

Projectile Impact Evaluation on Ballistic Gelatin

SEM 2011

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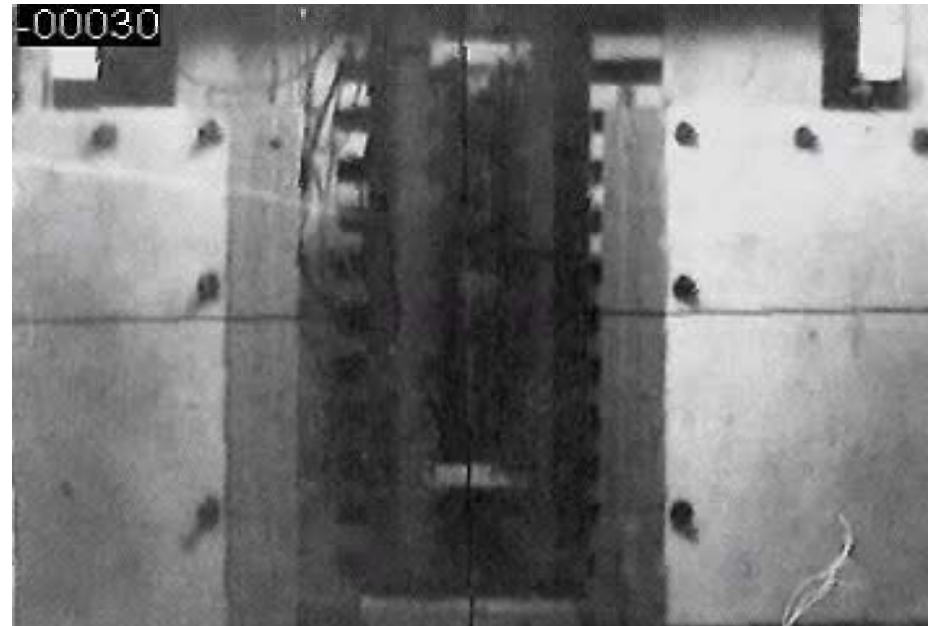
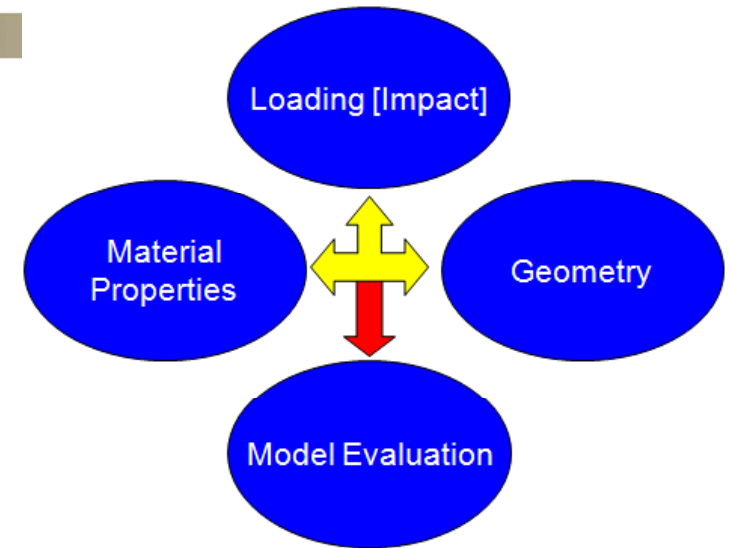
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Introduction / Background

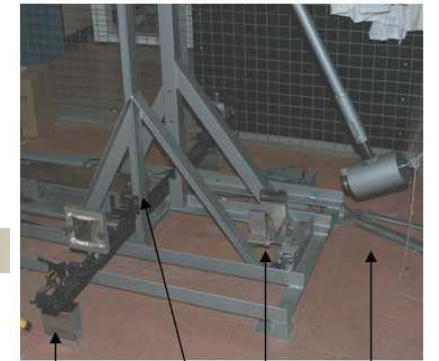
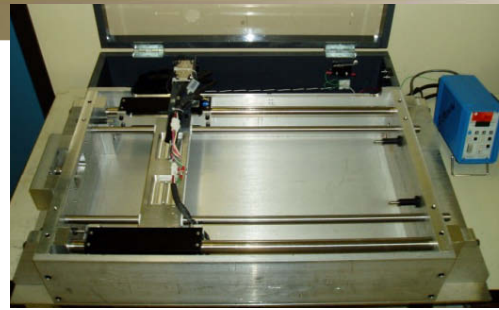
- Ballistic gelatin widely used as a tissue simulant (10% and 20%)
- Examples
 - Penetrating trauma (ballistic)
 - Tissue response to blast (lower extremity, torso)
 - Blunt trauma



Mechanical Testing

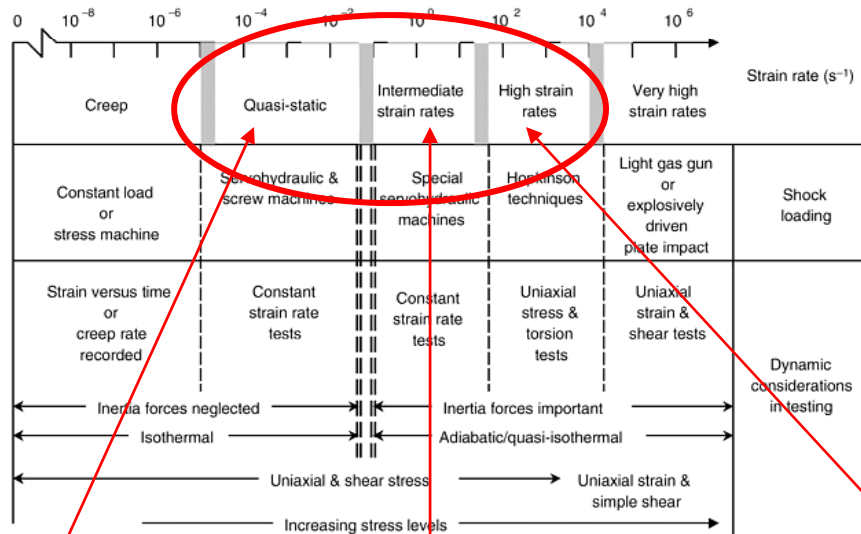


(~0.01-10 1/s)



Laser displacement system
Trigger
Pendulum
Load Cell

(~100-500 1/s)



From ASM, Volume 8, Mechanical Testing and Evaluation



(~300-3000 1/s)

Campbell, SEM 2007
Ouellet, Exp Mech 2006
Doman, Exp Mech 2006
VanSligtenhorst, JoB 2006
Ouellet, PASS 2004
Motuz, SAV 2003
VanSligtenhorst, ASME BED 2003
Salisbury, Plasticity 2002

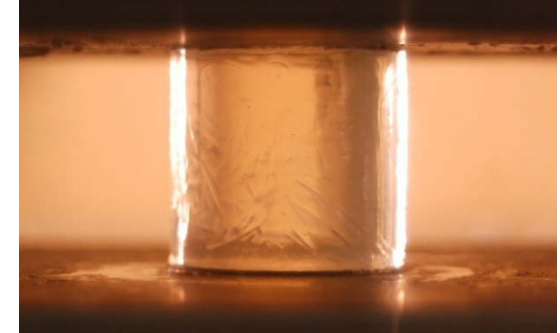
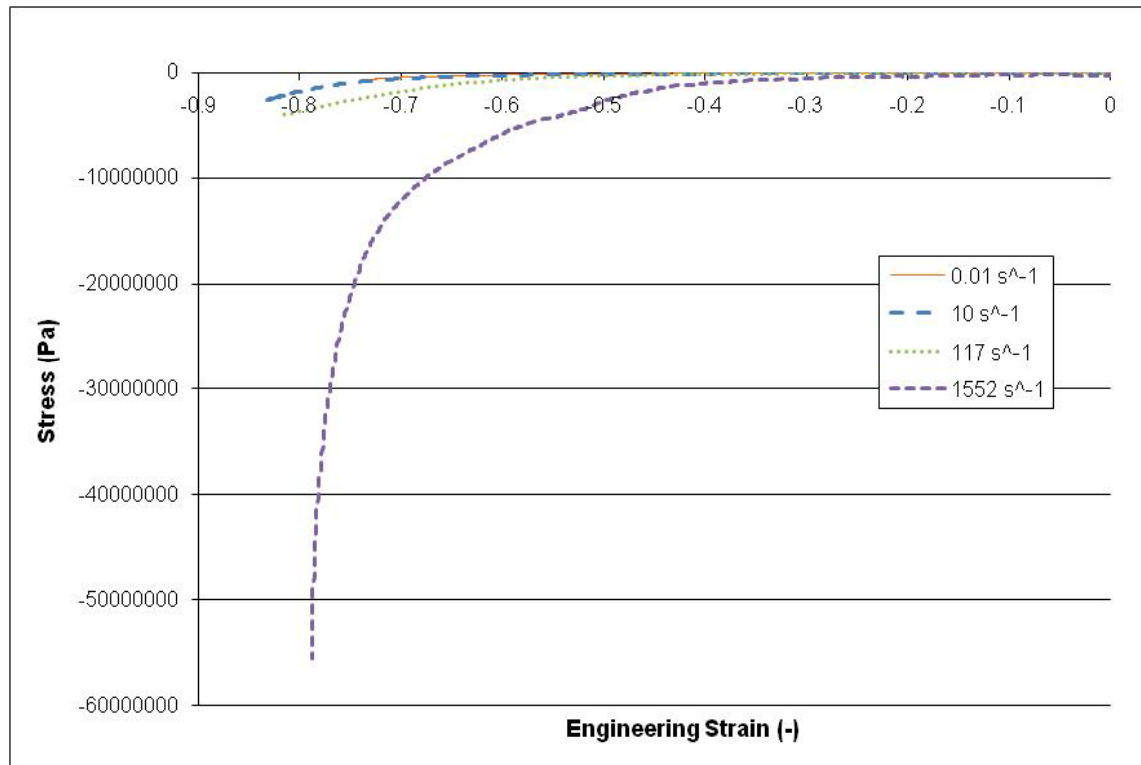
Servohydraulic

Pendulum Impact
Drop Tower
EM Test Frame

Polymeric Split Hopkinson
Pressure Bar Apparatus

Introduction / Background

- 10% / 4°C mechanical properties
 - similar to those of soft tissue [vanSligtenhorst 2004, Cronin, 2006]
- Hyperelastic model with rate effects [Kolling 2007]
 - Ogden formulation with linear bulk modulus

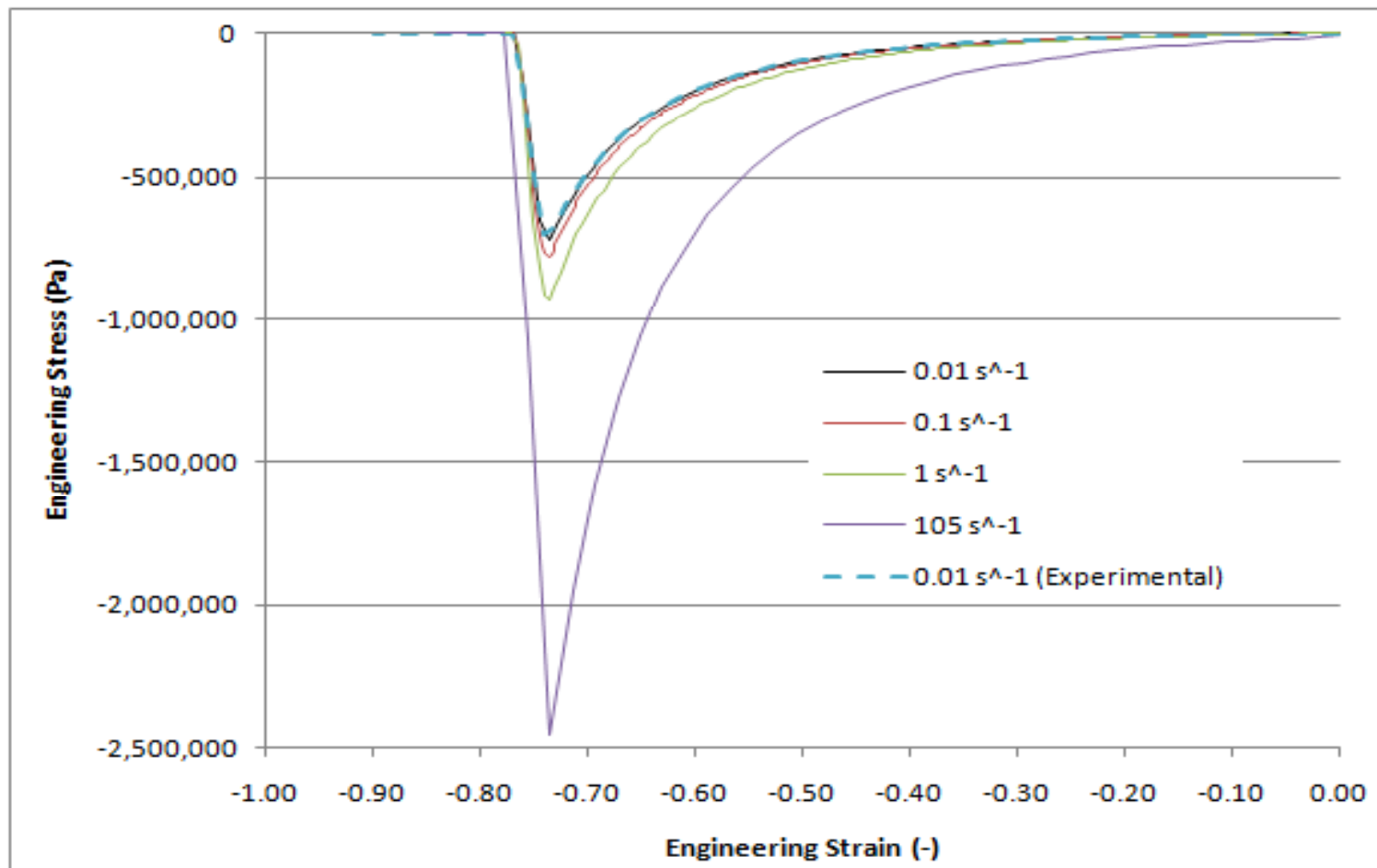


Impact modeling

$$f(I_1) = (I_1 - 3)$$

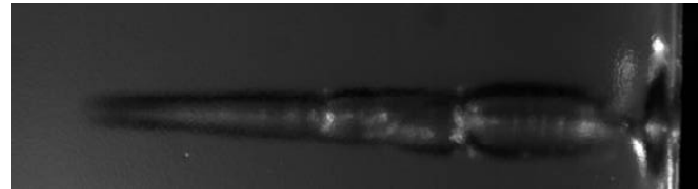
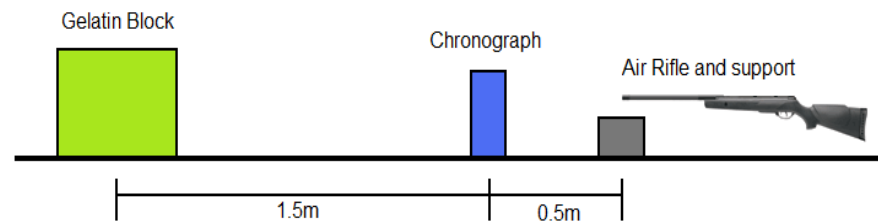
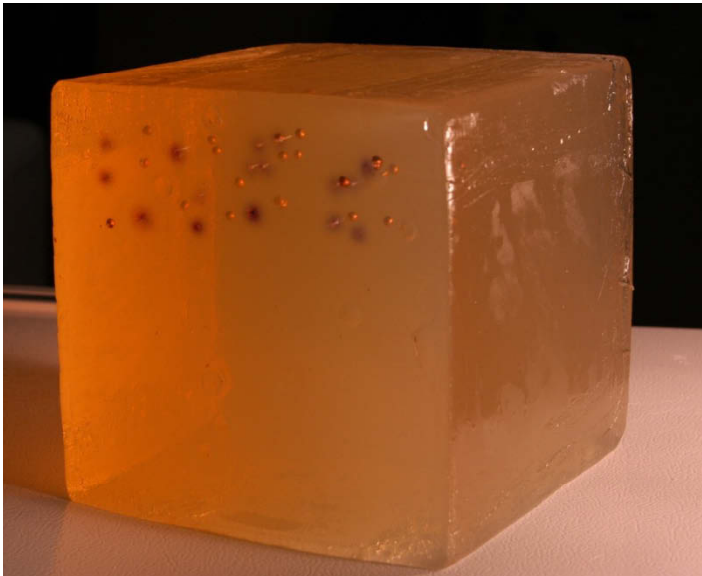
- Damage model
[DuBois, Kolling, LSTC]

$$D = \begin{cases} 0.0 & f \leq (1-h)K \\ \frac{1}{2} \left[1 + \cos\left(\frac{\pi(f-K)}{hK}\right) \right] & (1-h)K < f < K \\ 1.0 & f \geq K \end{cases}$$



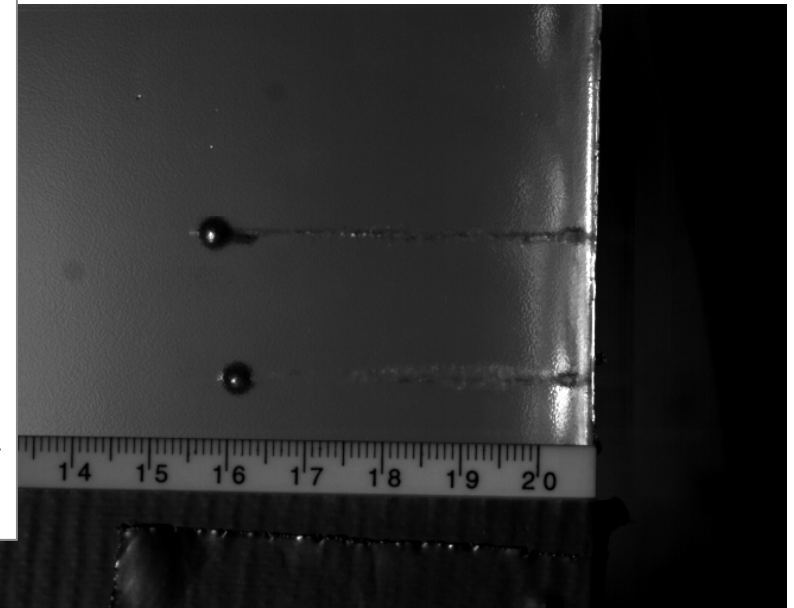
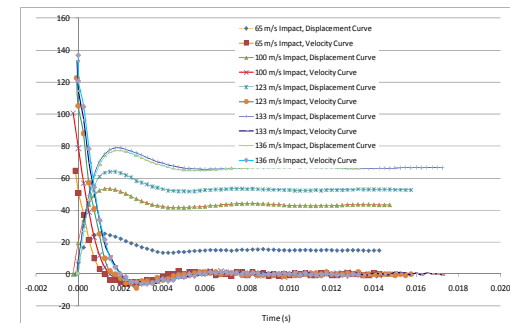
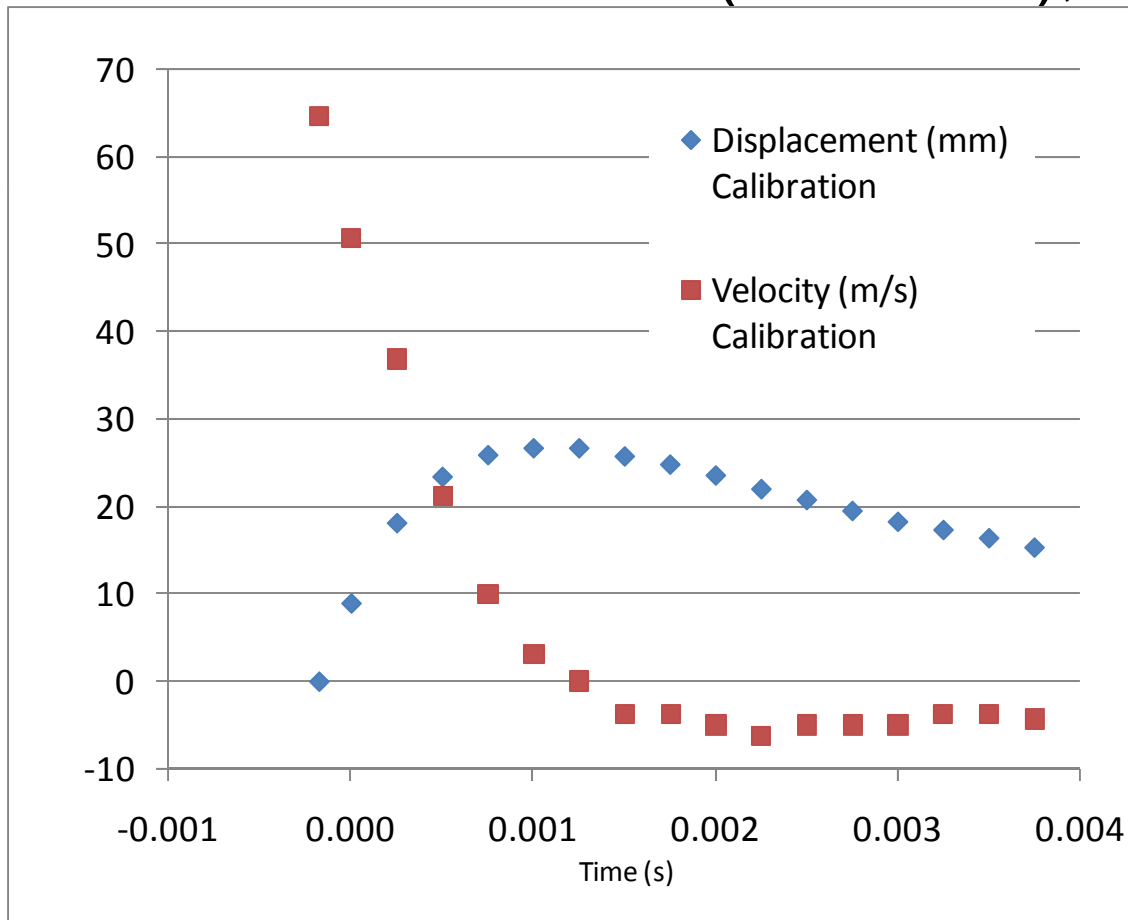
Methods – Gelatin Calibration

- Calibration (10%/4°C)
 - Impact at various velocities using a 4.35 mm diameter (0.35 gram) BB on a 250mm x 200mm x 200mm block (Jussila 2004)



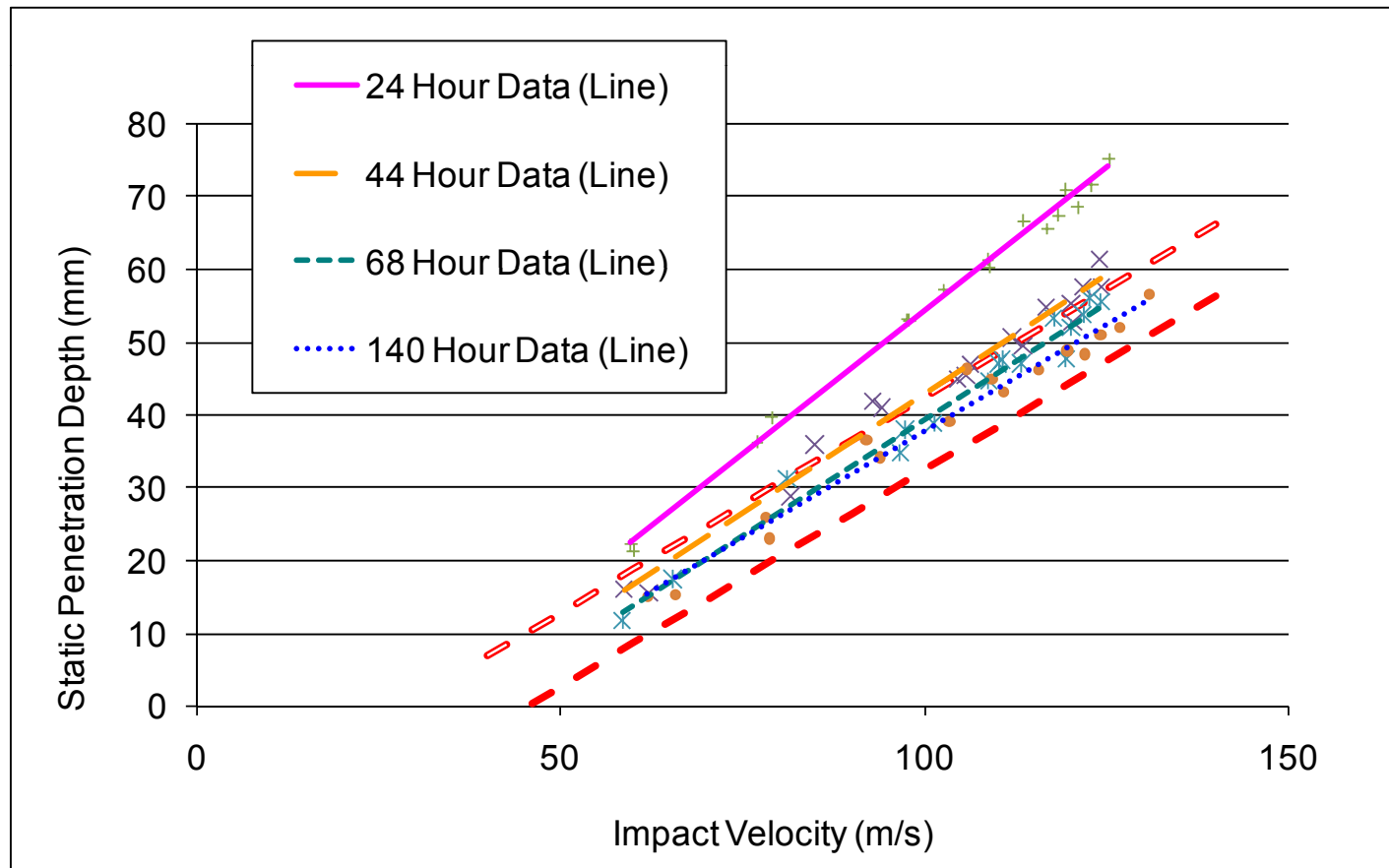
Results – Gelatin Calibration

- Calibration test (10%/4°C), 65 m/s Impact



Results – Gelatin Calibration

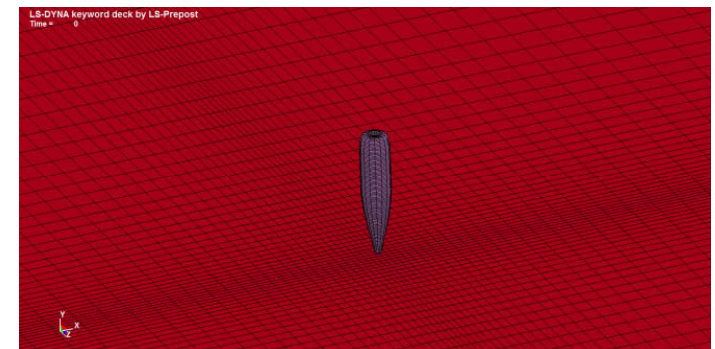
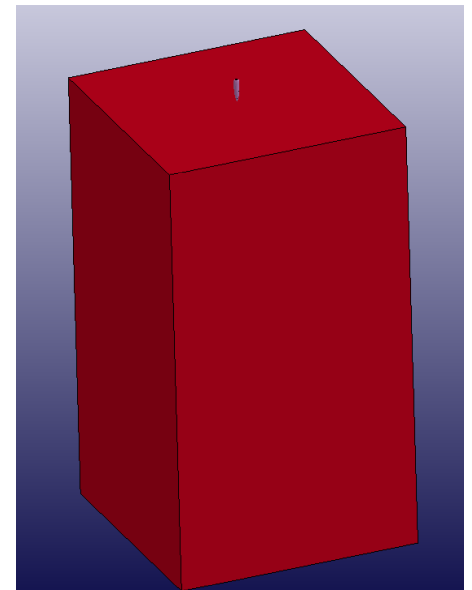
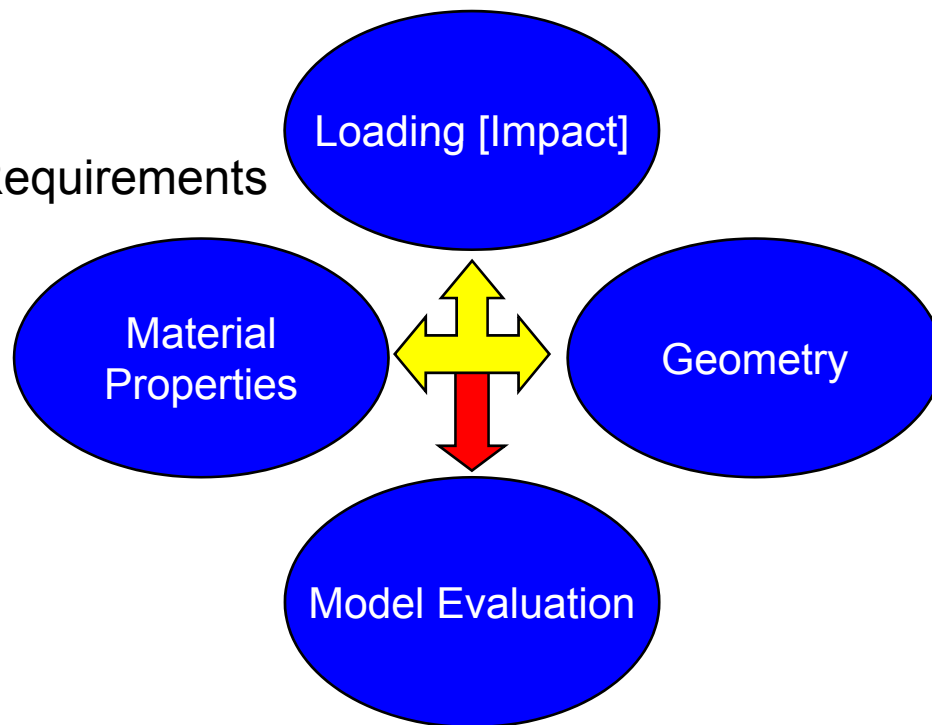
- Calibration tests at various impact velocities (10%/4°C)
 - Significant dependence on aging / conditioning time
 - Linear relationship ($r^2 = 0.97$ to 0.99)



Impact modeling

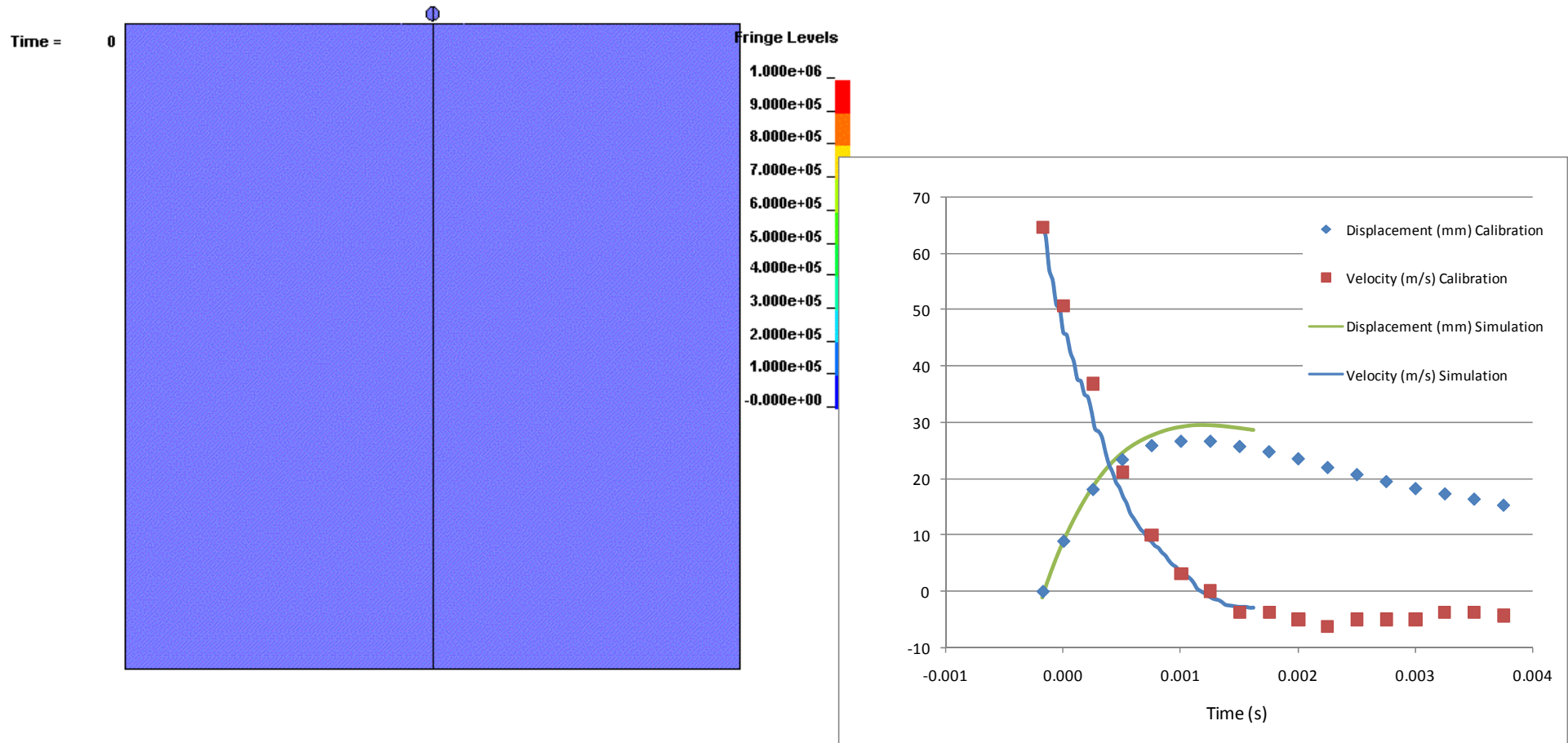
- Explicit FE (LS-Dyna v971) w/ LSOPT
- High strain rate material properties w/ damage/failure
- Lagrangian, ALE, EFG formulations

Model Requirements



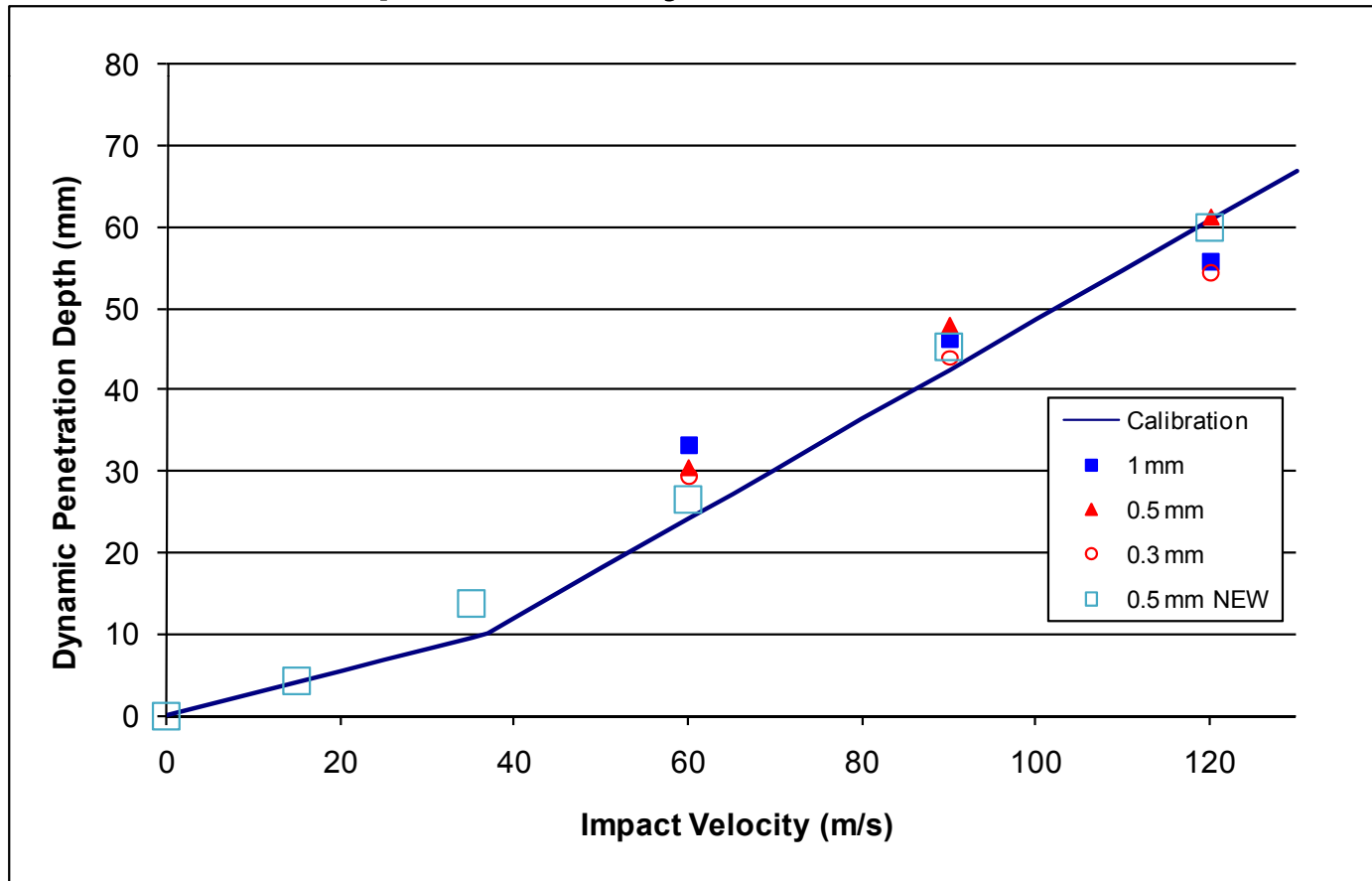
Impact modeling – Phase 1

- BB impact model
 - 65 m/s BB impact on gelatin block (10%/4°C)



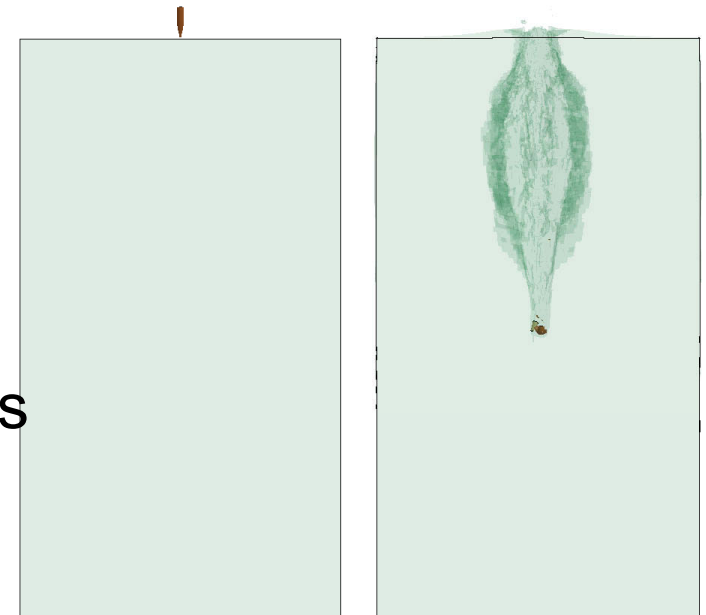
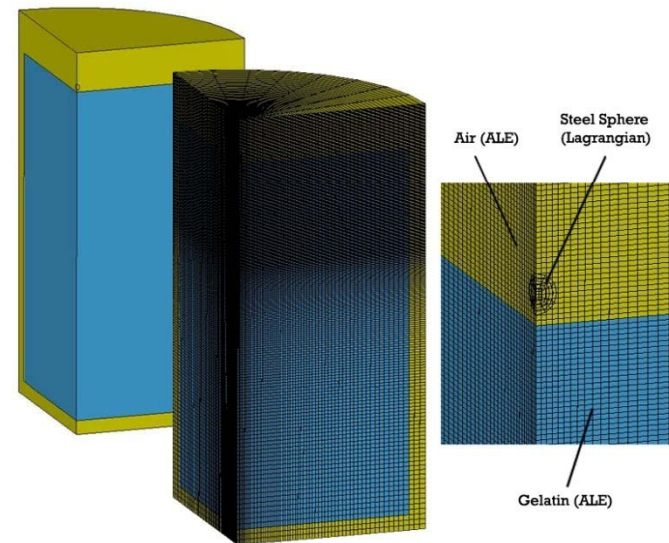
Impact modeling

- Generally in good agreement with experiments
- Mesh size dependency



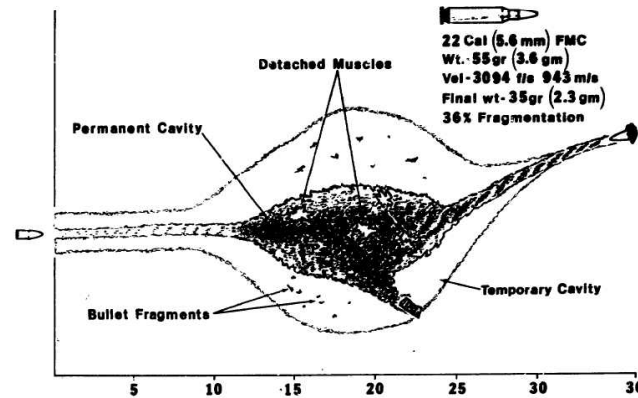
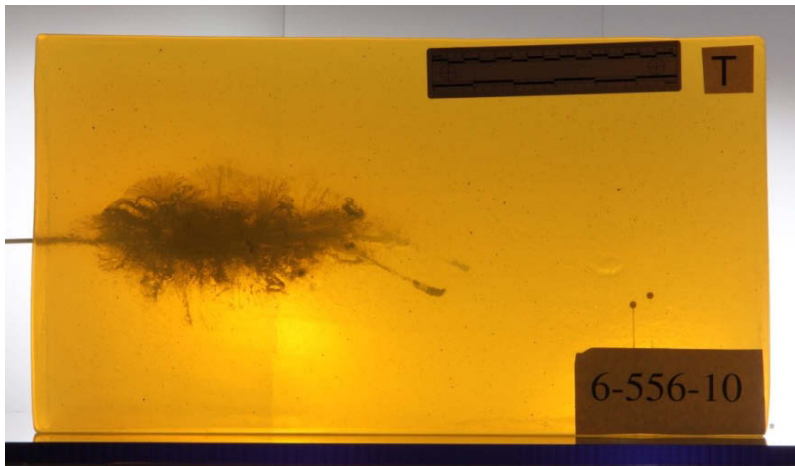
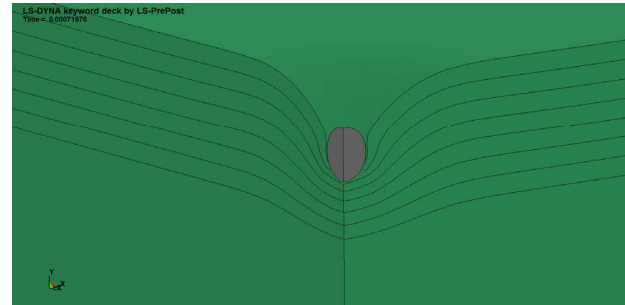
Impact modeling – Phase 2, 3

- 3-D Lagrangian model
- 3-D ALE model
 - Large deformation
 - Material ‘self healing’
 - Limited material models
- 3-D EFG model
 - Large deformation
 - Significant compute requirements



Impact modeling – Phase 3

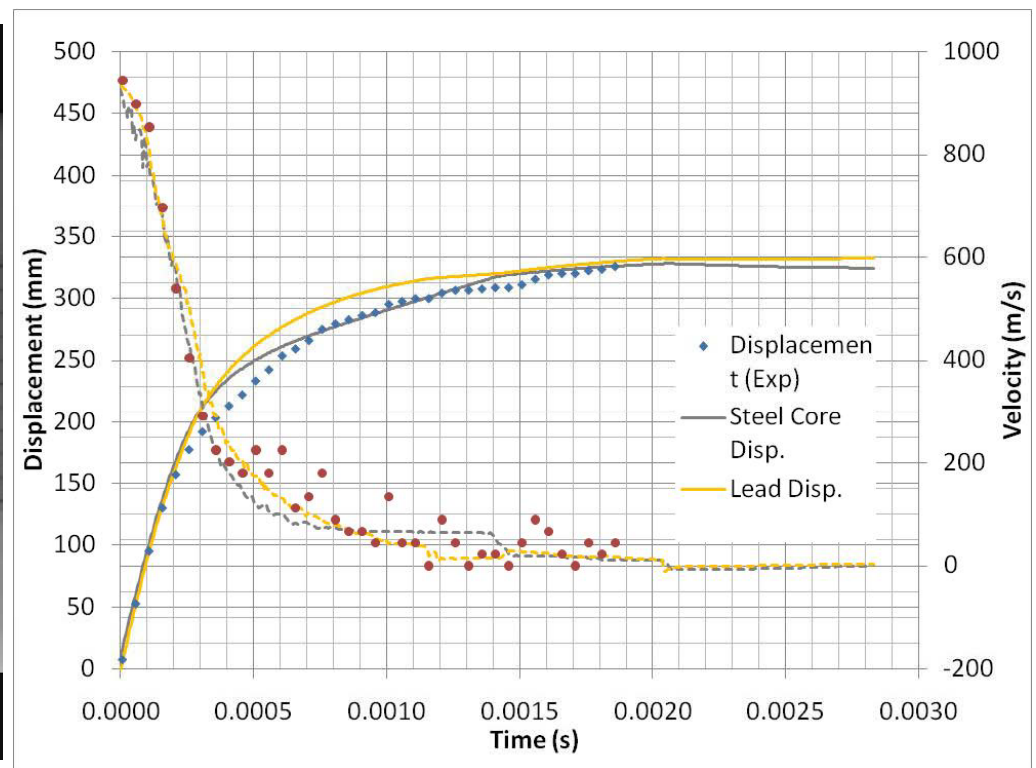
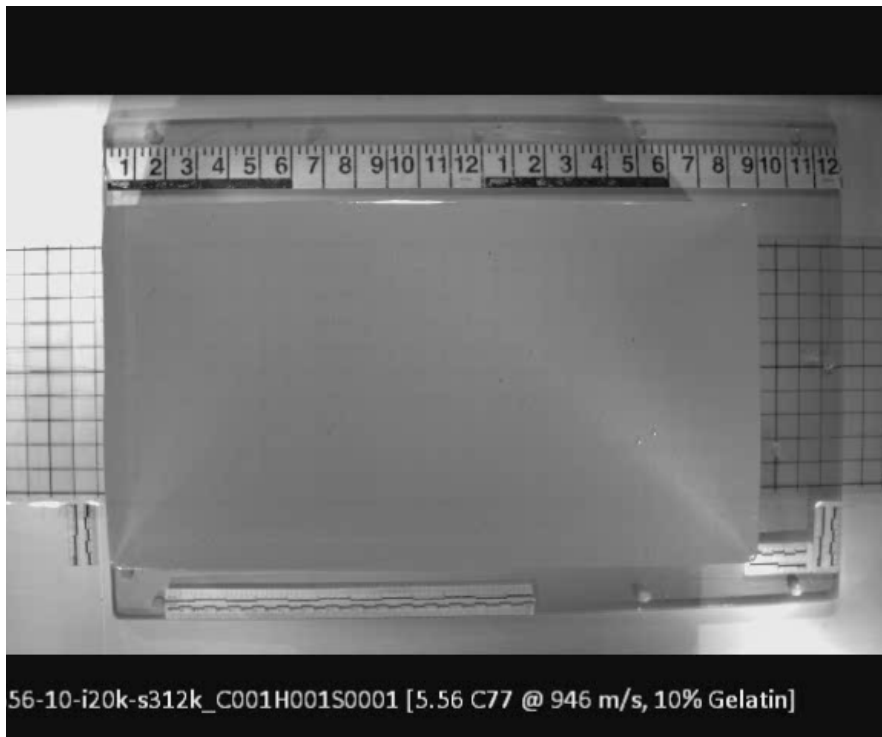
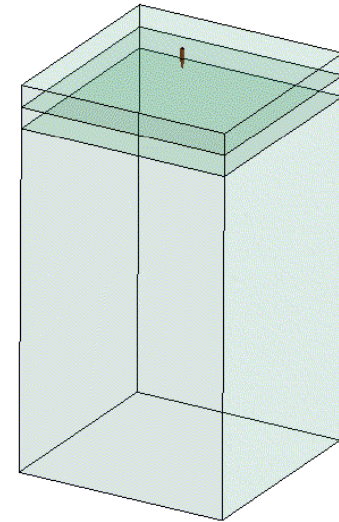
- 3-D Lagrangian model
 - BB impact simulations
 - Projectile impact – experimental data



Impact modeling – PI

- 3-D Lagrangian model
 - Projectile impact

Time = 0



Conclusions

- Mechanical characterization (10% / 4°C gelatin, 0.01 s⁻¹ up to ≈1500 s⁻¹)
 - Integration in constitutive model with damage
- Modeling of calibration test impact (BB)
 - Threshold velocity important
- 3-D Projectile impact models
 - ALE
 - Limited by available material properties
 - EFG
 - Promising for large deformations, but computationally expensive
 - Lagrangian
 - Good agreement with experimental data
 - Computationally efficient