Landing materials on the Moon or Mars with less fuel, engines, structure

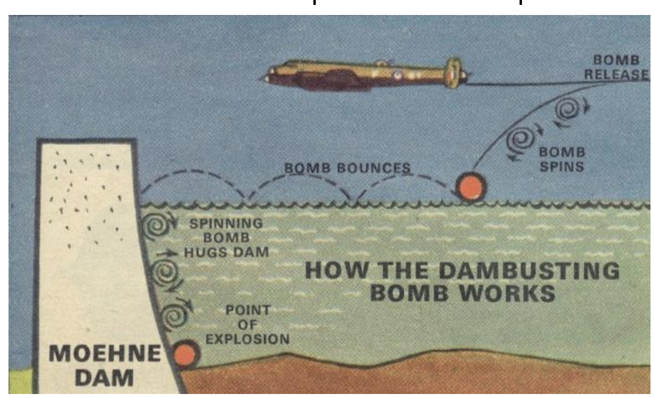
Glenn Johnson 8/5/2019

The next time we go to the moon NASA is expecting to be setting up a base that can be populated for extended periods. This Lunar Base will need a large amount of supplies to keep these people alive—food, water supply parts. During Apollo, this would be a very expensive endeavor since all the materials would require the spacecraft to be slowed down from lunar orbital speed down to 0 with expensive engines, lots of fuel and heavy structures (legs to hold up the lander). Close to 4/5th of the Apollo Lunar Lander was fuel, engines and landing structure. It is expensive to build parts that clutter the surface. To achieve a sustainable Lunar Base NASA will need to develop some reusable landing vehicles with enough fuel for getting back up to orbit and will probably be leaving significant components on the moon. We will need to come up with new techniques so that fewer parts are left behind.

One option could be that we develop different types of landers for different jobs. A lander that is only for food and water would not need to be as gentle at touchdown as a lander that carries people or sensitive equipment. Bringing some supplies down with a bigger bump, could save mass of fuel and allow a larger payload of supplies.

Without a lunar atmosphere, we won't be able to slow the vehicles down with air friction or parachutes. What if we could land materials on the moon not by using lots of fuel and heavy engines and support structure with legs but instead slow down the supplies more like skipping a stone across the water? The moon has long stretches of open sandy plains. Why not utilize those sandy, flat planes similar how we use dried lakebeds here on Earth as landing strips for planes?

There are some similarities with this idea to the Dam Buster of WWII where bomber planes would drop spherical or cylindrical bombs that would bounce across the lake until they slowed and bumped into the dam, sunk down in the water and exploded at an appropriate depth to damage the dam. They were dropped at low altitudes at speeds over 300 mph without exploding. There would be several differences from the dam busters of course. NASA supply pods for the moon would not contain explosives that might detonate on impact but they could be coming down at much faster speeds and would be hitting sand and rocks instead of water. The whole point is to use friction with the ground over a long distance to slow down the supply pod to save mass of fuel, engines and structure to increase the amount of supply mass can be placed on the Lunar or Martian surface.



The touch down speed could be slowed down to nearly any speed using engines and fuel and then release the supply pod from the engine/tank. The supply pod would bounce onto the surface and roll to a stop and the engine/tank would land somewhere else. However, it may be possible to touch down at very high speeds and use little to no fuel. Escape velocity for the moon is around 2,386 miles per hour. That's very fast. And the orbital speed could be much faster depending on the orbit the supply pod could be placed in as it comes from Earth. However, depending on the materials for the pod and some other factors, it might be possible by adjusting the orbit of the supply pod so that perigee of the supply pod just barely kisses the ground at one of the long, flat maria basins of the moon so the payload skims across the sand like a stone across water. Using the friction of the sand to slow it down instead of fuel and engines. Thanks to the wind action on Mars, using the flat sandy areas to slow down supply pods might be more practical on a planet that has more flattened surfaces than the moon, which has many more exposed craters.


Lunar Surface as seen from orbit

This could be tested on Earth with a high-speed jet doing a low strafing release of a test supply pod filled with similar supplies and sensors. It seems like NASA might know of a long, flat, dry lakebed in California or Arizona that would be similar to a lunar maria. One of the main questions will be how much deceleration the supply pod materials can handle without being damaged.

There are a number of techniques that could aid in increasing the survivability of the supply pod including but not limited to:

- Touchdown on a downward slope going into the basin
- Forward or backward spin on the supply pod—depending on how fast you want it to slow down or directing the bounce—forward spin would allow a slower deceleration and prevent 'decapitation' of the pod at touch down
- External and Internal dampening mechanisms
- Planned breaking apart after impact
- Inflated balloons similar to how JPL landed a Mars rover might be an option
- Orbital tethers—have an orbital component that lowers the supply pod down closer to the surface by way of tether. When the supply pod gets close to the ground, release the connecting tether as it touches down on the surface, let it bounce and roll to a stop. The orbital component would get slung out to a higher lunar orbit and might be reusable once the tether was reeled back in.

By understanding the speed of the touch down, the elasticity of the supply pod and its contents, the friction of the sandy surface, it seems that engineers could predict within a fairly small space (half mile radius maybe?) of where the supply pods would come to a stop. This would not be much different from predicting where a baseball would stop in the outfield given the initial conditions of the hit from the bat, the energy absorbed in a bounce on the ground and the friction of rolling in the grass. Once stopped, the astronauts could collect up the supply pod or the planned scattered pieces using the lunar rover.


Martian surface as seen by Curiosity Rover

On Earth, the military drops supplies from airplanes for the troops on a regular basis without the planes touching down. Of course, they use parachutes most of the time to control the decent and they don't drop them at supersonic speeds. But this doesn't have to only be science fiction. During WWII allied planes were dropping bombs on Germany from heights between 10,000 and

20,000 feet. Bombs dropped from these heights would attain velocities between Mach 1 and 2. Most of these bombs would detonate on impact however some would not and the German government is still removing unexploded ordinance from WWII today. This is true in all of the places where there has been a war. Despite our defense contractors best efforts to make their bombs reliably explode on impact with tons of explosive, there are still some that don't explode. It seems that if people can engineer bombs that are suppose to explode at high speeds but don't, it seems we might be smart enough to design pods that would stay together at high speed impacts especially if they are only filled with water and non-explosive materials. Whether the supply pod comes down at 2,000 miles per hour or something much slower, food and water, hammers and nails do not require a soft landing.

The moon and Mars both have plenty of open spaces. Because Mars has wind and dust storms, the Martian surface is smoothed out more than the moon's making it more likely that we could find a relatively even surface to roll to a stop. The less fuel, engines and landing structure used for placing those supplies on the lunar surface, the more supplies and the cheaper NASA can outfit our crews for success.

Some of the Variables that need to be modeled:
Mass of container and contents
Velocity at touchdown
Angle of contact with the surface
Surface particle size—sand to gravel to rocks to boulders
Undulation of the surface
Coefficient of restitution of pod
Spin of pod—forward or backward
Strength of supply pod—key question—can the pod and supplies survive—the faster the touch down, the more mass saved in fuel and the more food for the crew.
Internal or external dampening of supply pod
Is there advantage to the pod being larger or smaller in terms of survivability
Although it is the goal to model all of these factors (and I expect there are more), modeling just some of these may give us an idea if this is possible.

Helpful tips:
Consider looking at golf ball or tennis ball calculations. Golf balls because they may have simulations for rolling on the grass to a stop and a changing surface. Tennis balls because they use back or forward spin on the ball. There are several video games that would use similar software and equations. I don't know if they would have equations for changing the strength of the ball.

A simplified supply pod:
A hollow sphere making contact with a smooth sandy surface may be a good, simple beginning for the initial condition for a calculation of how the ball might behave. Imagine a titanium, spherical shell 2m in diameter with a wall thickness of 2cm. This might behave similar a ping-pong ball with lots of bouncing. The next step may be to add frozen water in the ball. The impact, bouncing and friction of the ball on the sand may melt the ice and absorb some of the energy of the supply pod. Another step may be to have liquid water where the swirling of the water would allow the ball to continue rolling for a longer period of time. Then try adding packets of MREs (food packets) and other supplies that would increase

the density and complications related to the center of mass and how that mass may change with motion. Each of these changes would alter the restitution of the ball as it bounces and how far it will roll. Knowing when the titanium ball might break apart is the key factor. How thick does the titanium shell need to be to survive as the touch down velocity increases? I'm not sure where you might find that information. Can you suggest other containers that might survive better?

The next step might be to add undulations to the sandy surface. The moon's surface is much more cratered than Mars since there isn't any wind or water action to shift the sand. Even in areas that look smooth in the Apollo photos from orbit, there are craters that are several meters deep and tens of meters across. This would certainly complicate a rolling touch down in some areas if not make it impossible. The sand on Mars will probably be more even but still have ripples, hills and valleys that will cause bouncing.