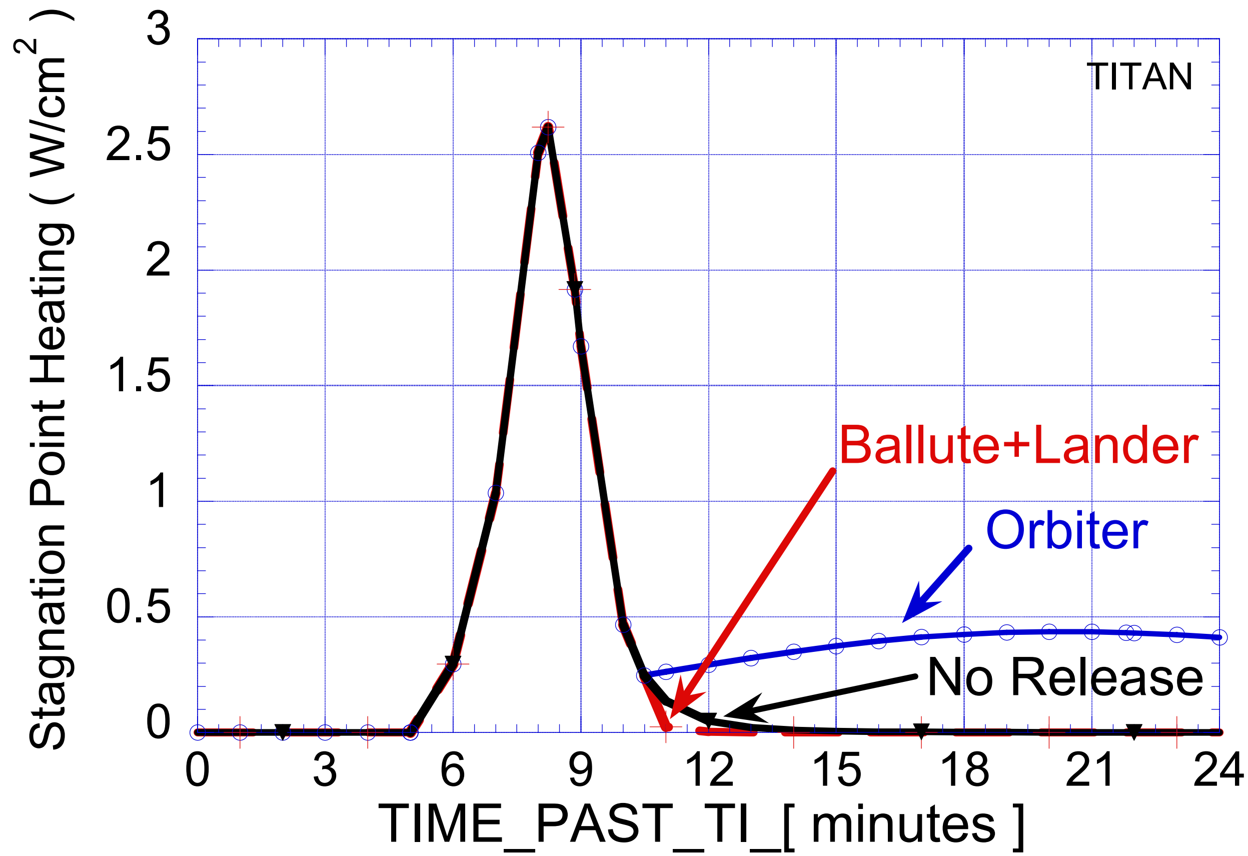
Slow speed relative to the atmosphere means that <u>winds</u> will determine the landing site … not suitable for precision landing unless ballute is released before landing.

Ballute Release occurs after the maximum deceleration, so deceleration on the Orbiter drops suddenly at release, but the deceleration on the ballute+lander increases suddenly since the force remains large, but the mass becomes small.



Lander hardware will have a higher G-load than the orbiter. The lighter the lander package, the higher the G-load.

Peak heating occurs Before ballute release, so No new aerodynamic heating constraints for the Landed instrument package.



Key Events

Atmospheric Entry & Exit at 1025 km.

Maximum Heating at Entry + 194 sec at 575 km.

Maximum Deceleration(all) at Entry + 232 sec at 540 km.

Max. Decel. (Ballute+Lander Only) Entry + 330 sec at 504 km.

Ballute Release at Entry + 330 sec at 503 km.

Periapsis (Orbiter Only) at Entry + 1009 sec at 441 km.

Exit Atmosphere (Orbiter Only) Entry + 4623 sec at 1025 km.

Summary

In Space Propulsion program has been funding Ballute Technology development that has been making significant progress in the last few years.

The ballute simulations have been focused on releasing the ballute at the right time and then ignoring it to focus on the trajectory of the orbiter.

The ballute will land on the surface, so there is an opportunity to piggyback a small lander payload on the ballute structure and get a “free” ride to the surface.

A dedicated ballute can be used to aerocapture and land a larger payload.

Issues

Holding on to the ballute all the way to the surface may not always be desirable. In this Titan example, the drag from the ballute was so large that it took many <u>hours</u> to reach the surface! Depending on the mission objectives and the atmospheric properties of the target body, the ballute might have to be released or deflated to achieve the mission objectives. For example, the Huygens Titan probe will discard a large parachute and then open a smaller one in order to reach the surface before the battery power runs out.

Once the orbiter is released, the deceleration on the ballute increases dramatically. A lander payload that is piggybacked onto an orbiter mission will have to be designed for Higher G-loads than one that is designed to for landing.