ANALYSIS OF A LANDING SYSTEM FOR PLANETARY PAYLOADS UTILIZING PASSIVE ENERGY ABSORBING COMPOSITE STRUCTURE

MATLOCK MENNU, JACOB PUTNAM, JUSTIN LITTELL

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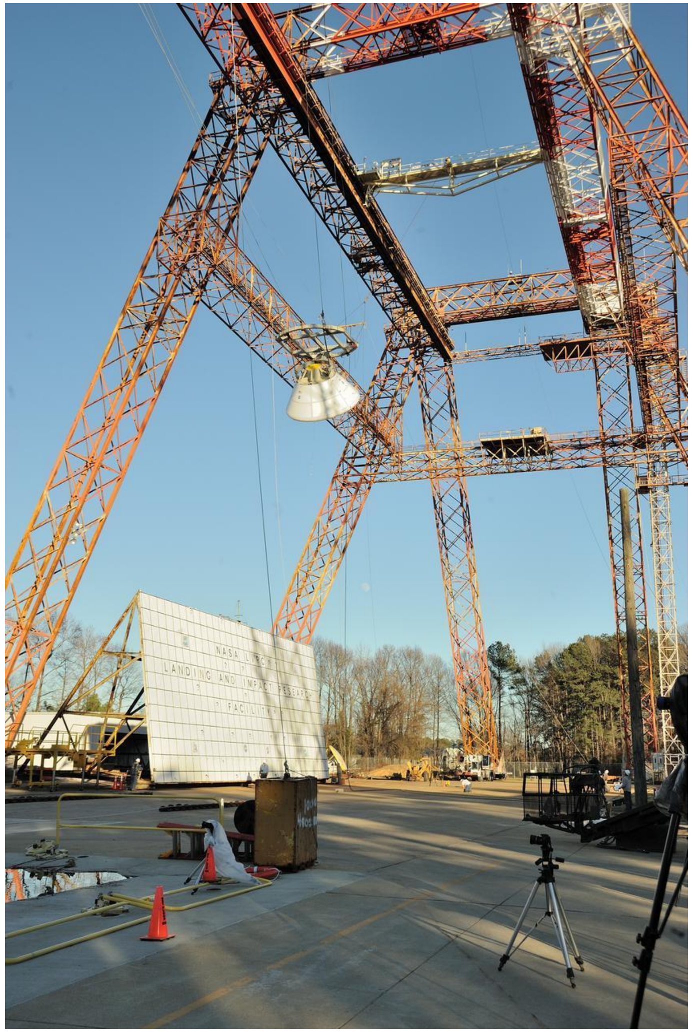

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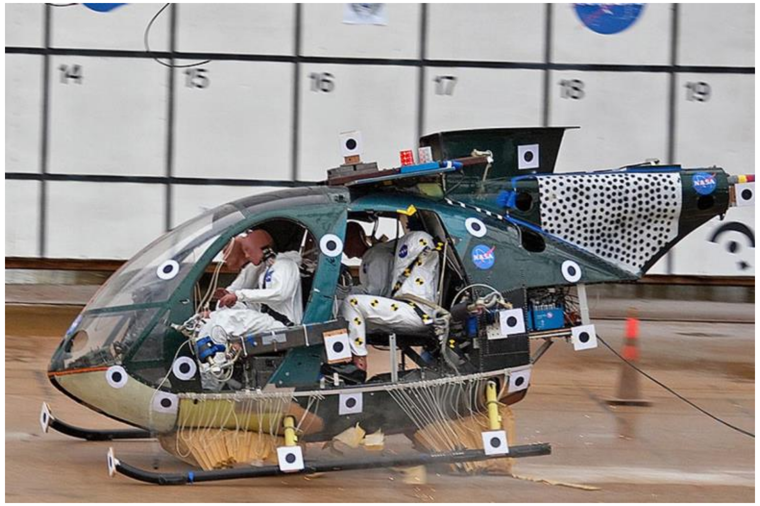


https://newatlas.com/nasa-tests-helicopter-airbag/13571/

https://www.nasa.gov/centers-and-facilities/langley/nasa-crash-tests-evtol-concept/

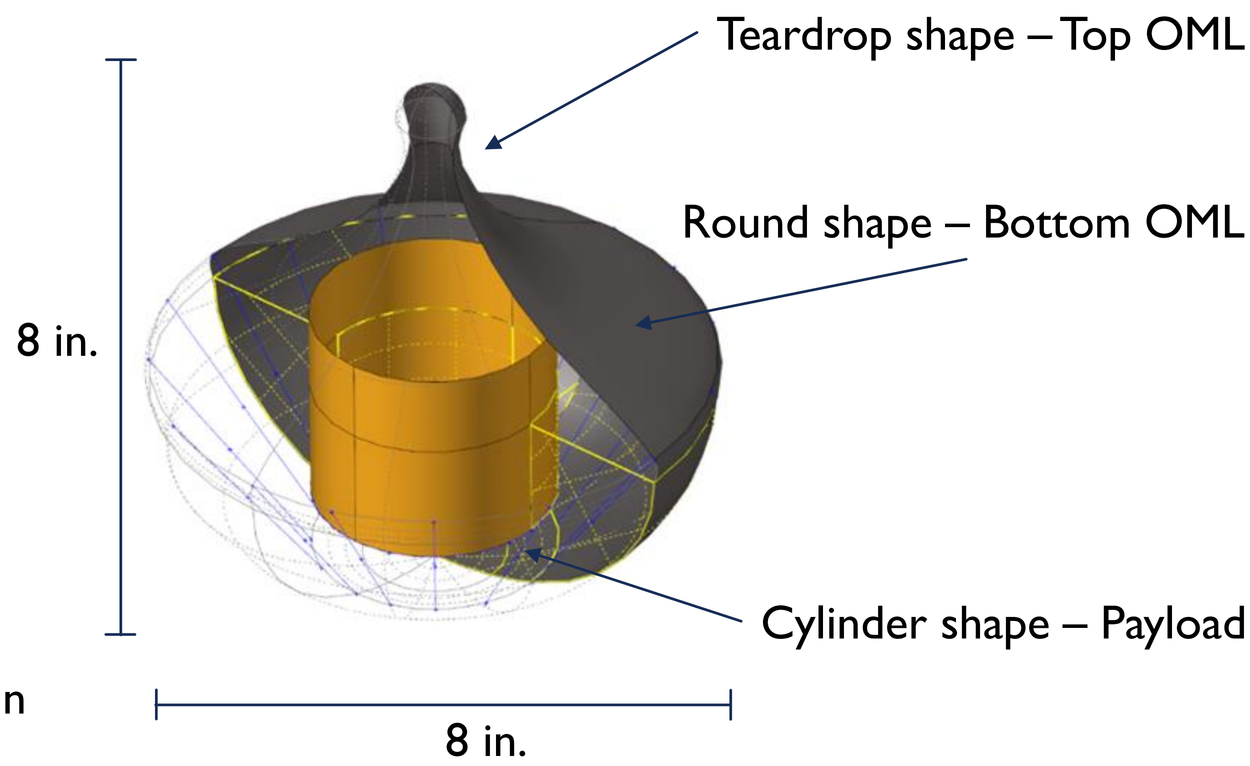
BACKGROUND

- Delivery of equipment and payload requires a transportation mechanism that can ensure safe arrival of these items to the planetary surface.
- Landing system designs must consider the variability in payload size and landing conditions.
- Many designs consider the use of active energy attenuation system such as retrorockets and deployable parachutes, but these systems are prone to failure.
- A different design approach was considered using passive energy attenuation mechanisms. Energy absorption materials were identified and designed to withstand acceleration at various landing conditions.
- This approach has also been used by various NASA projects as alternative means of designing landing system.

https://en.wikipedia.org/wiki/Retrorocket#/media/File:Rocket_assisted_descent.jpg

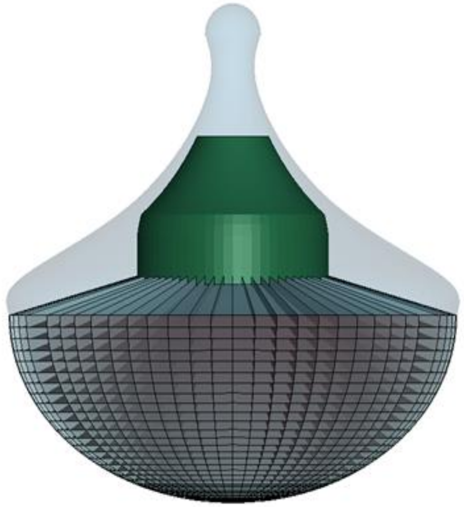
OBJECTIVE

- The goal is to design a payload delivery system using passive energy attenuation mechanisms i.e., energy absorption materials previously studied at NASA.
- The design of the outer mold line (OML) of the capsule needs to contain the payload as well as provide passive up-righting capability.
- Design needs to be robust enough to ensure the internal payload doesn't exceed the specified acceleration limits.
- Honeycomb design was used as energy absorption material inside the payload capsule.
- Different density of honeycomb structure was modeled to observe the changes in the peak loads in the capsule during impact.

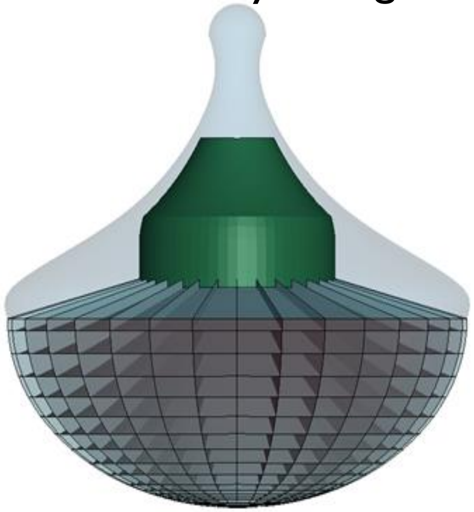


HONEYCOMB CELL SIZING

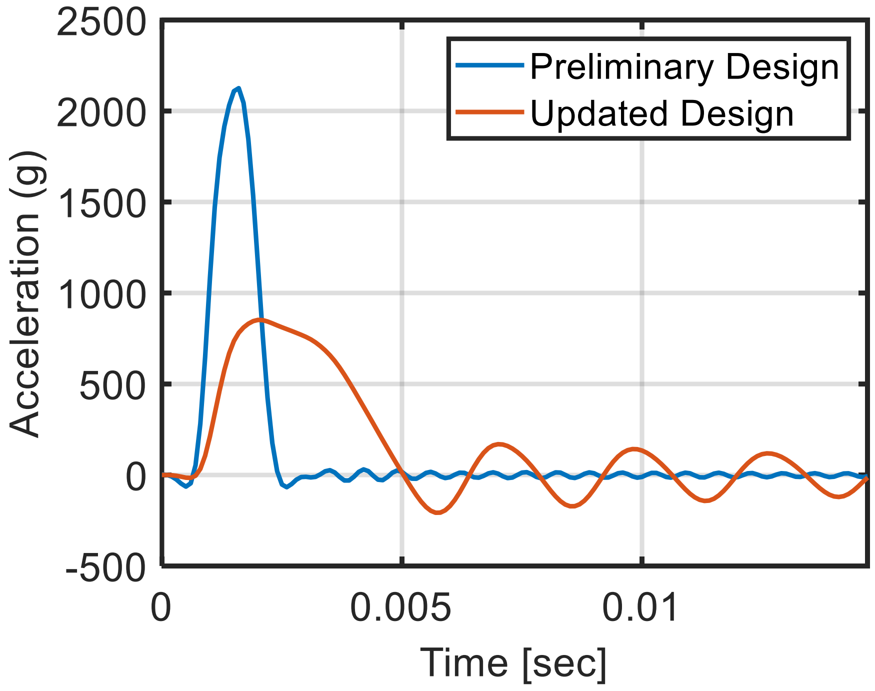
- Model for the honeycomb lander was accomplished in LS-DYNA.
- Quadrilateral shell elements of approximately 0.2 in was used for outer capsule, payload shell, and honeycomb structure.
- Previously modeled concrete was used as landing surface. Simulation was vertical drop at 50 ft/s.
- Two honeycomb designs are presented here.
  - Preliminary design: 0.2 in x 0.4 in.
  - Updated design: 0.4 in x 0.8 in.
- 62% reduction in peak acceleration with updated design.



Preliminary Design



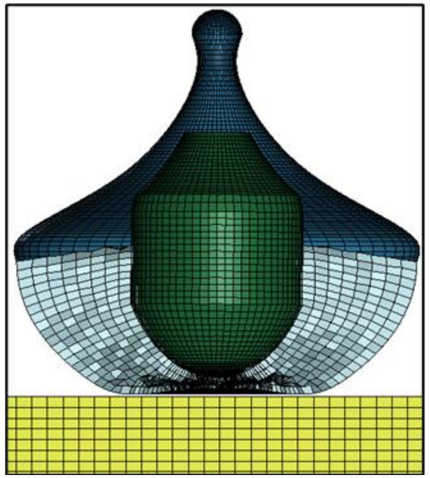
Updated Design



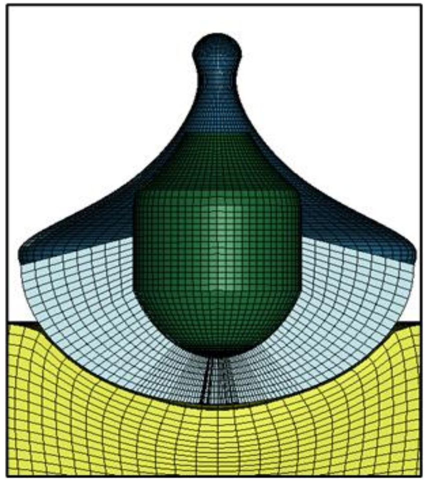
IMPACT SURFACES

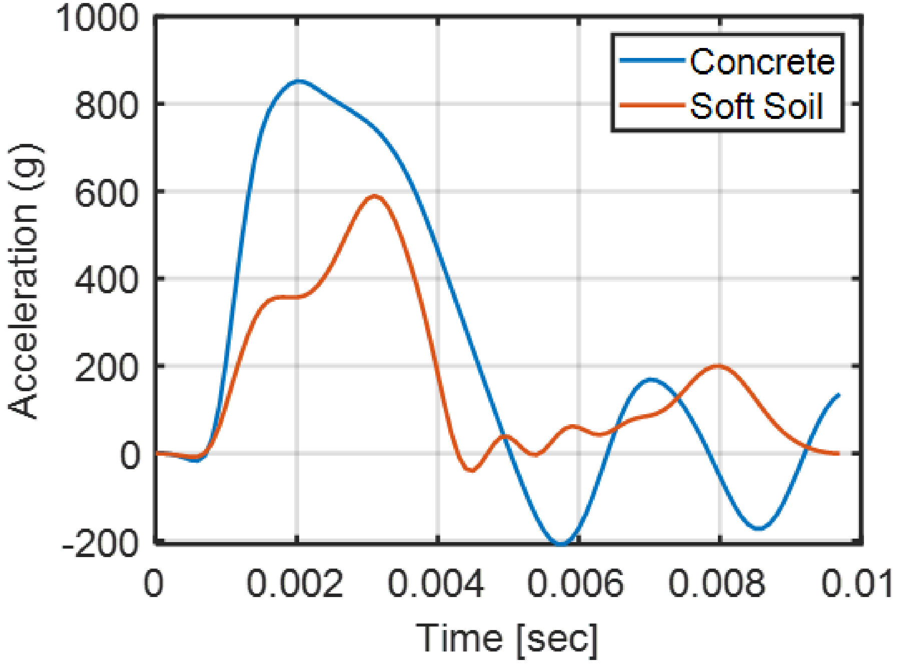
- Honeycomb design impact on two different representative surfaces was studied. Concrete surface and soil impact surface were explored.
- Representative soil model obtained from previous testing conducted at NASA.
- 50 ft/s vertical drop simulation compared for concrete vs soil surface.
- Soil impact surface acts as energy absorption rather than the honeycomb in this case.
- Design needs to consider how to optimize effectiveness in both landing surfaces.

Concrete Impact



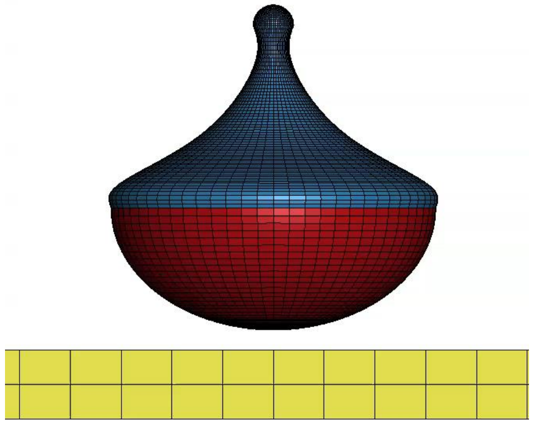
Soil Impact



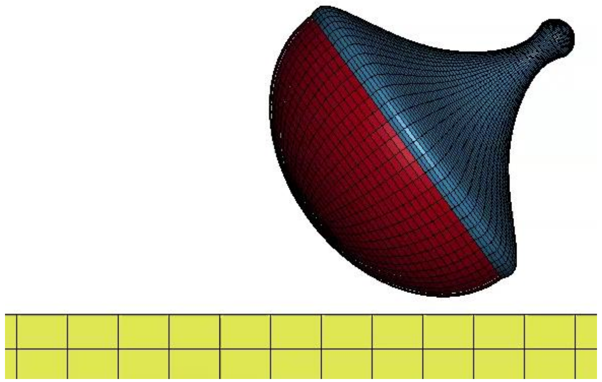


LANDER ORIENTATION

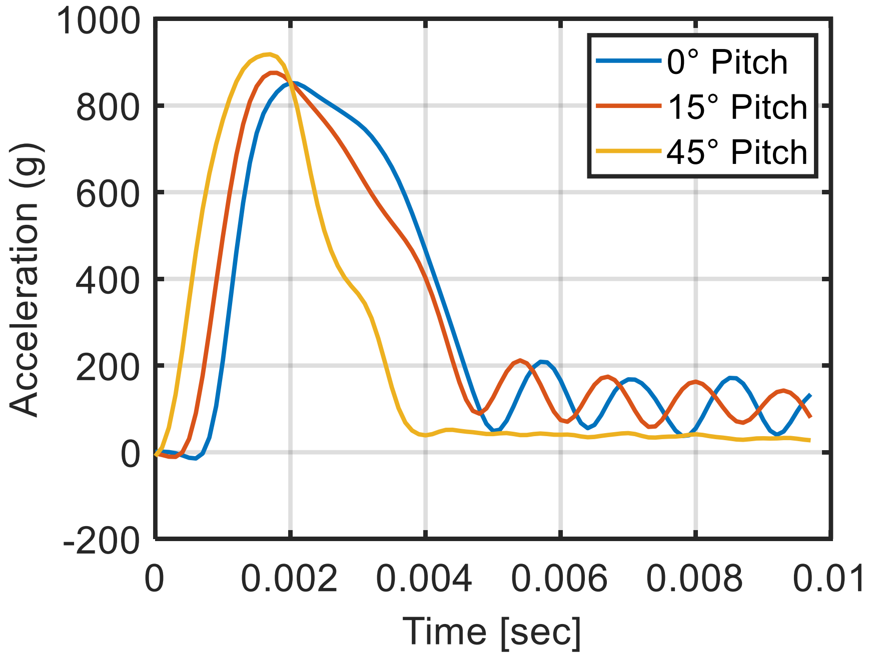
- Impact of pitch angle on the landing system was studied. Pitch angle was the orientation of the landing system velocity in relation to the surface. 0 degree is vertical drop of the lander.
- Z-direction acceleration measured along local coordinate system of the landing system.
- Pitch angle of 0, 15 and 45 degrees were studied using concrete landing surface to observe honeycomb structural response.
- Increased pitch angle caused slight increase in acceleration response of the lander indicating larger lateral stiffness in the design.



0-degree pitch

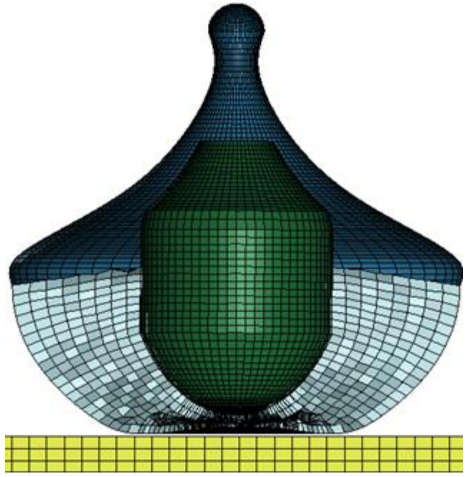


45-degree pitch

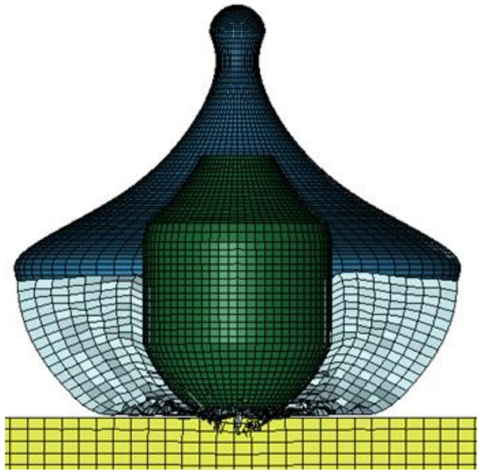


IMPACT SPEED: CONCRETE

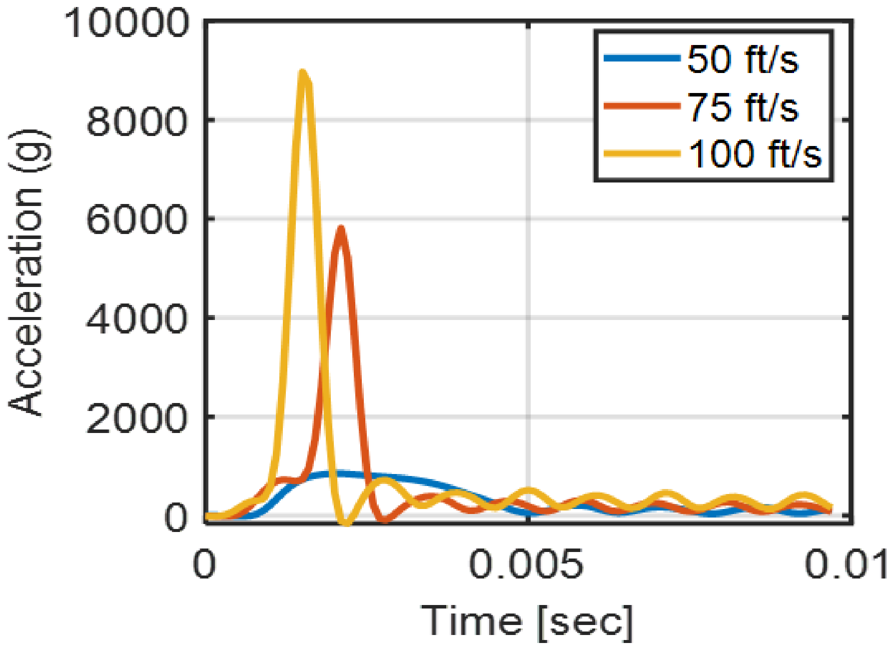
- The speed at which the lander impacts the surface was explored for the concrete surfaces.
- 50 ft/s, 75 ft/s and 100 ft/s vertical drop simulation (0° pitch angle) were conducted.
- Increasing the impact speed above 50 ft/s caused the honeycomb structure to bottom out and allow the payload to impact the concrete surface leading to a spike in acceleration.



50 ft/s impact

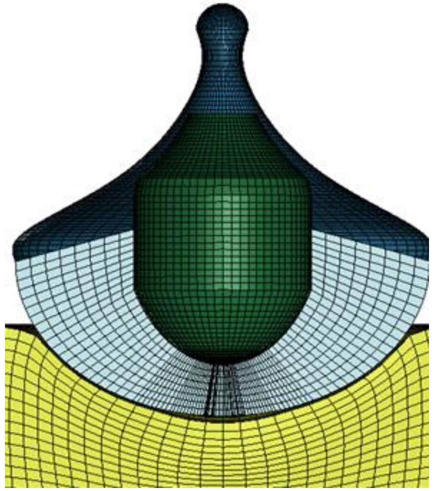


100 ft/s impact

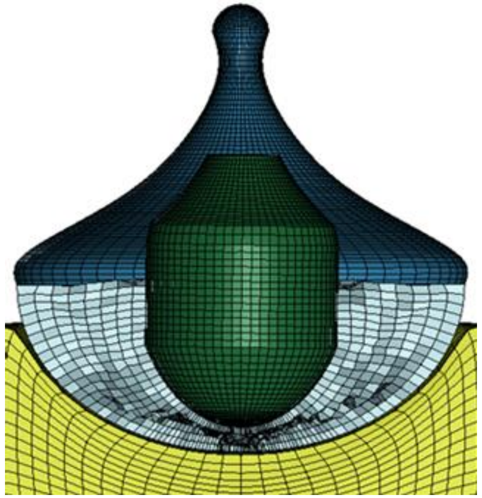


IMPACT SPEED: SOIL

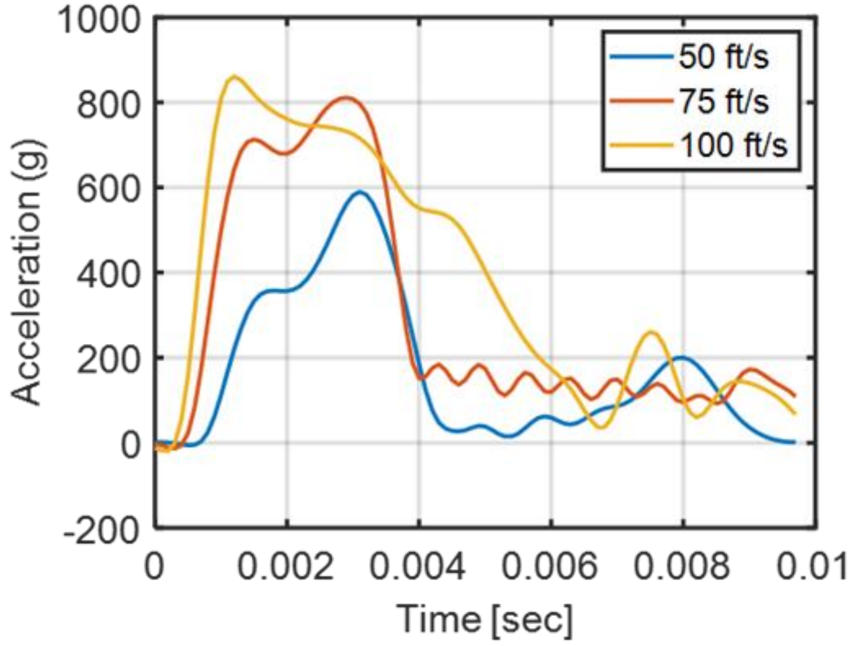
- 50 ft/s, 75 ft/s and 100 ft/s vertical drop simulation (0° pitch angle) were conducted on the soil landing surface.
- For the soil surface, impact speeds above 50 ft/s initiated crushing in the honeycomb structure maintaining acceleration levels of 800 g.
- Factors such as impact speed, landing condition, impact pitch angle must be explored simultaneously to design a lander suitable for all conditions.



50 ft/s impact

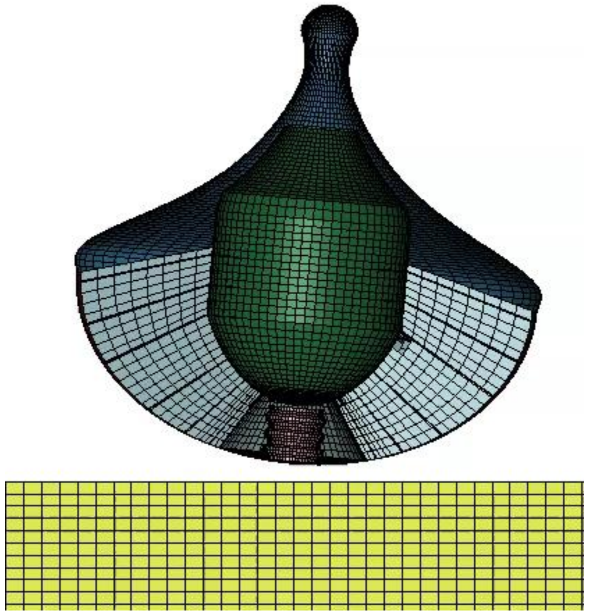


100 ft/s impact

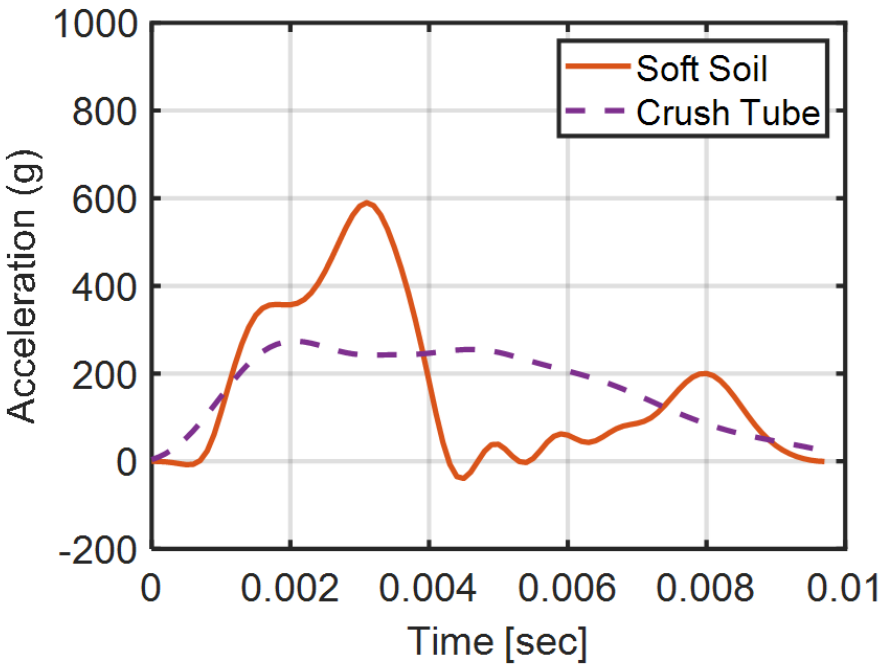


COMPOSITE CRUSH TUBE: SOIL

- In addition to honeycomb material, composite crush tube with corrugated sides used in energy absorption for seat designs was explored.
- Honeycomb and composite crush tube can be combined to optimize the design to limit accelerations in various conditions.
- Honeycomb cell size and composite crush tube size was adjusted to reduce previous acceleration peaks of 800 g.

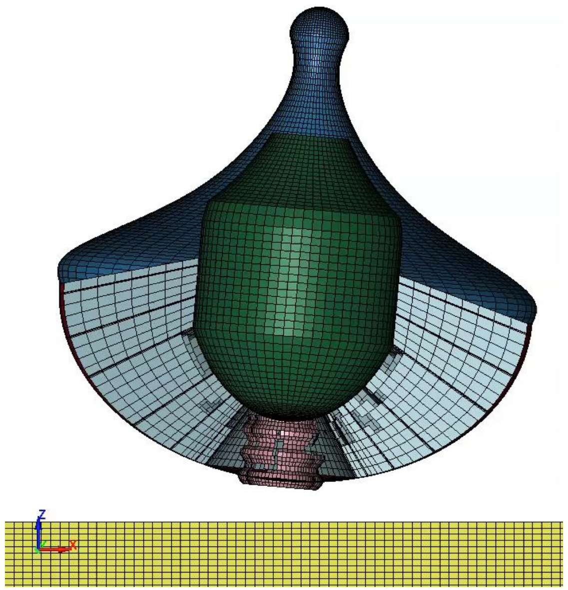


50 ft/s impact

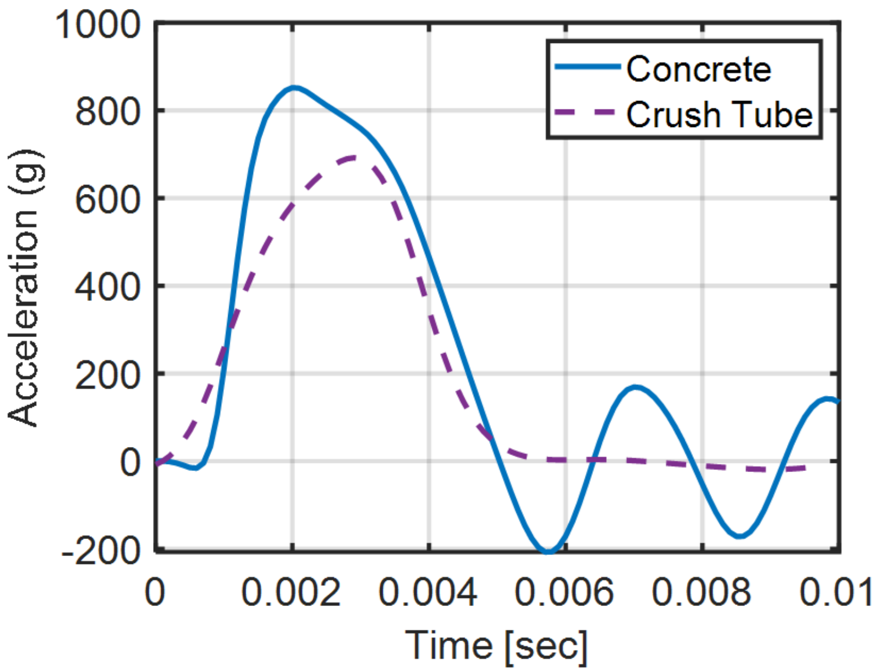


COMPOSITE CRUSH TUBE: CONCRETE

- Composite crush tube design was also evaluated with the concrete landing surface.
- Initial design of composite tube bottoms out and impact concrete surface for impact speed of 50 ft/s.
- The diameter and thickness of the composite tube was adjusted to provide additional stiffness.

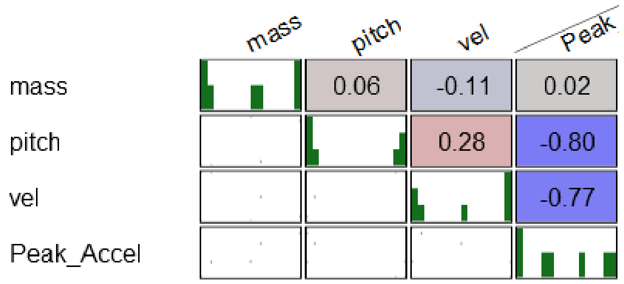


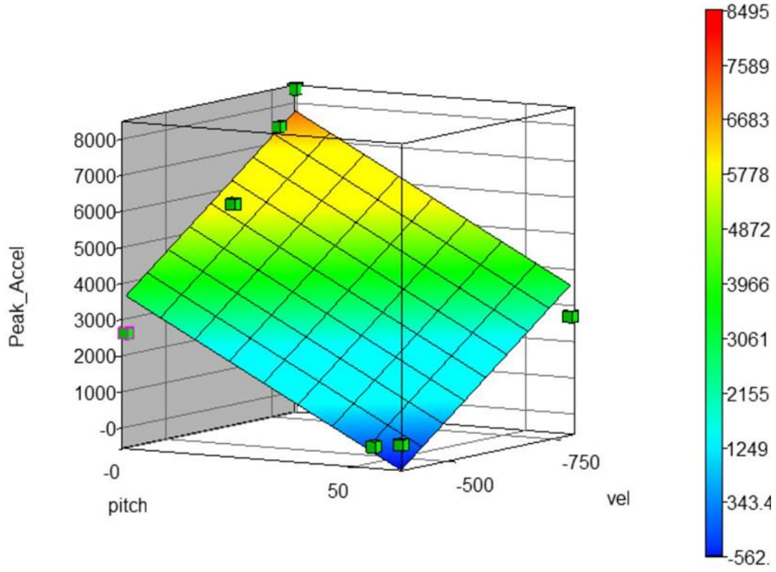
50 ft/s impact



PARAMETRIC STUDY

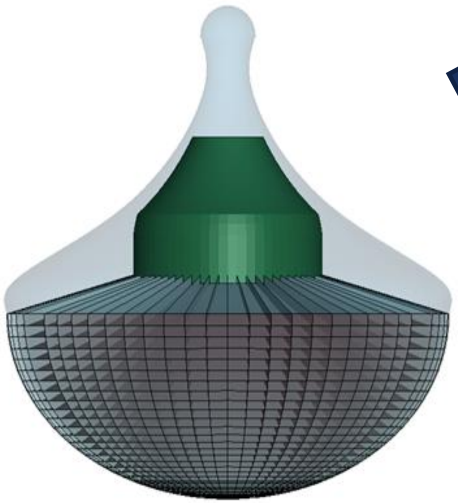
- Parametric study on the impact of speed, pitch angle and payload mass was studied using LS-OPT.
  - Multiple speeds (33.3 ft/s-66.7 ft/s)
  - Multiple pitch angle (0°-60°)
  - Multiple masses (15 – 23 lbs.)
- Seven points were selected to conduct the simulation. Linear response surface derived from the simulations.
- Peak acceleration in the concrete surface was mainly dependent on pitch angle and impact speed rather than mass.

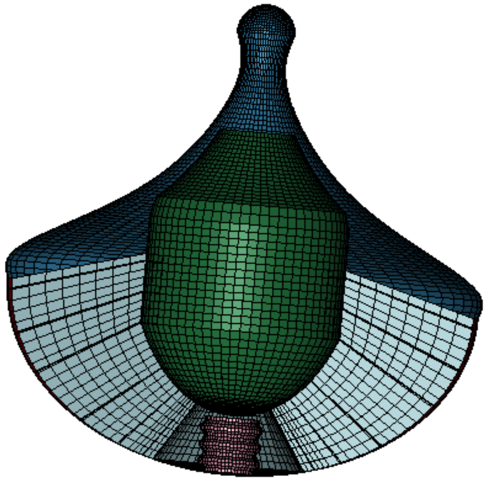




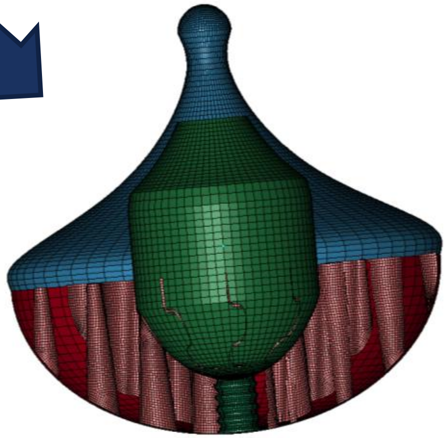
CONCLUSION

- Passive energy attenuation is a viable means of design vehicle used for payload delivery.
- Several factors must be considered to optimize the design to ensure payload stays within acceptable limits.





- Future designs can optimize the shape and size of the internal material through design iterations based on the known constraints such as landing location and impact speeds.



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THANK YOU

matlock.m.mennu@nasa.gov