A HVI simulation study on honeycomb and aluminum foam sandwich structure

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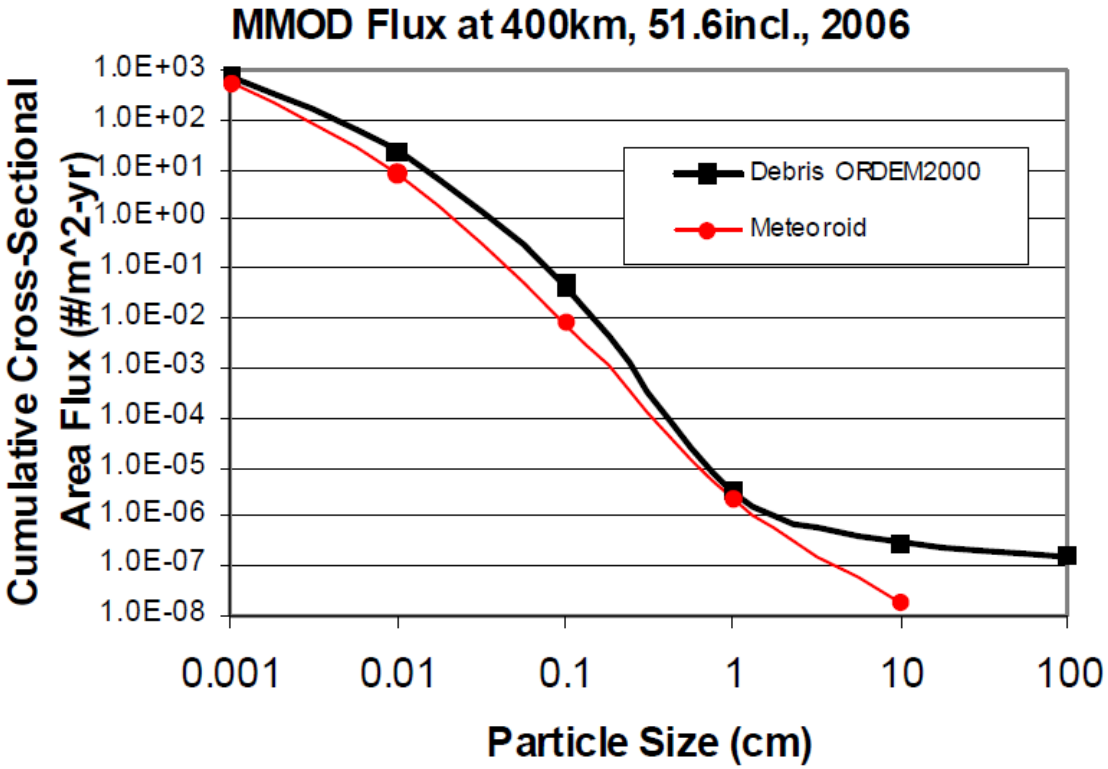
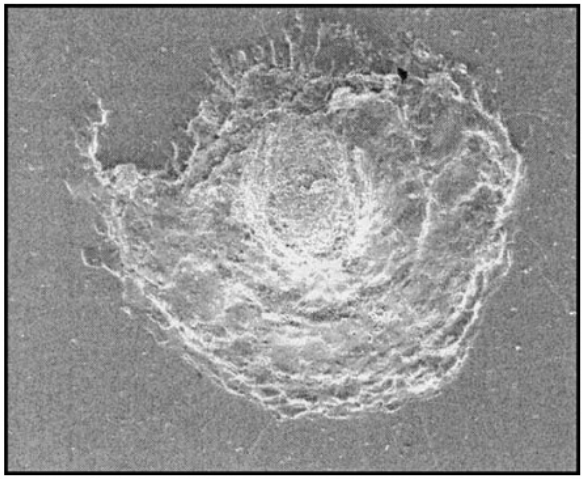
Micro-meteoroid and orbital debris (MMOD)

- Orbital debris consists of high-density (metals, primarily) impacting at hypervelocity (1 km/s to 15 km/s)
- Meteoroids are a hypervelocity threat (10 km/s to 70 km/s) present in Earth and lunar orbit, as well as the lunar surface

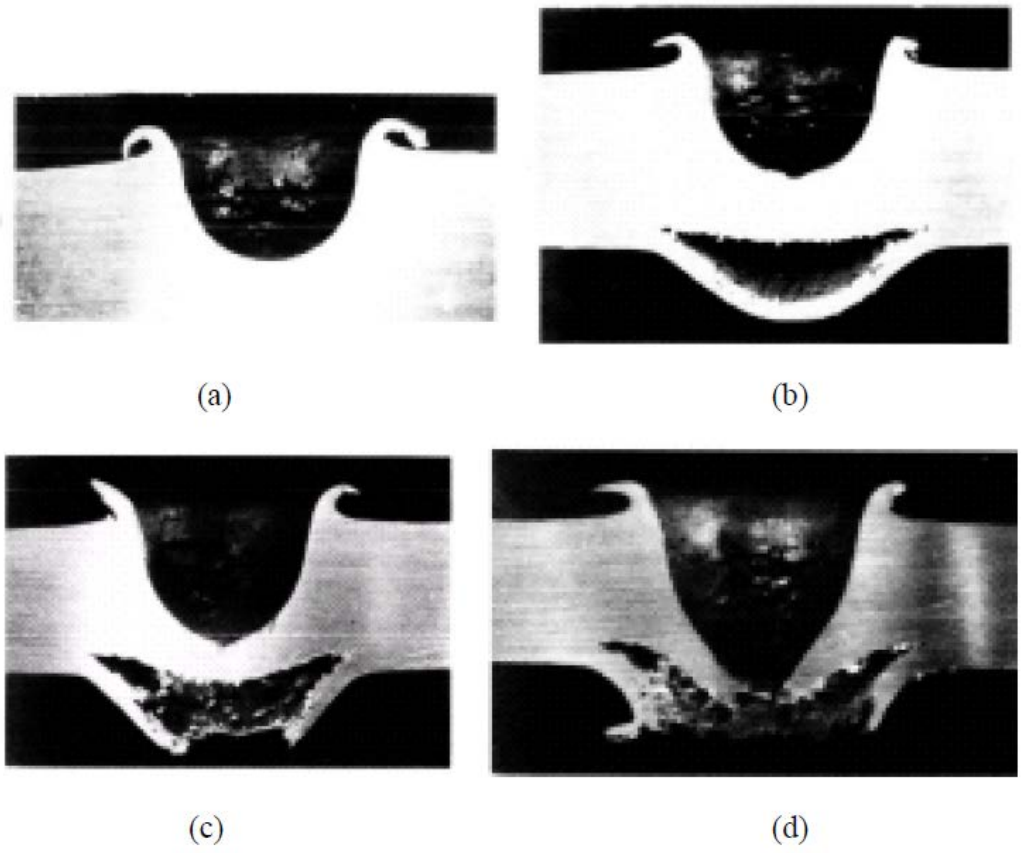
MMOD threat





- In LEO, a spacecraft with10 m^2 project area may expect at least one impact by MMOD larger than 1 mm per one year

HVI damage modes on aluminum



- HVI damage modes in aluminum:

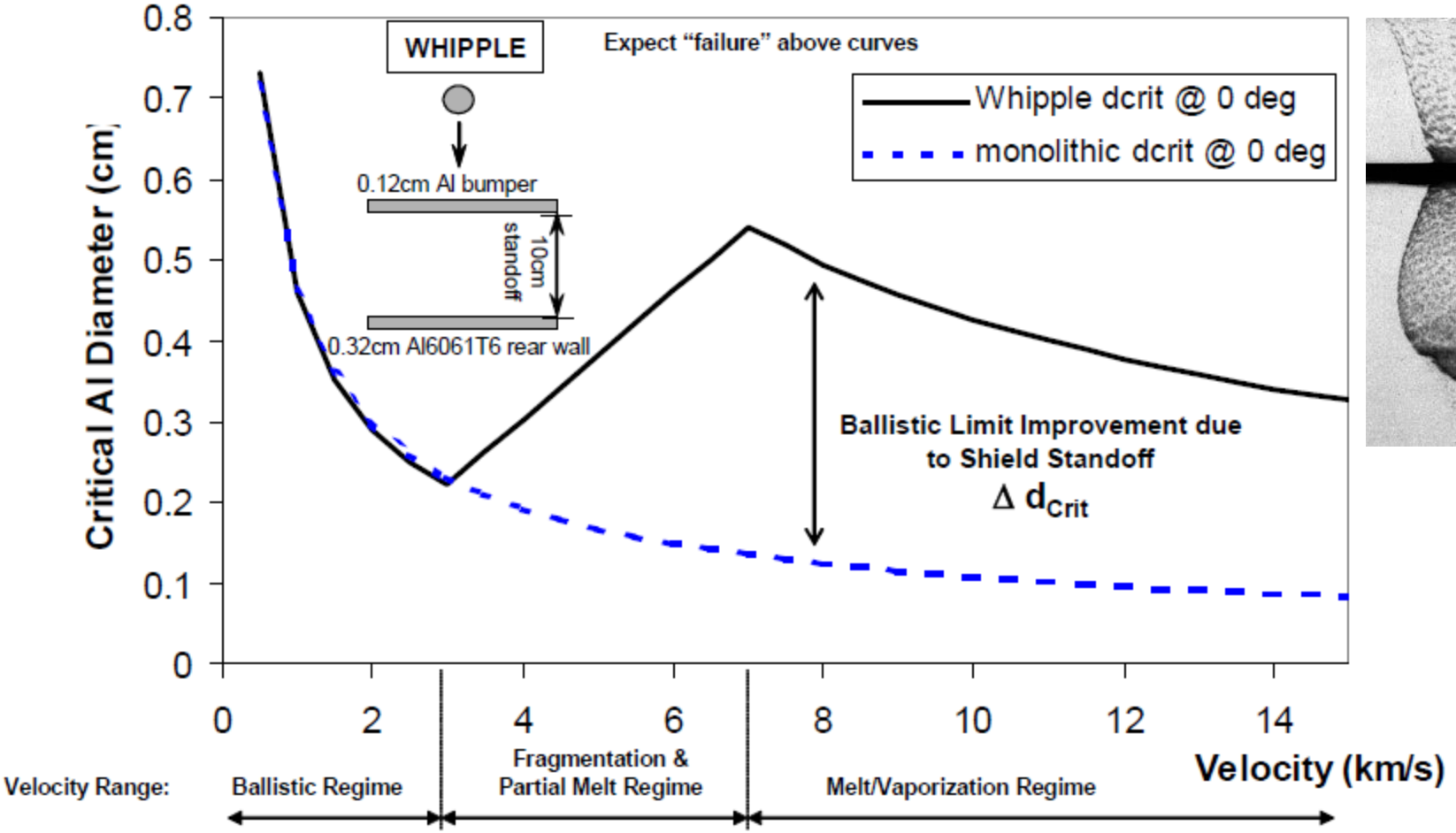
  (a) craters in semi-infinite targets

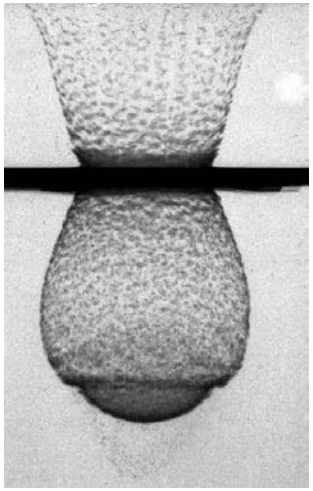
  (b) attached spall

  (c) detached spall

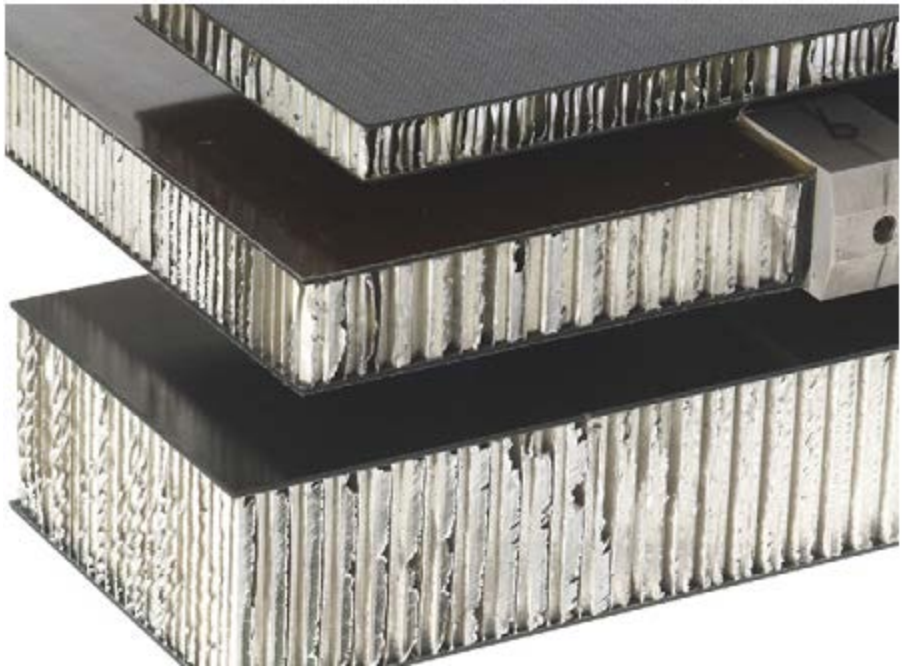
  (d) complete penetration or perforation of the target.

Whipple shield



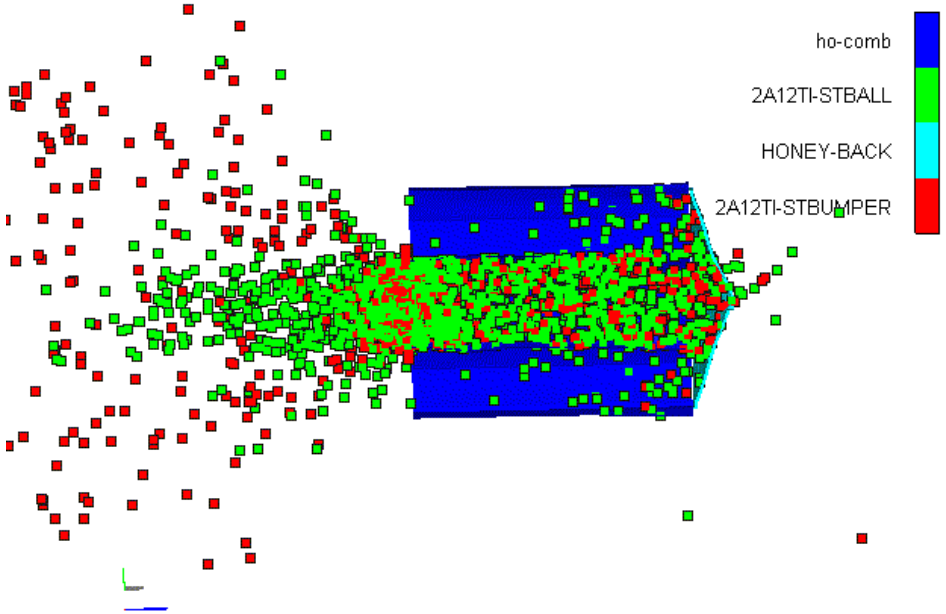


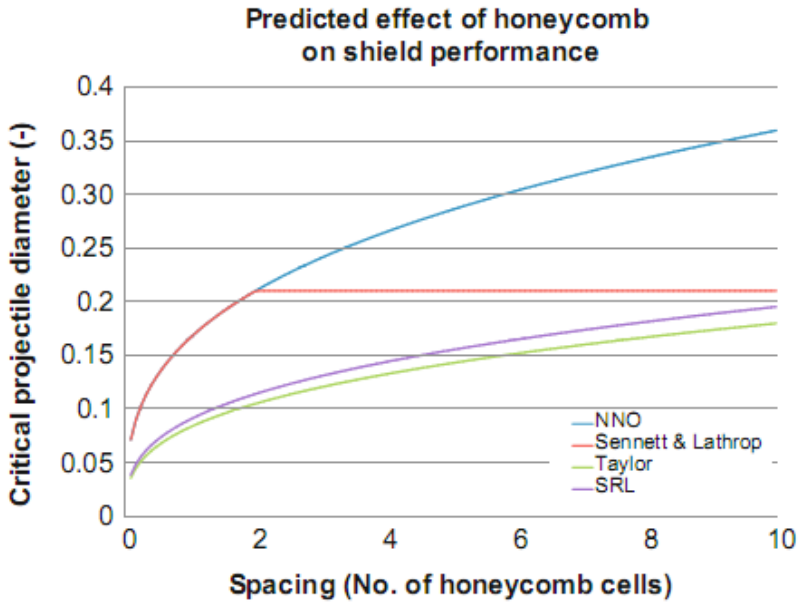
Honeycomb



- Honeycomb sandwich structure can be often seen on spacecrafts for its High Strength to Weight Ratio

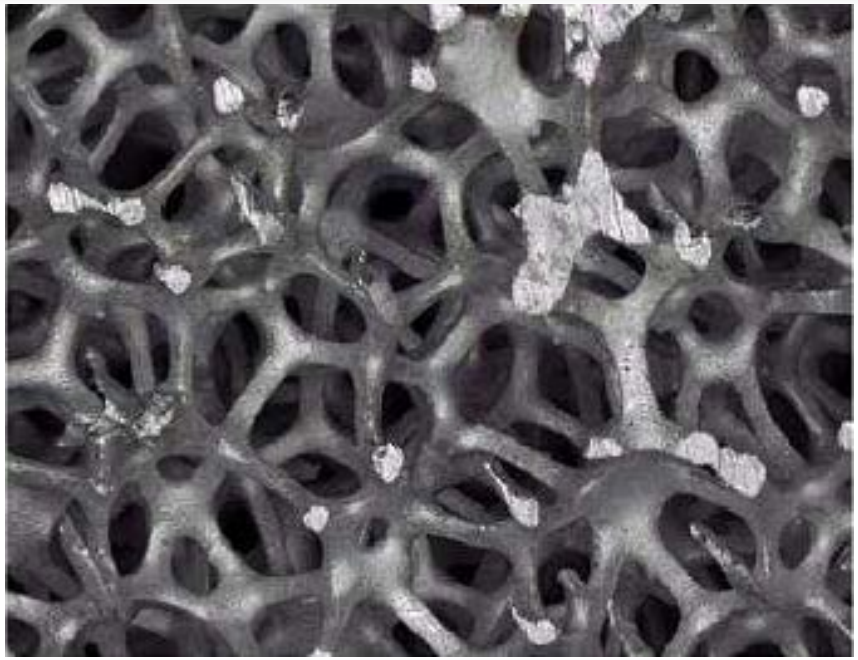
Honeycomb

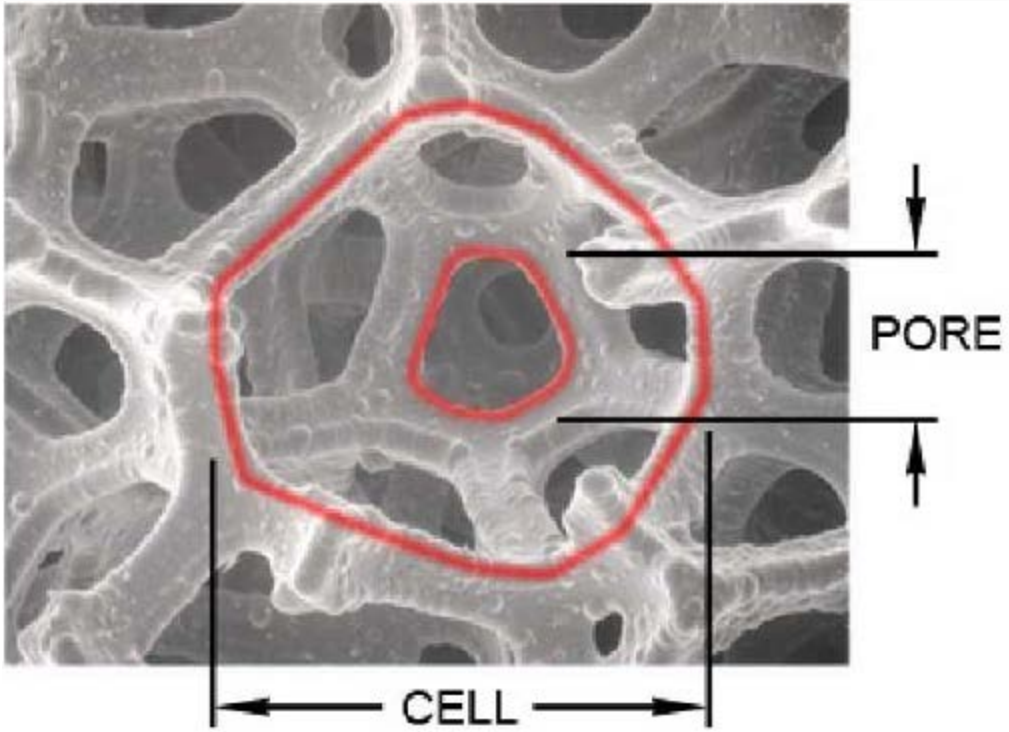




- The honeycomb core tends to channel the debris cloud behind the first facesheet, which results in greater penetration of the second facesheet compared to without the honeycomb

Open cell aluminum foam

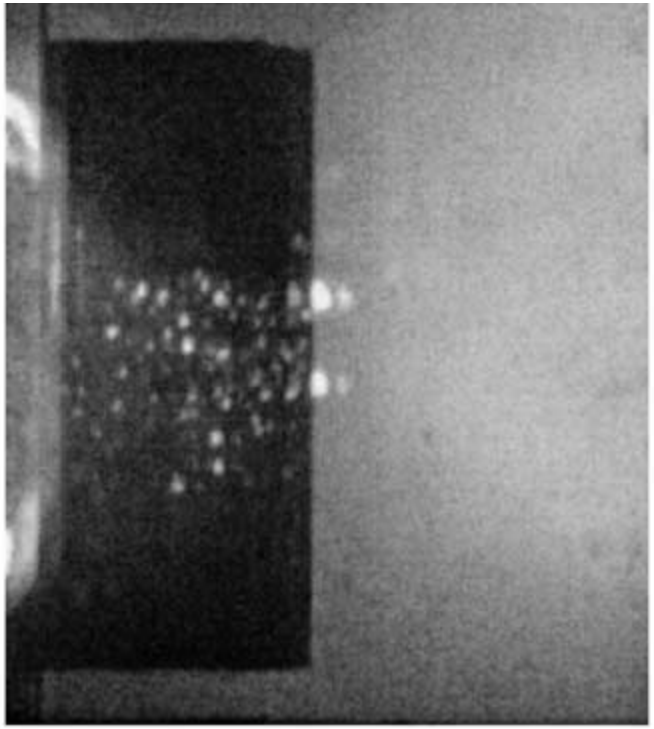




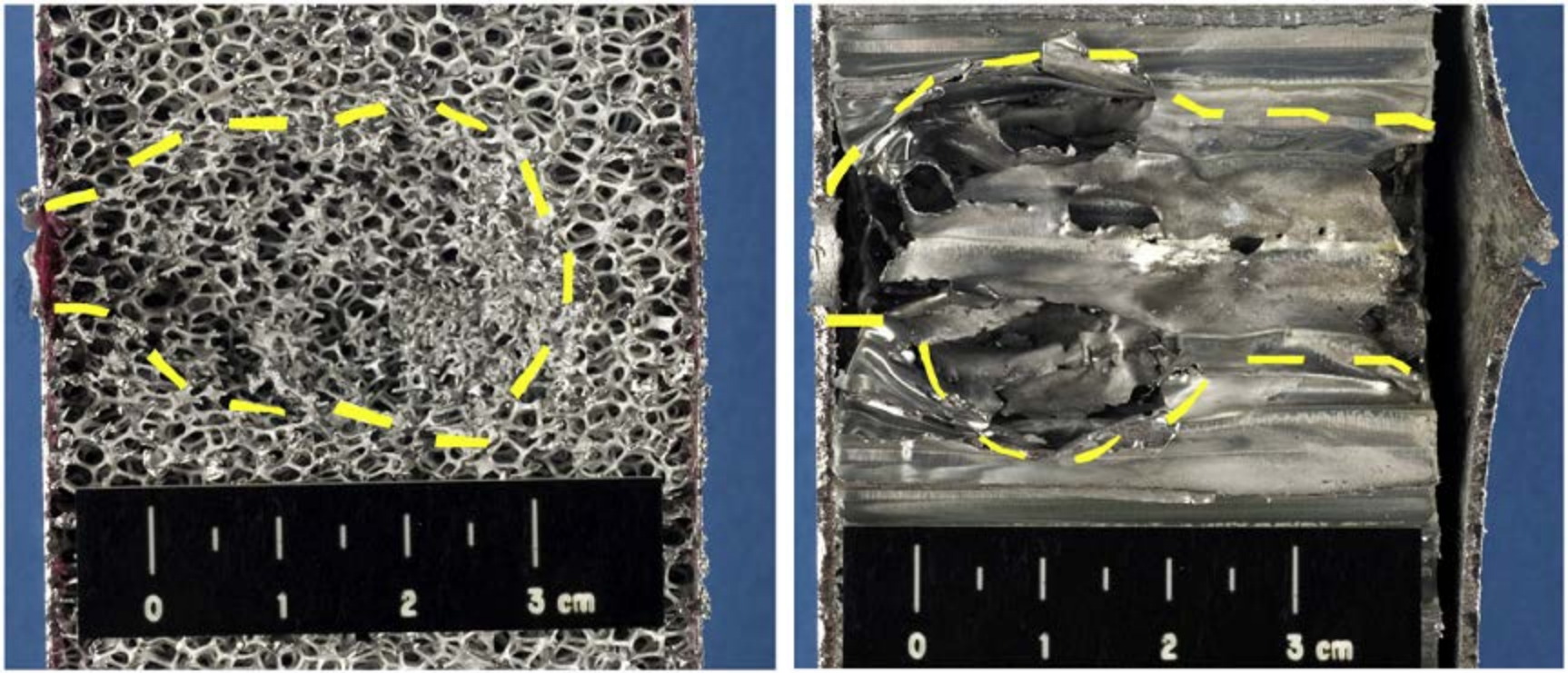
- Open cell aluminum foam is a novel material which can be used as core of the sandwich structure.
- Open cell aluminum foam also has a High Strength to Weight Ratio

Aluminum foam

- Compare with honeycomb core, Aluminum foam would not channel the debris clouds.
- Multi-shock can be observed in the HVI experiment.
- Aluminum foam has higher areal density than honeycomb core.



Honeycomb vs foam

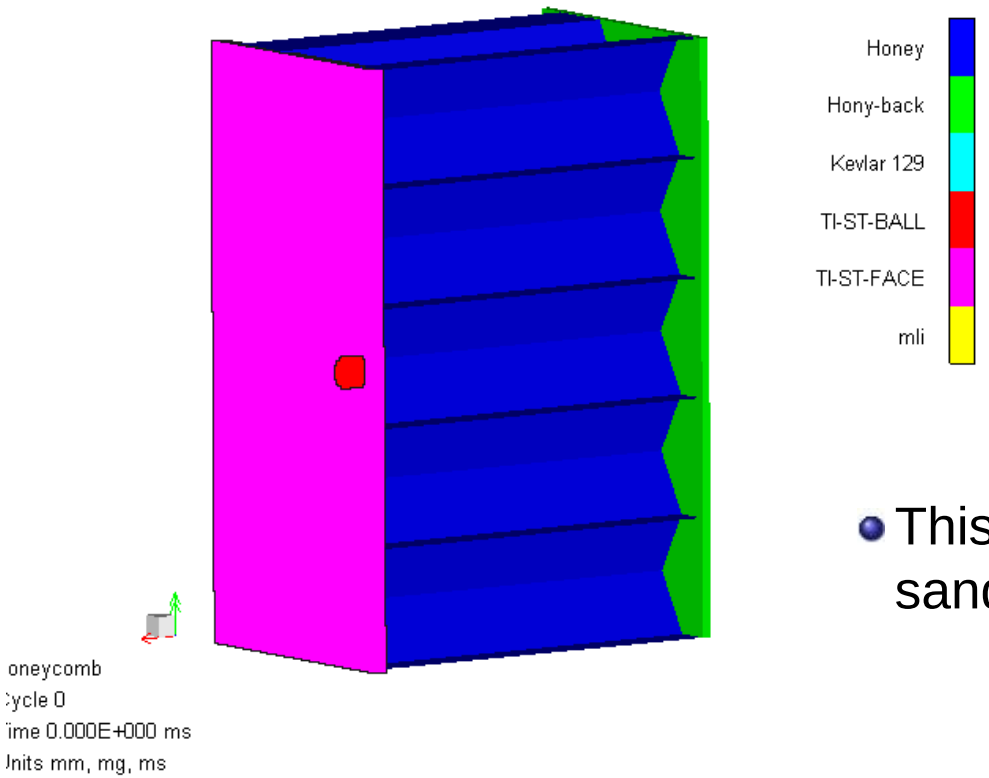


- NASA compared honeycomb with foam and find that with the same areal density, the foam structure is obviously better than honeycomb on shielding performance.

Modeling steps of honeycomb

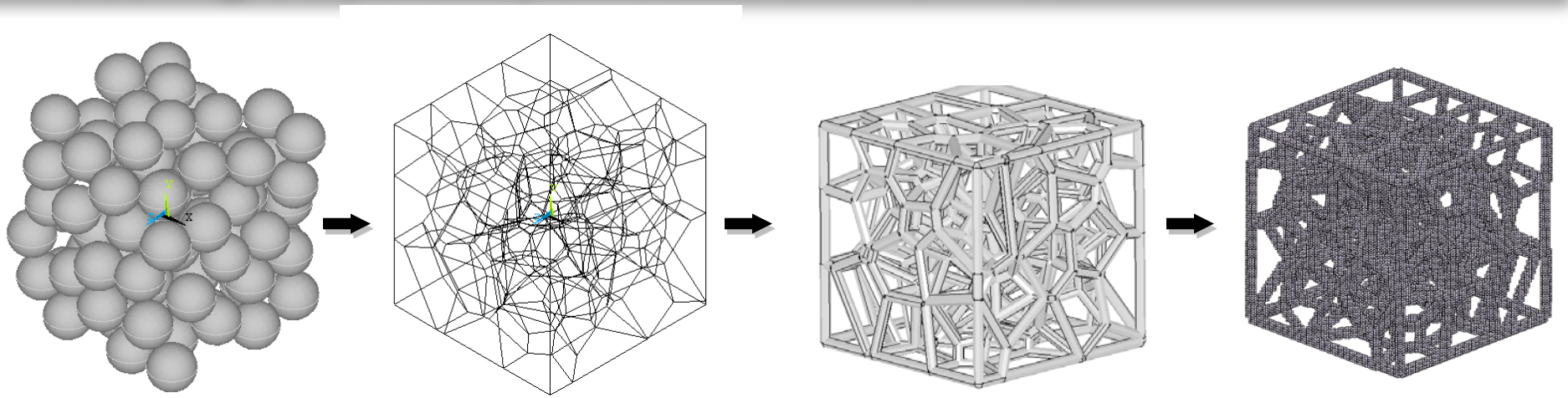
- Draw the basic unit
- Copy the basic unit on X and Y direction
- Drag the lines into faces
- Mesh the faces

Honeycomb sandwich model



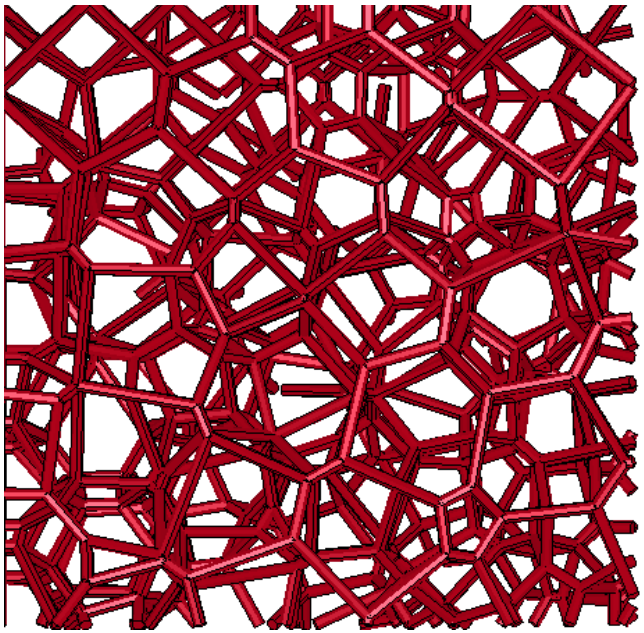
- This is the model of honeycomb sandwich.

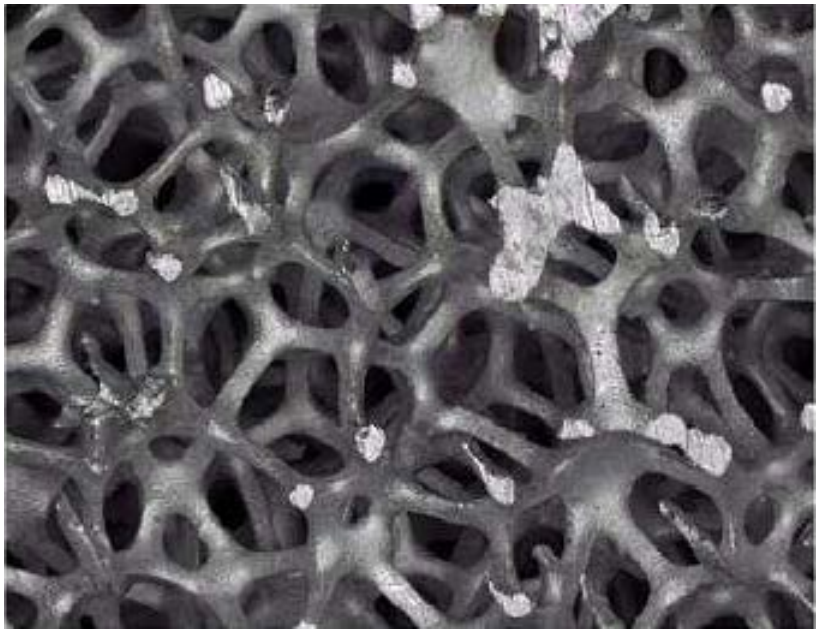
Modeling steps of open cell aluminum foam



- Sphere packing
- Laguerre tessellation
- Geometry model
- FEM and SPH model

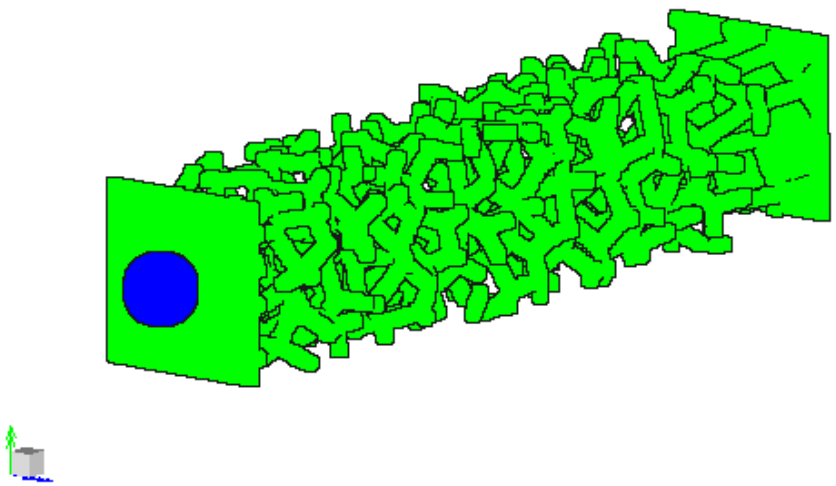
Comparison between model and real foam





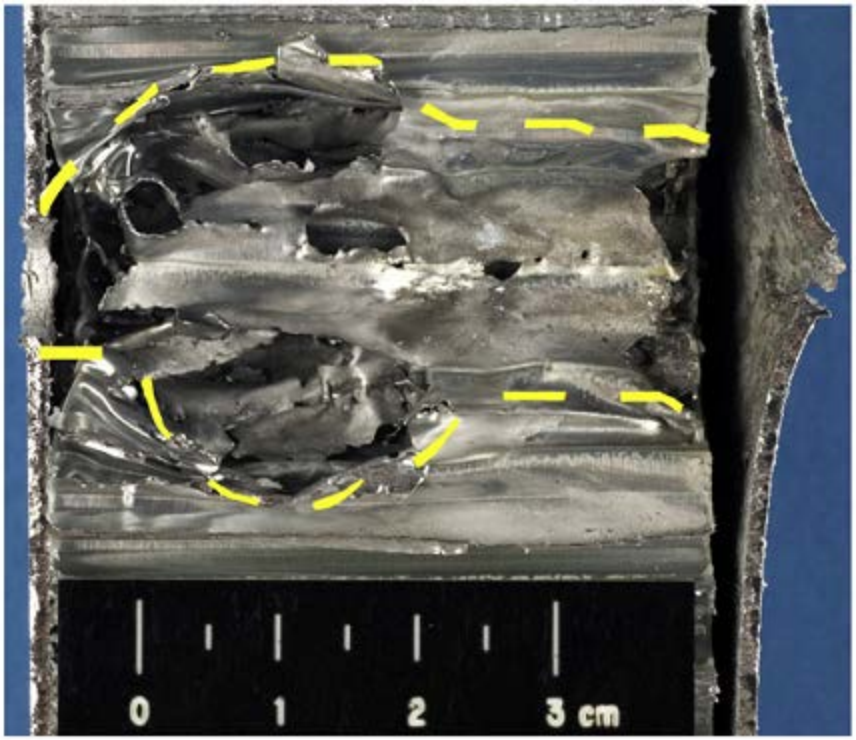
- Geometry model is close to the real foam

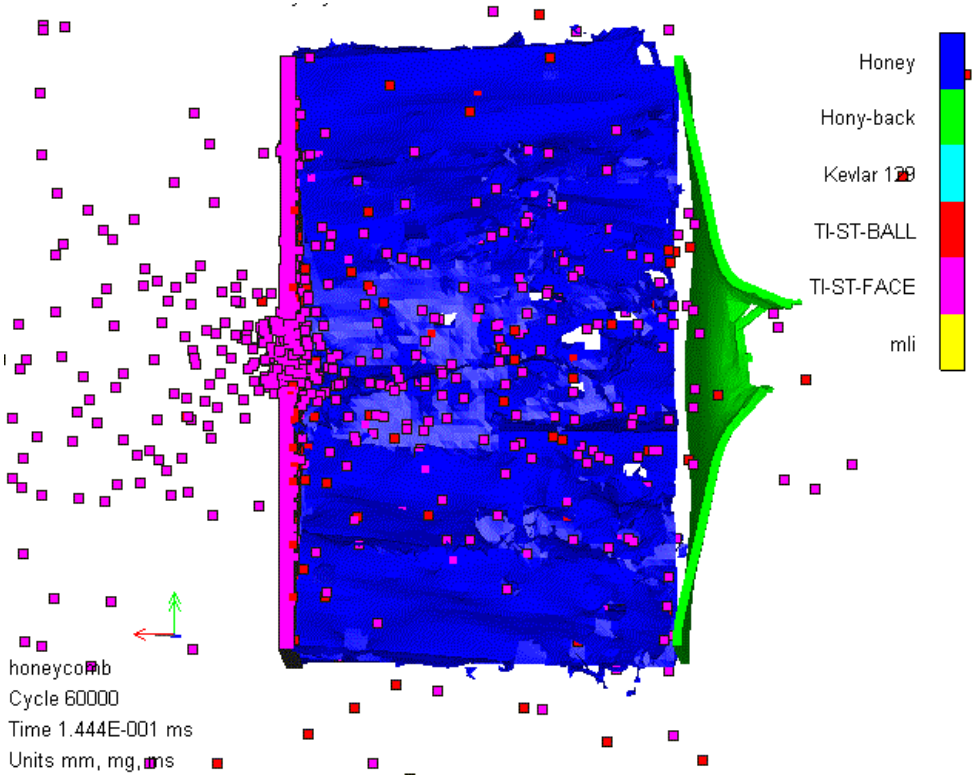
Open cell aluminum foam model



- Due to the limitation of computational ability of PC. Only the central part of the foam is modeled.

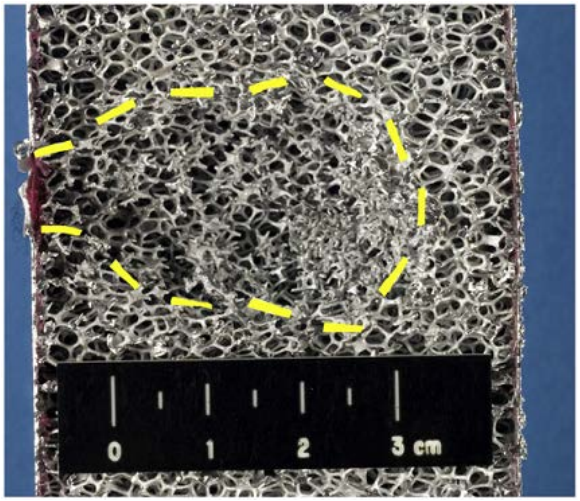
Comparison between simulation and physical results

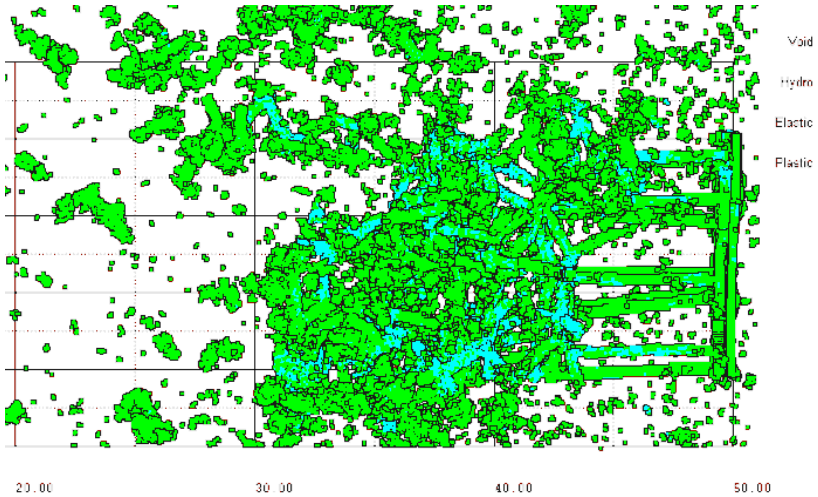


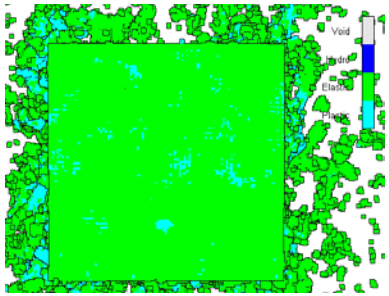


- Both the simulation and physical results of HVI on honeycomb sandwich are penetrated.

Comparison between simulation and physical results







- The foam is partly eroded and partly failure from 3 cm to 4 cm section, which is comparable with NASA's HVI test along impact direction.

Conclusion

- The modeling method of open-cell aluminum foam and honeycomb is introduced.
- Open cell aluminum foam and honeycomb sandwich models corresponded to NASA's HVI physical foam tests are built and simulated.
- The computer simulation results are partly comparable to physical results.

Thank You !