

Updated Numerical Analysis Benchmarks for Meteoroid Relevant Materials

**Joshua E. Miller^{1,2}, Bruce (Alan) Davis²,
Eric L. Christiansen³ and James L. Hyde²**

¹ University of Texas at El Paso, 500 W. University Ave., El Paso, TX 79986

² Jacobs, NASA Johnson Space Center, 2224 Bay Area Blvd., Houston, TX 77058

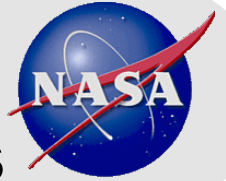
³ NASA Johnson Space Center, 2101 NASA Road One, Houston, TX 77058

Interagency Space Debris Coordination Committee (IADC)

2023 IADC in Darmstadt, Germany

12-15 June 2023

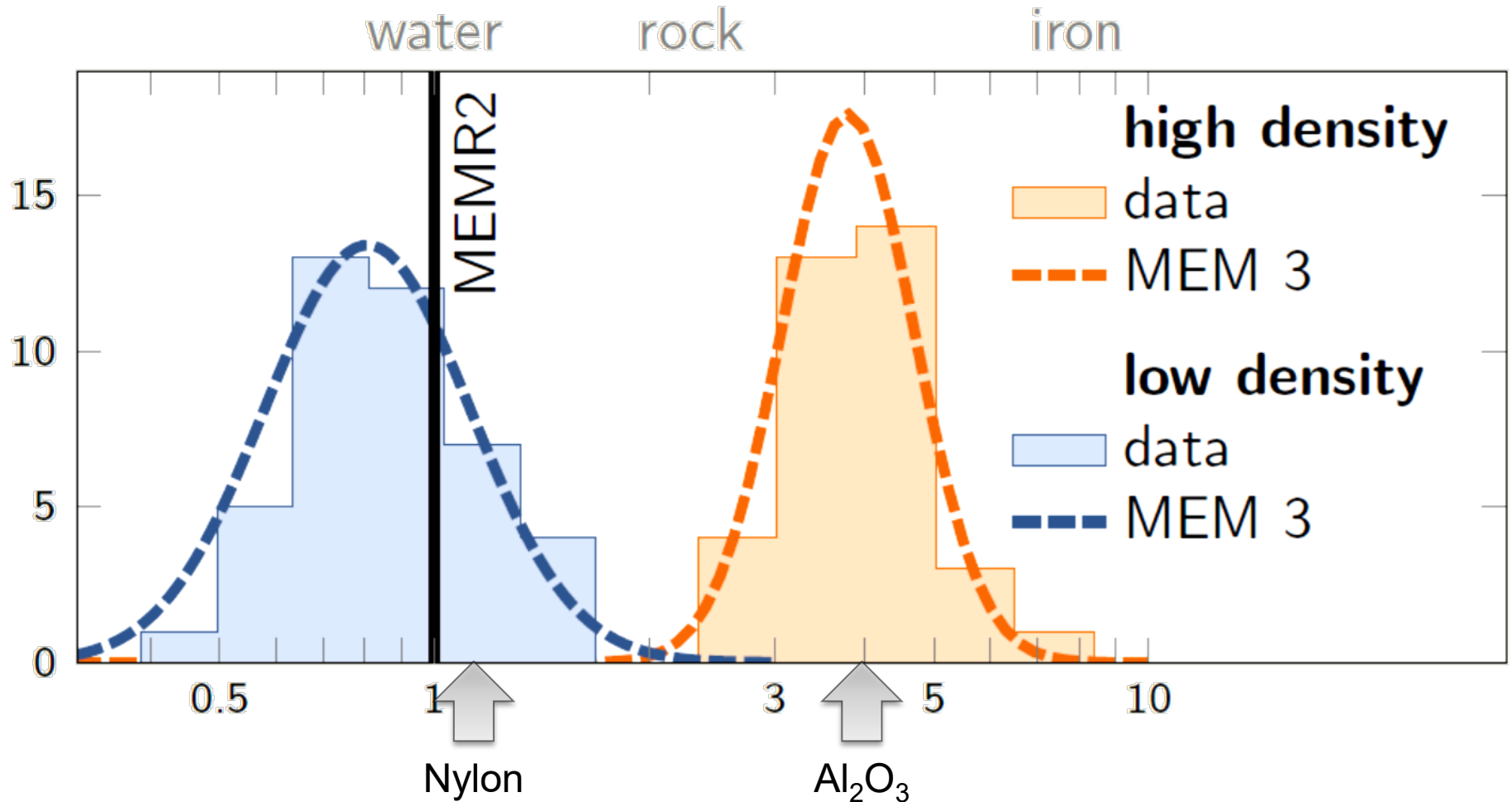
Proposal for update of numerical analysis benchmark for meteoroid relevant materials



- **Two recently performed shots are proposed to be numerical analysis benchmarks for numerical simulations of impacts of high-density meteoroids (Al_2O_3 surrogate) and low-density meteoroids (Nylon surrogate)**
- **A pair of general Whipple shields have been studied**
 - Bumper and rear walls are the same material and thickness between shields
 - Separation is 4.5 cm for Al_2O_3 and 1.5 cm for Nylon
- **Information gathered includes high speed (1 MHz) shadowgraphs of debris cloud, bumper hole size and rear wall hole area**

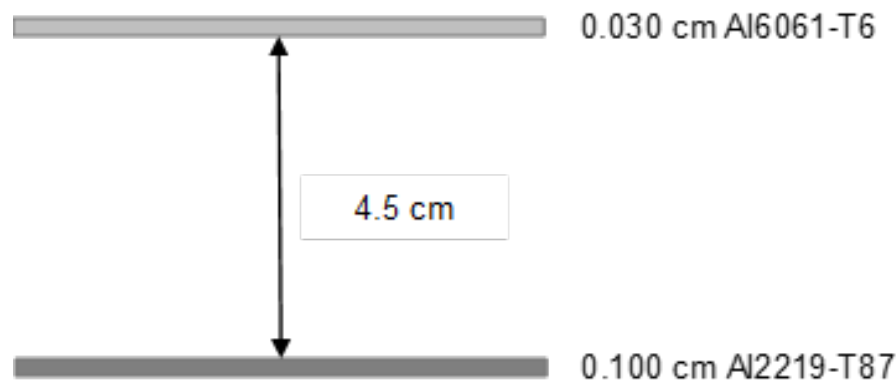
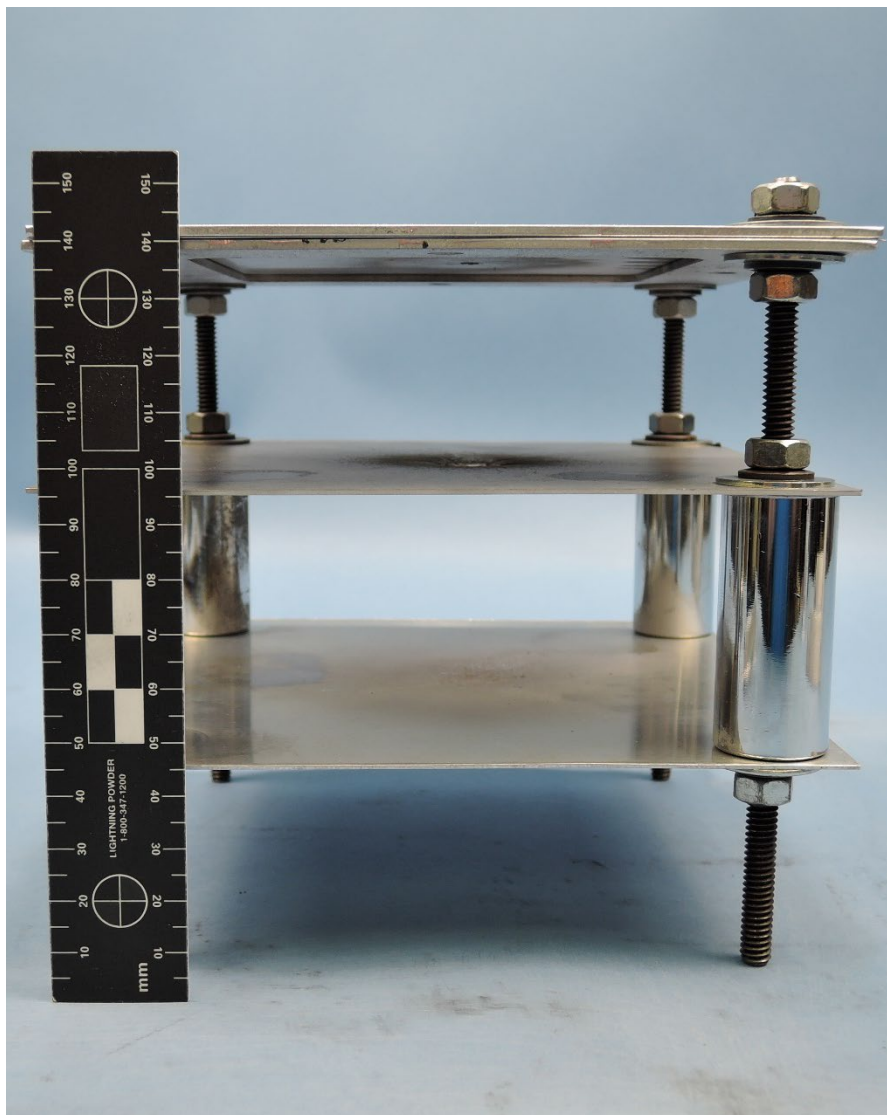
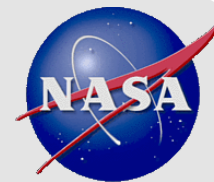


Current NASA meteoroid models have two density families (dirty snow and rocky/metallic)



NASA has settled on using Nylon and Al₂O₃ to represent these families

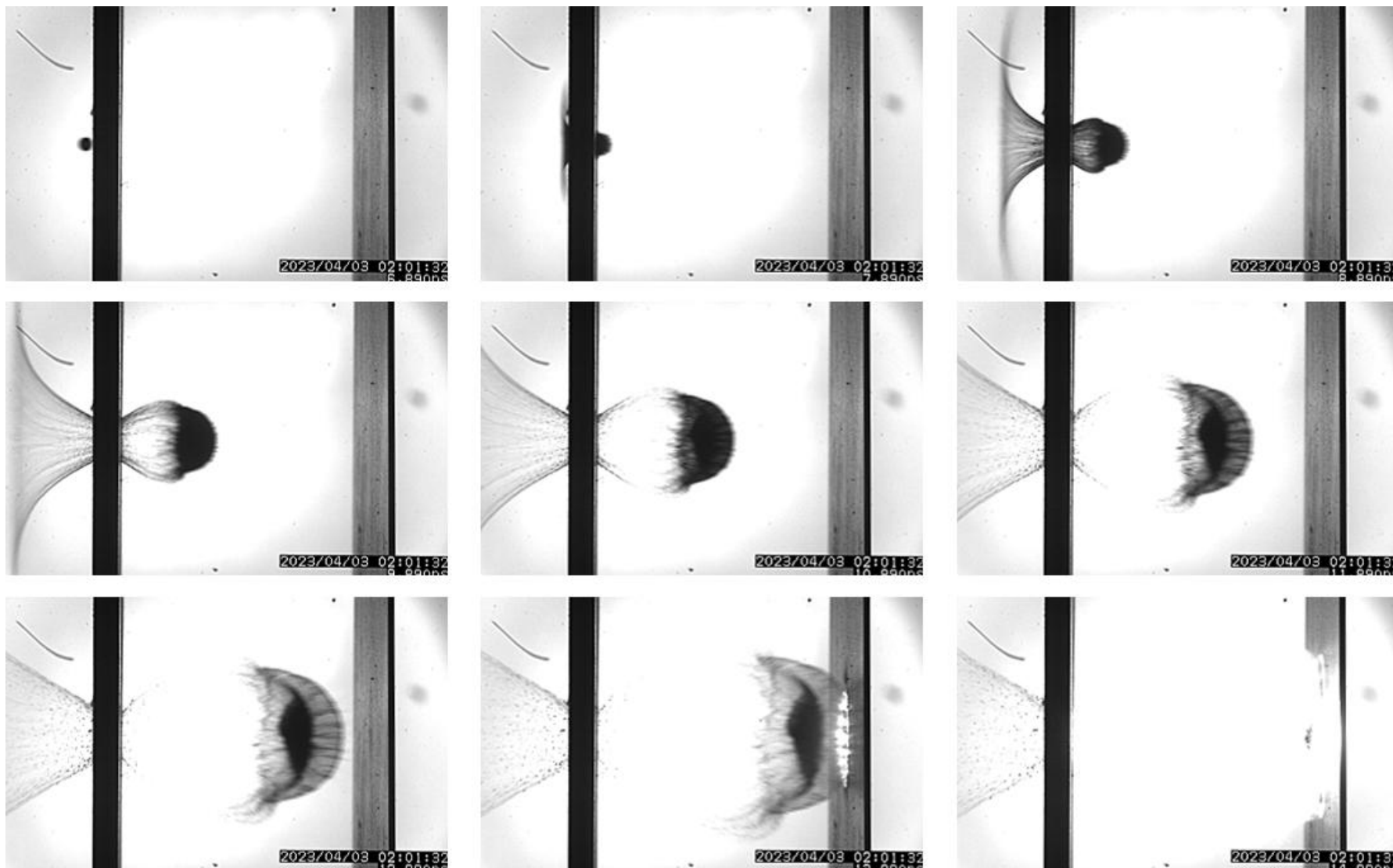
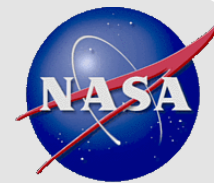
Overall description of the shield used for the Al_2O_3 projectile and video of impact



Nominal Values



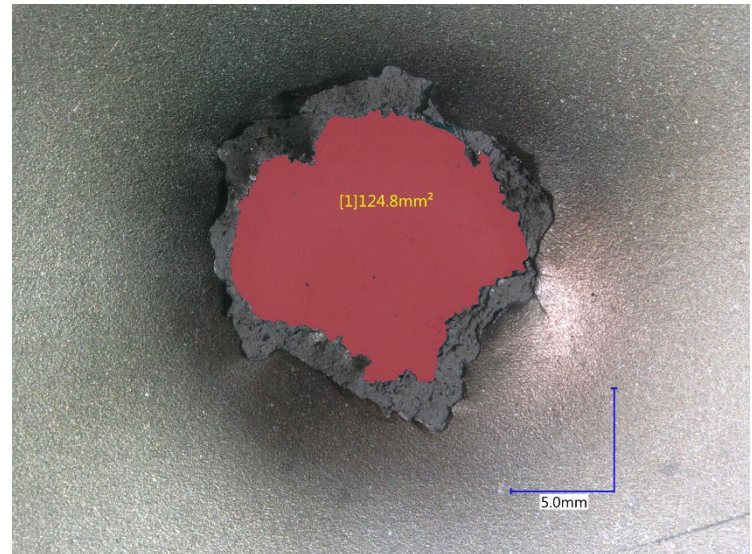
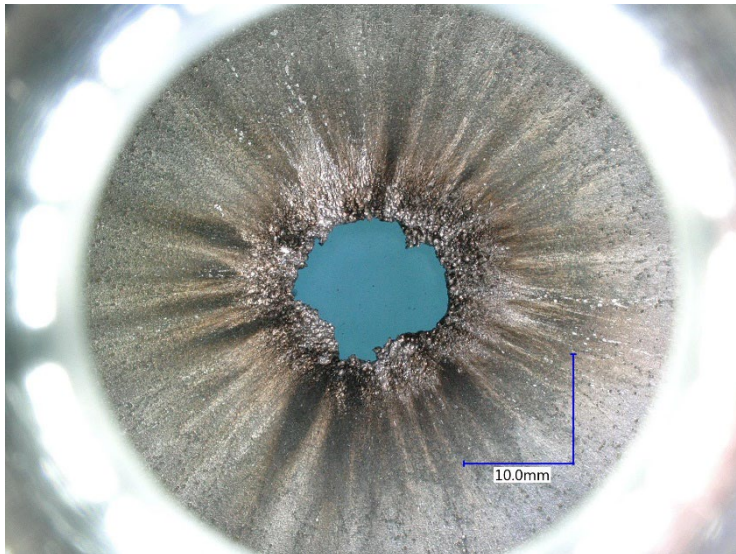
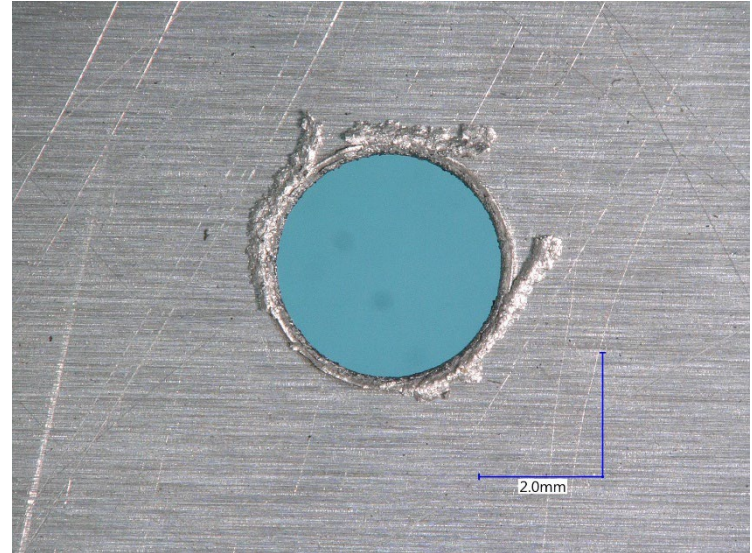
Stills from video at 1 μ s interframe rate (debris cloud took $\sim 7 \mu$ s to traverse gap)



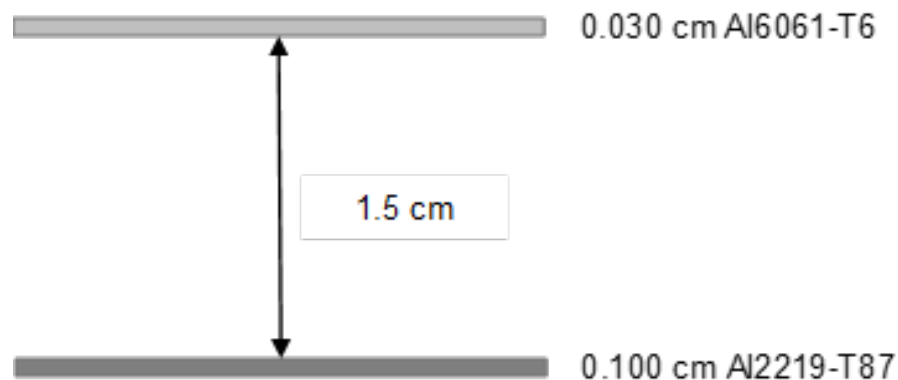
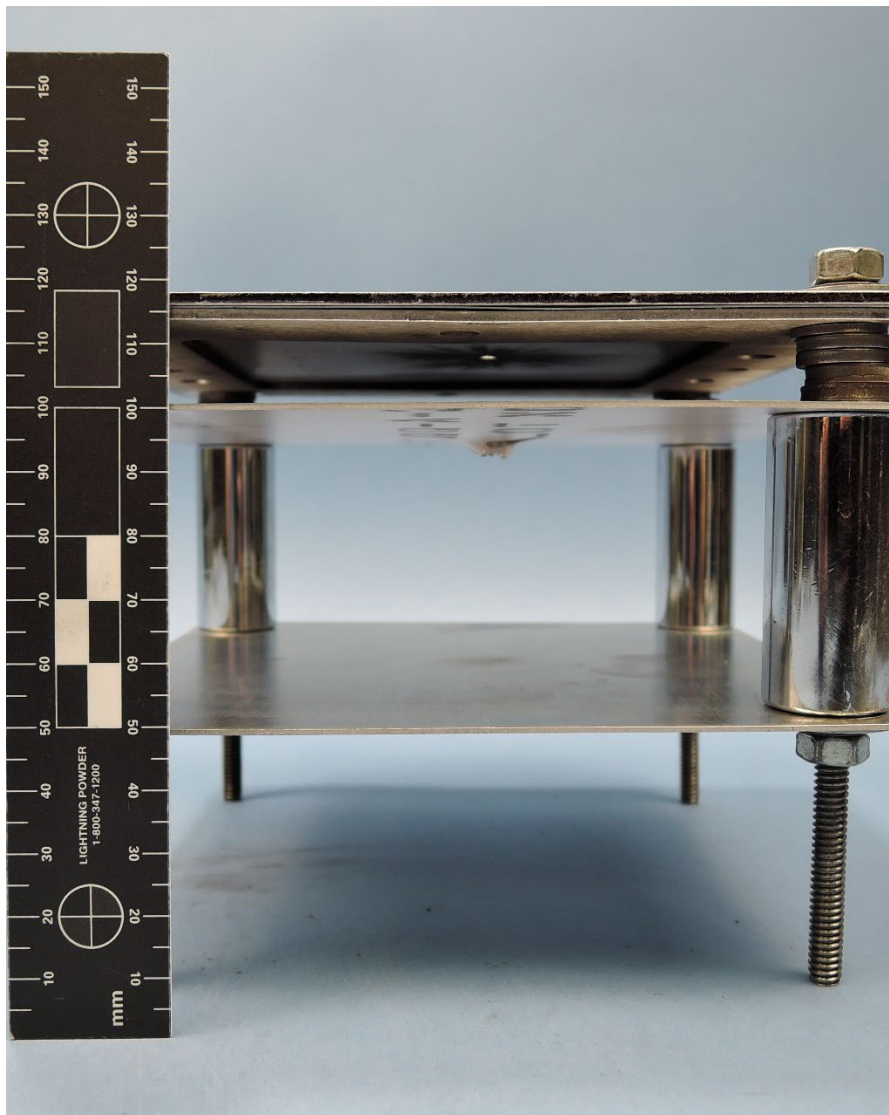
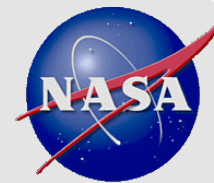


Conditions and images from the proposed numerical benchmark for Al_2O_3

- Projectile: Al_2O_3 sphere, $D=2.52$ mm, $m=0.03267$ g, $\rho=3.9$ g/cm³
- Impact: $V_i=6.62$ km/s, $\theta_i=0^\circ$
- Bumper: Al6061-T6, $t_B=0.29$ mm, $D_H=3.6$ mm, $S=4.5$ cm (back to front)
- Rear wall: Al2219-T87, $t_{RW}=1.07$ mm, mm, $A_H=124.8$ mm², $\langle D_H \rangle=12.6$ mm



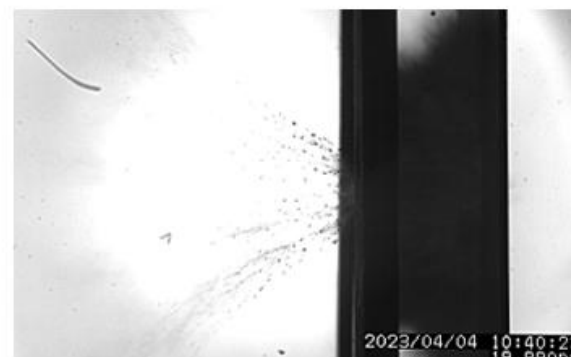
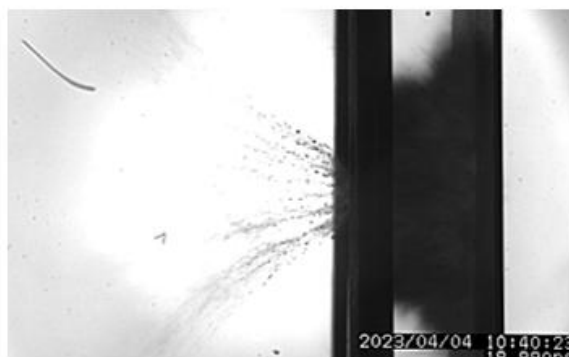
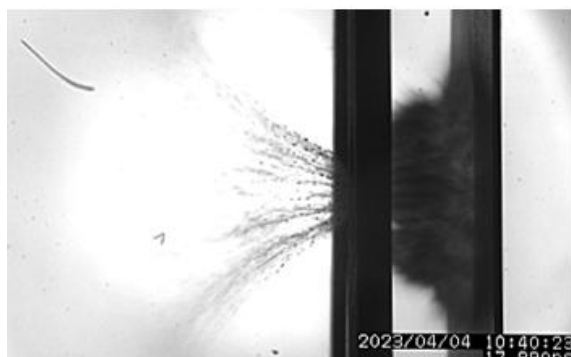
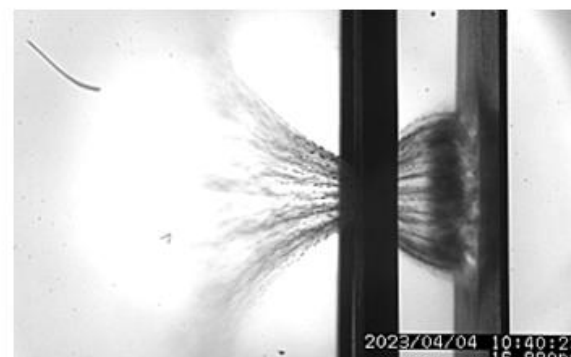
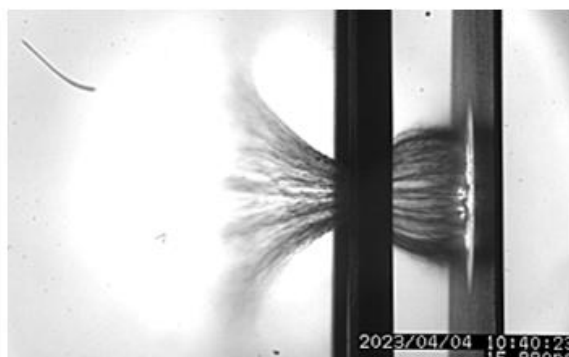
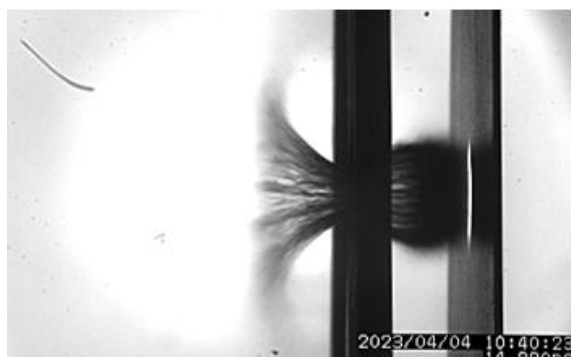
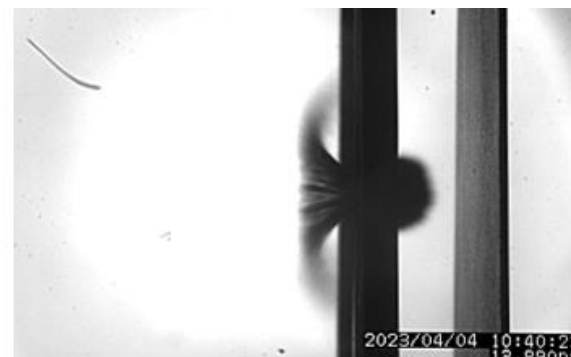
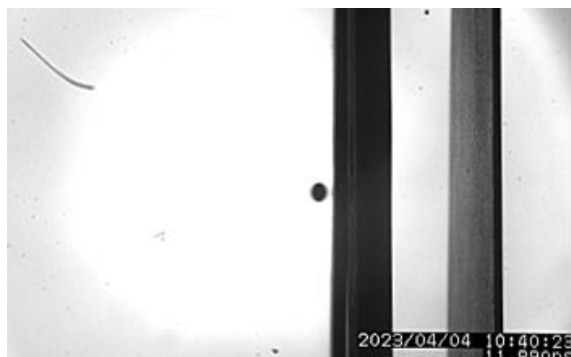
Overall description of the shield used for the Al_2O_3 projectile and video of impact

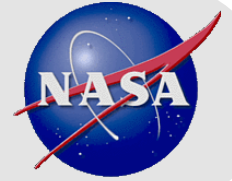


Nominal Values



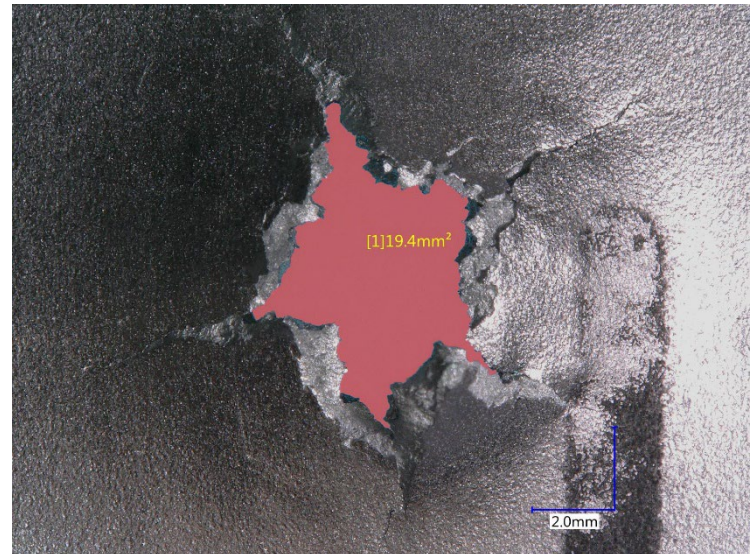
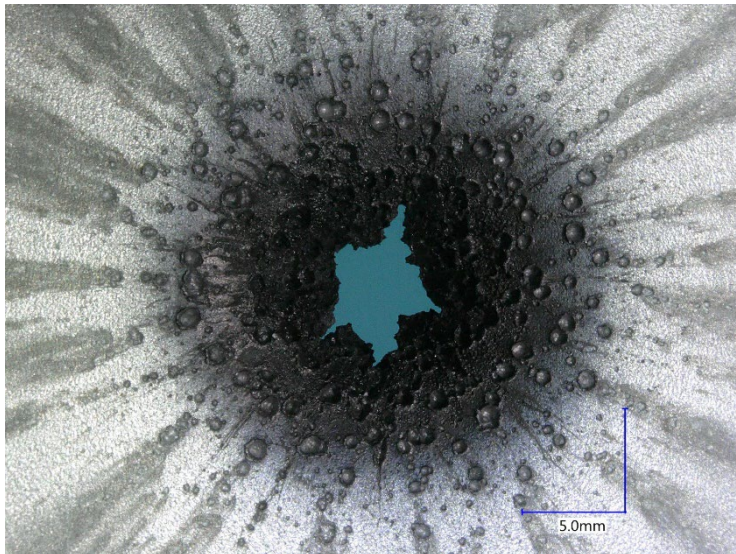
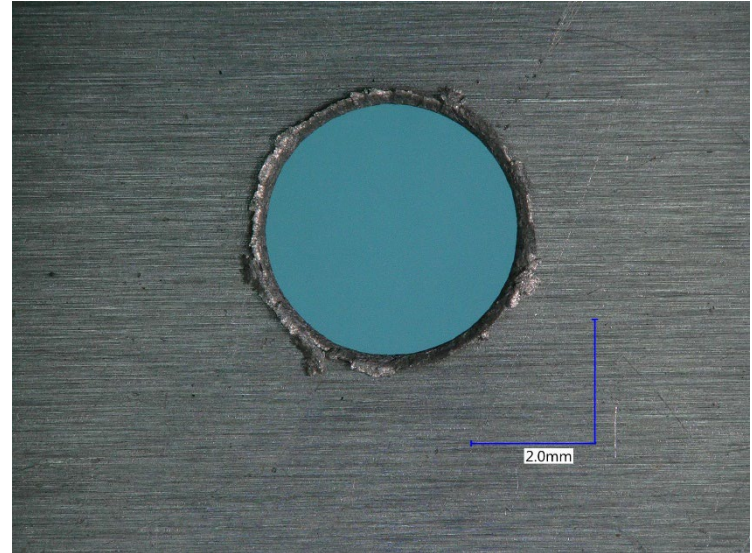
Stills from video at 1 μ s interframe rate (debris cloud took $\sim 2.5 \mu$ s to traverse gap)





Conditions and images from the proposed numerical benchmark for Nylon

- Projectile: Nylon sphere, $D=2.75$ mm, $m=0.01243$ g, $\rho=1.14$ g/cm³
- Impact: $V_i=6.49$ km/s, $\theta_i=0^\circ$
- Bumper: Al6061-T6, $t_B=0.29$ mm, $D_H=3.6$ mm, $S=1.5$ cm (back to front)
- Rear wall: Al2219-T87, $t_{RW}=1.07$ mm, $A_H=19.4$ mm², $\langle D_H \rangle=5.0$ mm





Forward Work

- **These benchmarks are impacts at ~ 6.5 km/s and 0° to normal from the shield**
- **These benchmarks do not include any passive thermal control materials**
- **Additional work under these approximate conditions has been performed with multi-layer insulation (MLI) in place, those could be made available if desired by the working group**
- **Additional work considering oblique impacts has been performed, those could be made available if desired by the working group**
- **If later efforts produce impacts at >9 km/s, those could be added as benchmarks if desired by the working group**