NEW KEYWORDS RELATED TO BLAST & PENETRATION:
A FEW SIMPLE APPLICATIONS

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OUTLINE

BLAST

***SECTION_ALE1D -** *mapping to 2D or 3D*

***ALE_REFINE -** *Static or Adaptive*

***LOAD_BLAST_ENHANCED -** *Additional Coupling to MM-ALE*

- Axisymmetric Geometries
- Surface Burst
- Height of Burst

***INITIAL_IMPULSE_MINE** – *Buried Charges*

PENETRATION

***CONTROL_SPH** – *2D Solver:*

- IDIM=-2 Axisymmetric
- IDIM= 2 Plane Strain

***CONTROL_ADAPTIVE_SOLID_TO_SPH**

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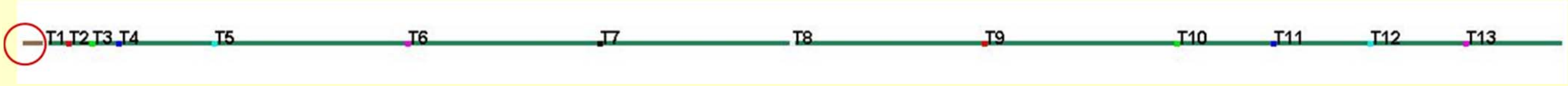
*SECTION_ALE1D

*SECTION_ALE1D

```
$                                  ALE-1D
*SECTION_ALE1D
$  SID  ALEFORM  AET   ELFORM
    10,   11,      ,    -8
$  THICK THICK THICK THICK
    1.0,  1.0,  1.0,  1.0
$

ALEFORM = 11 Multi-Material ALE
ELFORM
    -8=Spherical
     8=Cylindrical
     7=Plane Strain
THICK – values ignored for ELFORM = -8 Spherical
```



Beam element spherical mesh with spherical charge (red circle) and tracer particles.

LSTC Developer: Nicolas Aquelet

*SECTION_ALE1D

Initial Volume Fraction Geometry works with 1D ALE Mesh:

```
$
*Initial_Volume_Fraction_Geometry
$  FMSID FMIDTYP BAMMG NTRACE
    100,   1,      2,    3
$  CONTTYP FILLOPT FAMMG
     6,     0,      1
$    X0     Y0     Z0      R0    -- Sphere
     0.0,  0.0,  0.0,  52.712
$
```

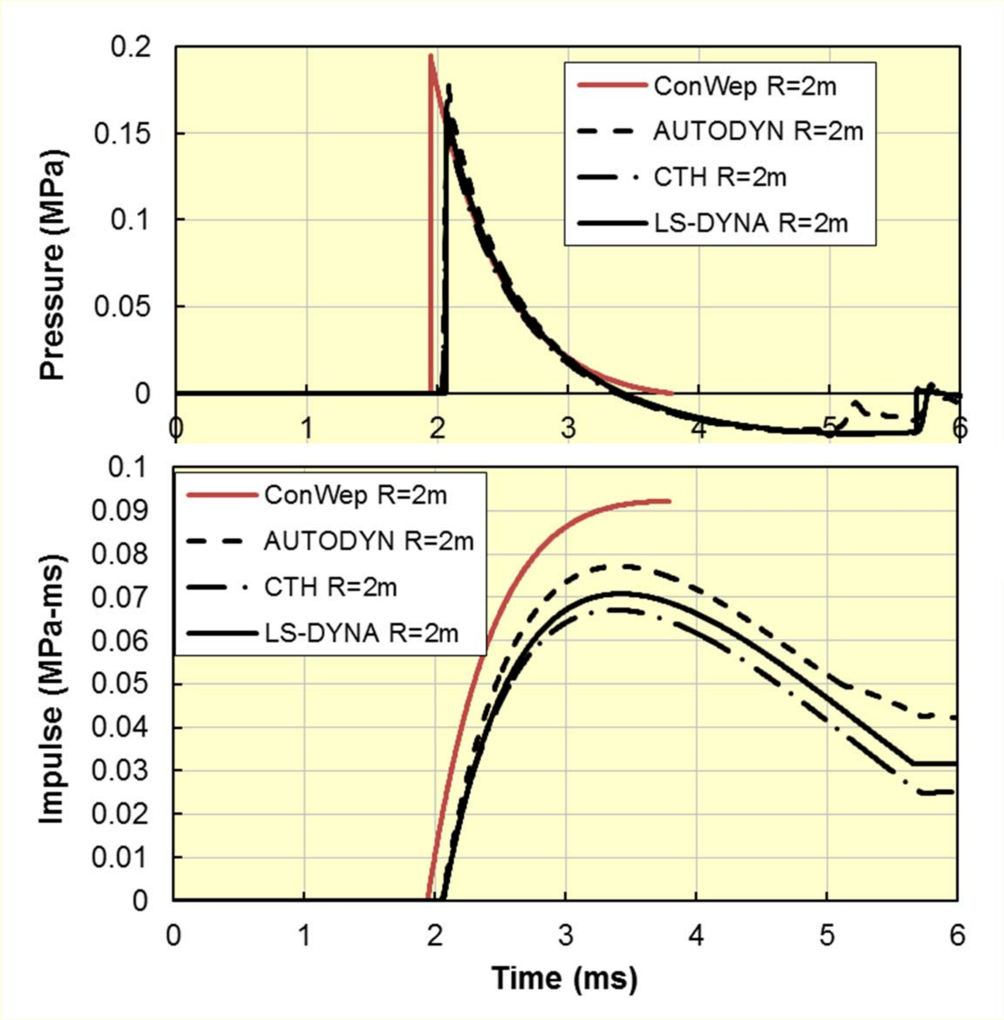
ALE1D allows for high resolution in vicinity of Explosive Charge
Use Mapping to include axisymmetric or 3D targets:

- 1D to 2D
- 1D to 3D
- **1D to1D (No!)**

2 meters @ 0.5mm
Total Number of Elements:
1D Model = 4.0E3
2D Model = 16.0E6
3D Model = 64.0E9

*SECTION_ALE1D

Spherical Free Air Burst – 1 kg TNT at 2 Meter Range
Comparison with ConWep, CTH and AUTODYN using 0.5mm Beam Elements



*ALE_REFINE

*REFINE_ALE

*REFINE_ALE2D

*REFINE_MPP_DISTRIBUTION

*REFINE_SHELL

*REFINE_SOLID

*ALE_REFINE

Defines Portion of the Mesh Subjected to Refinement

Option 1: Automatically Refine Part of a MM-ALE Mesh

```
*ALE_REFINE
$   ID  TYPE  NLVL  MMSID  IBOX
   100,   1,       1,      222
```

Refinement Criteria

Coarsening Criteria

Option 2: *Adaptively* Refine/Coarsen Part of a MM-ALE Mesh

```
*ALE_REFINE
$   ID  TYPE  NLVL  MMSID   IBOX
   100,   1,      1,      222
$  NTOTRF  NCYCRF CRITRF  VALRF  BEGRF ENDRF LAYRF
   10000,        1,           2,         0.999,     0.0,     1.0e6,     2
$   MAXRM  NCYCRM CRITRM  VALRM  BEGRM ENDRM
   10000,     100,            3,            0.5,        0.0,      1.0e6
```

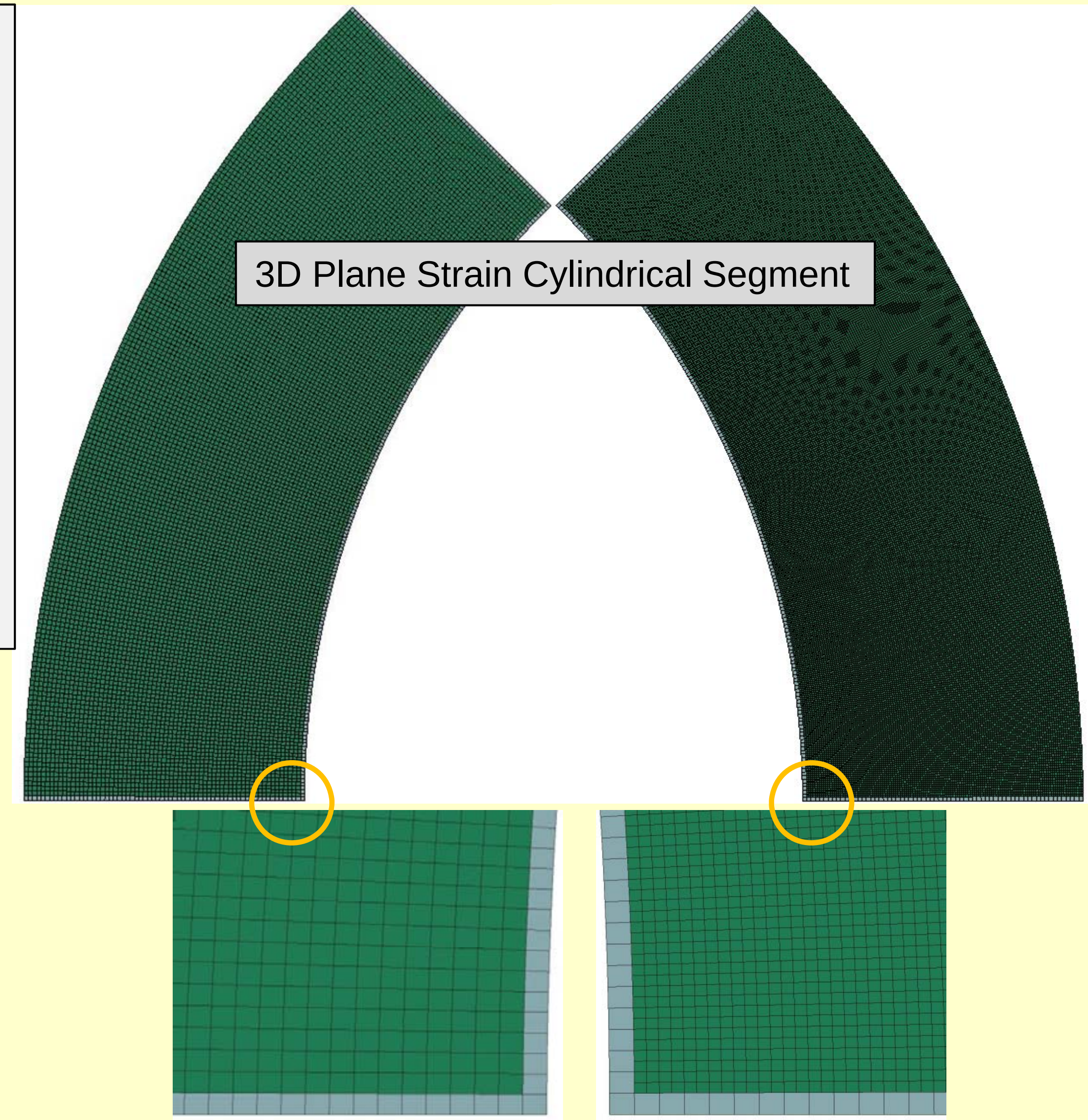
LSTC Developer: Nicolas Aquelet

*ALE_REFINE

Option 1: Automatically
Refine Part of a MM-ALE Mesh

```
*ALE_REFINE
$   ID  TYPE  NLVL  MMSID  IBOX
  100,   1,     1,    222
*SET_MULTI-MATERIAL_GROUP_LIST
$ AMSID
  222
$ AMGID1  AMGID2
   2
```

Air:	Ambient:
PID=100	PID=99
AMMGID=2	AMMGID=1



NLVL - Number of refinement levels
NLVL=1 > each solid becomes 8
NLVL=2 > each solid becomes 64

*ALE_REFINE

Option 2: ***Adaptively*** Refine/Coarsen Part of a MM-ALE Mesh

```
*ALE_REFINE
$   ID  TYPE  NLVL  MMSID   IBOX
  100,   1,      1,      222
$  NTOTRF  NCYCRF CRITRF  VALRF  BEGRF ENDRF LAYRF
   10000,        1,          2,        0.999,      0.0,      1.0e6,      2
$   MAXRM  NCYCRM CRITRM  VALRM  BEGRM ENDRM MMSRM
   10000,     100,          3,           0.5,        0.0,      1.0e6,      0
```

Refinement Criteria

Coarsening Criteria

NTOTRF / MAXRM – Total Number to be refined / Max Number of child clusters to remove
NCYCCRF / NCYCRM – Cycles between refinement / Cycles between coarsening
CRITRF / CRTRM – Refinement Criterion / Coarsening Criterion
VALRF / VALRM – Refinement Threshold / Coarsening Threshold
BEGRF-ENDRF / BEGRM-ENDRM – Refinement Time Begin-End/ Coarsening Time Begin-End
LAYRF – Number of Layers to be Refined
MMSRM – Multi-Material Set ID for the Coarsening

Criteria:

=1 Pressure (P > VALRF or P < VALRM)
=2 Relative Volume (V/V0<VALRF or V/V0 > VALRM)
=3 Volume Fraction (Volume Fraction > VALRF or Volume Fraction < VALRM)

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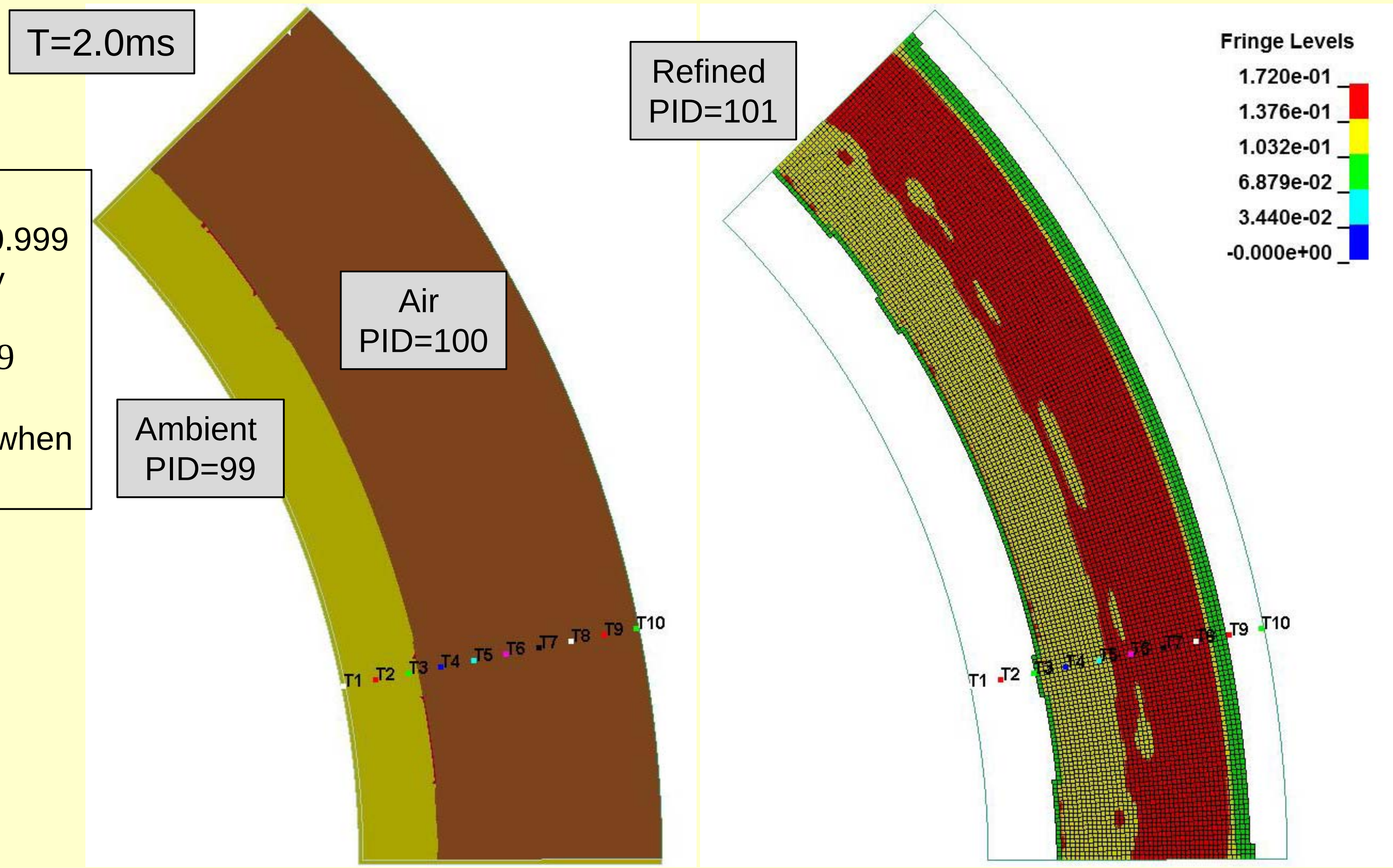
*ALE_REFINE

CRITRF:
Relative Volume<0.999
or equivalently

$$\frac{V}{V_0} = \frac{\rho_0}{\rho} < 0.999$$

Density increases when shock arrives.

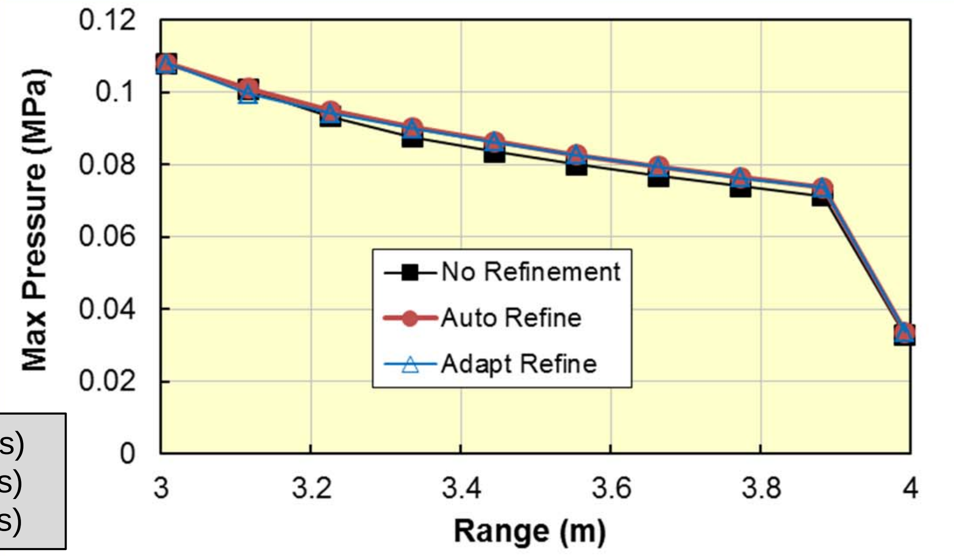


PID=101 is new Part ID automatically created for Refinement/Coarsening and visualization.

*ALE_REFINE

Three Cases:

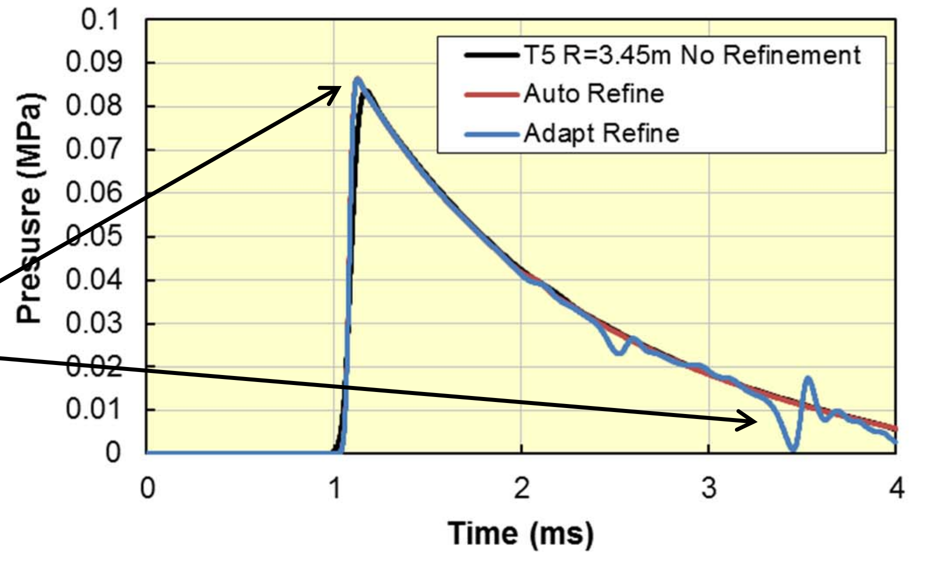
1. Original Mesh *(No Refinement)*
2. Static Refinement *(Auto Refinement)*
3. Adaptive Refinement



No Refinement 360 seconds (0 hours 6 minutes 0 seconds)
Auto Refine 2638 seconds (0 hours 43 minutes 58 seconds)
Adapt Refine 4493 seconds (1 hours 14 minutes 53 seconds)

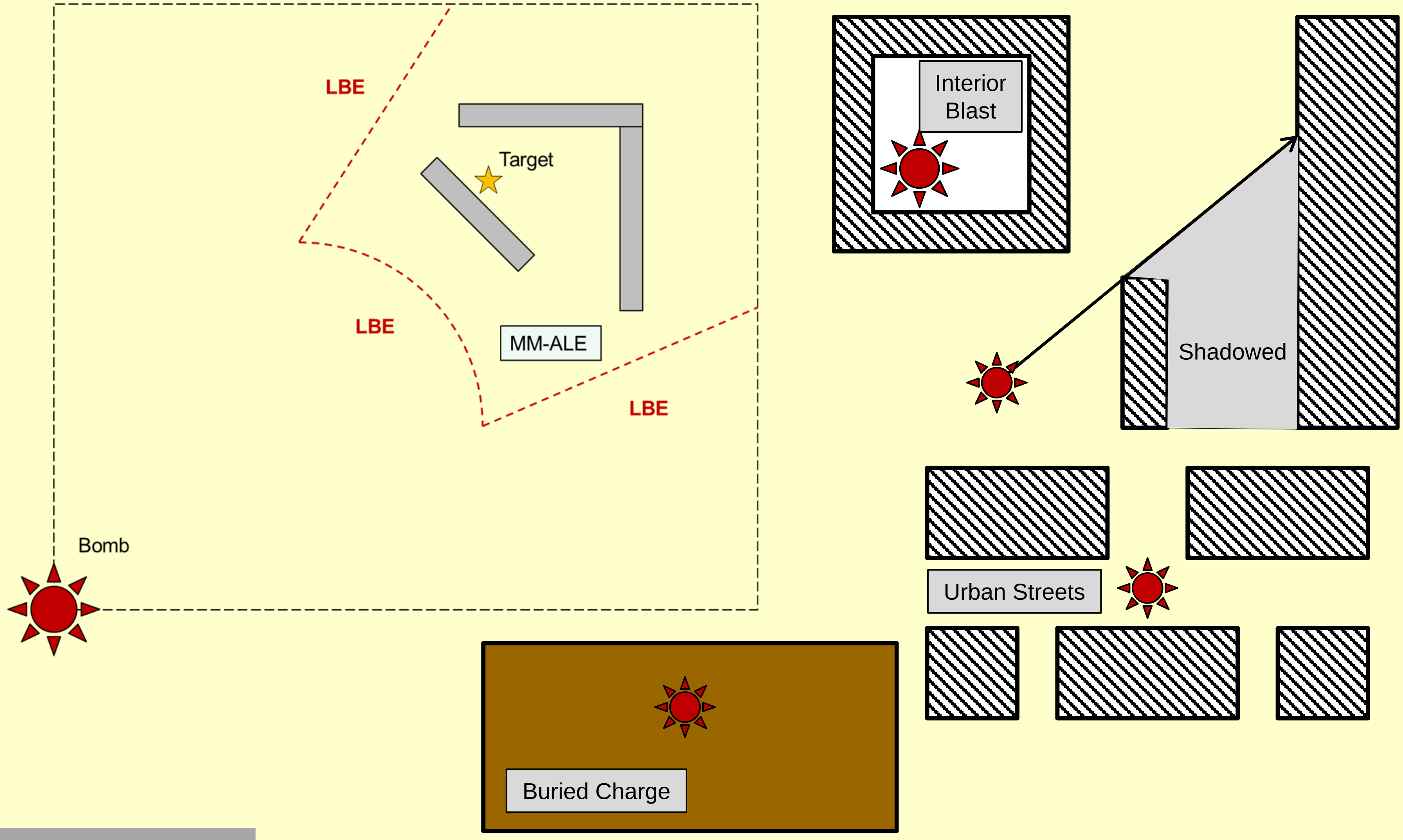
Not an optimal demonstration of *ALE_REFINE as original mesh (*No Refinement*) was converged.

Note: Adaptive refinement better resolves maximum pressure and introduces some noise.



*LOAD_BLAST_ENHANCED

*LOAD_BLAST_ENHANCED



LSTC Developer: Todd Slavik

*LOAD_BLAST_ENHANCED

***LOAD_BLAST_SEGMENT_SET**

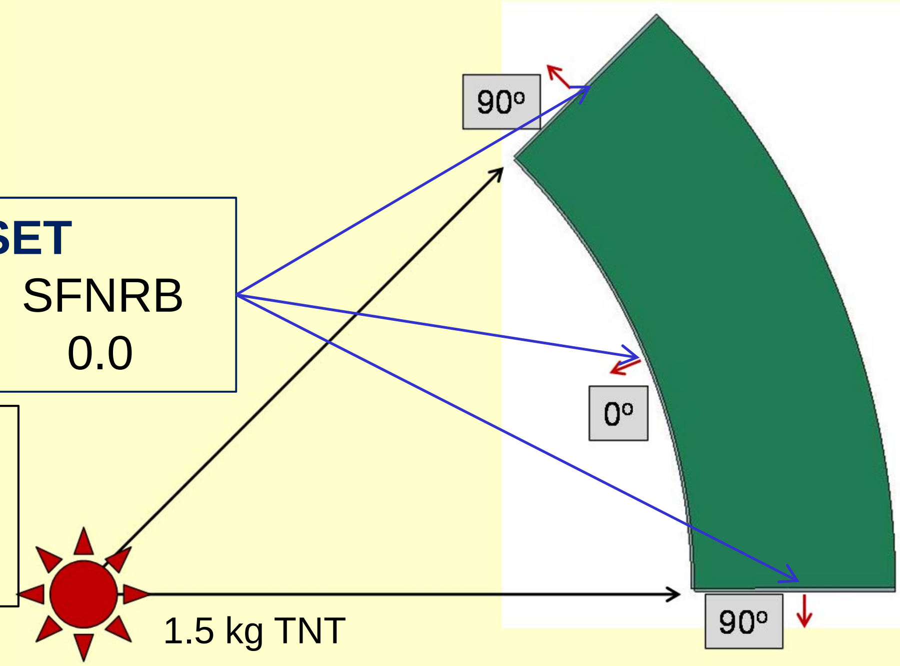
$	BID	SSID	ALEPID	SFNRB
	1	99	99	0.0

***PART**

Ambient ALE

$	PID	SECID	MID	EOSID	HGID	GRAV	ADAPT	TMID
	99,	99,	100,	100,	10,	0		

*MAT_NULL for Air
*EOS_Linear_Polynomial



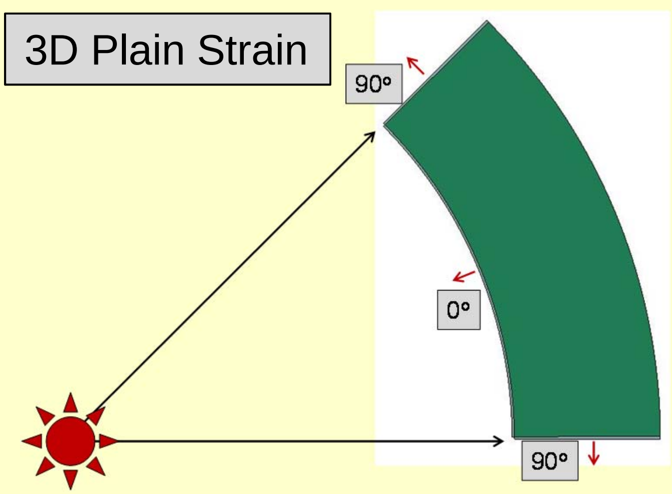
***LOAD_BLAST_ENHANCED**

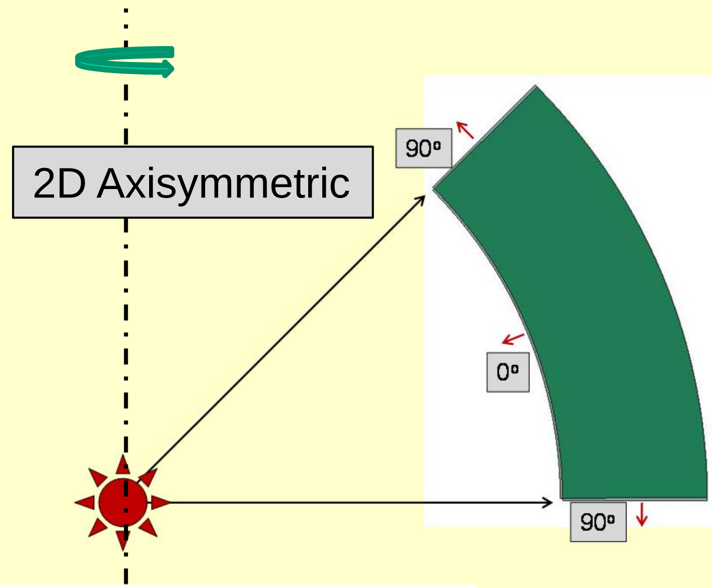
$	BID	M	XB0	YB0	ZB0	TB0	IUNIT	BLAST
	1,	1500.0,	0.0,	0.0,	0.0,	-3.5e-0,	5,	2

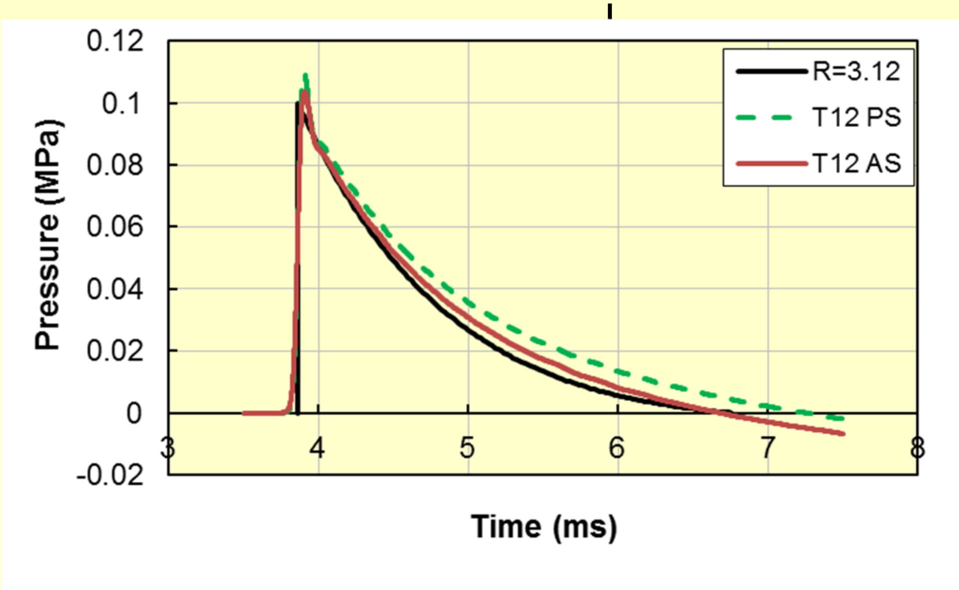
$	CFM	CFL	CFT	CFP	NIDBO	DEATH	NEGPHS
	2.2e-3,	3.28E-3,	1.0,	145.0			

Same as UNIT=8
g, mm, ms, MPa

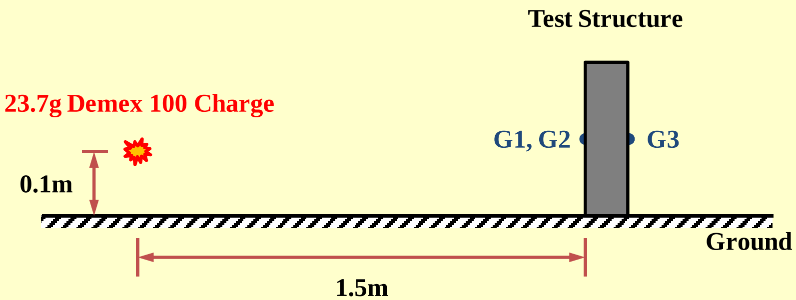
*LOAD_BLAST_ENHANCED

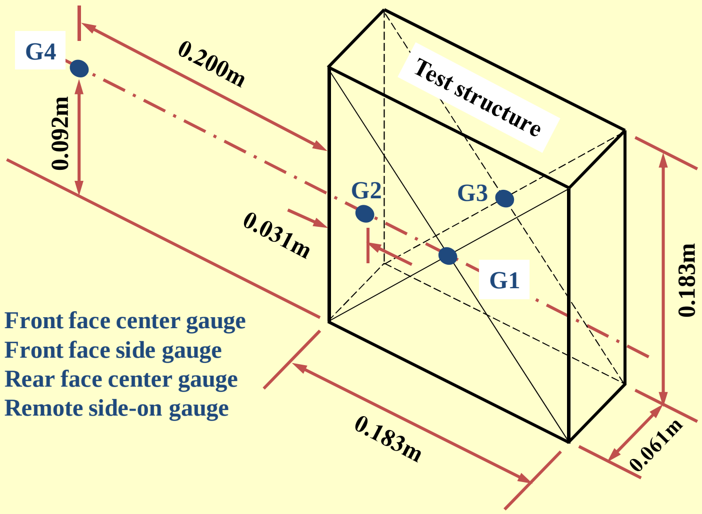




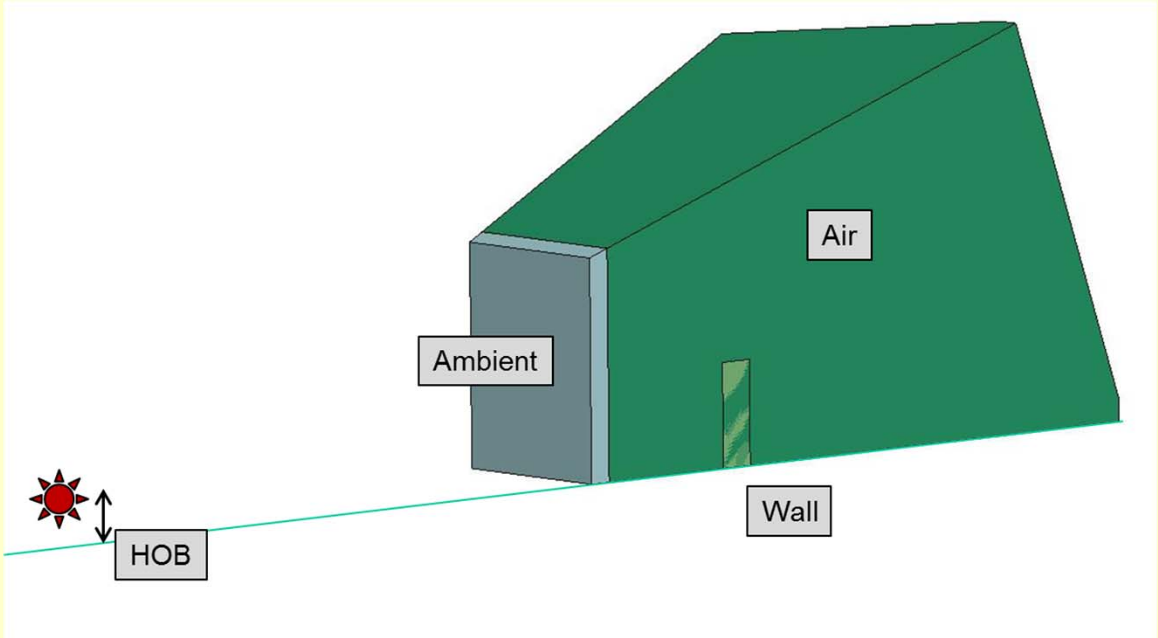


*LOAD_BLAST_ENHANCED





G1 Front face center gauge
G2 Front face side gauge
G3 Rear face center gauge
G4 Remote side-on gauge



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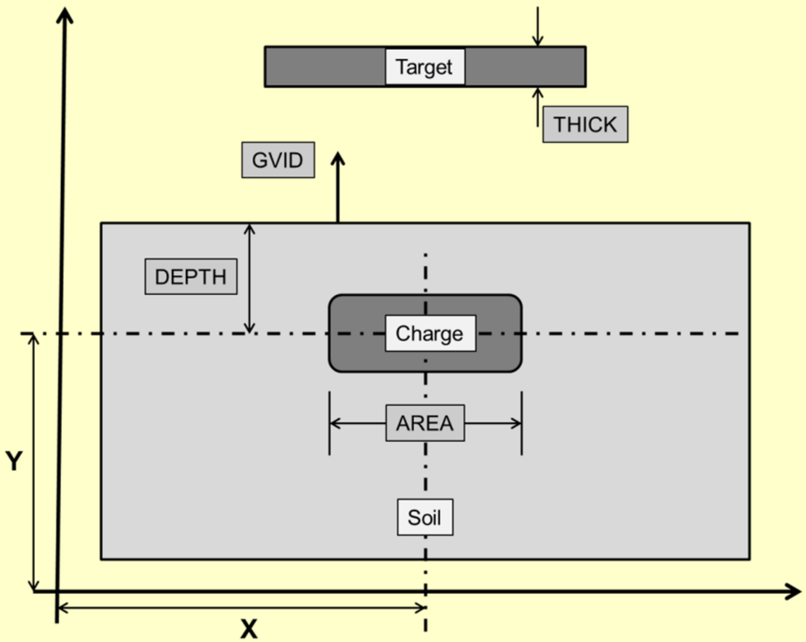
*INITIAL_IMPULSE_MINE

*INITIAL_IMPULSE_MINE

```
*INITIAL_IMPULSE_MINE
$  SSID       M        RHOS      DEPTH       AREA     RHOP/SCAL  THICKP   UNIT
    333,   6500.0,    1.60E-3,   70.0,   55.15E3,      0.0,       0.0,     6
$     X      Y      Z     NIDMC    GVID    TBIRTH    PSID    SEARCH
    0.0, -70.0, 0.0,    0,      222
$
```

```
 SSID – Target Segment Set to be Loaded
    M – Equivalent Mass of TNT
 RHOS – Soil Density
DEPTH – Distance Surface to Charge CG
 AREA – Cross Sectional Area of Charge
 UNIT – Select System of Units
X-Y-Z – Global Coordinates of Charge CG
 GVID – Ground Surface Vector ID
```



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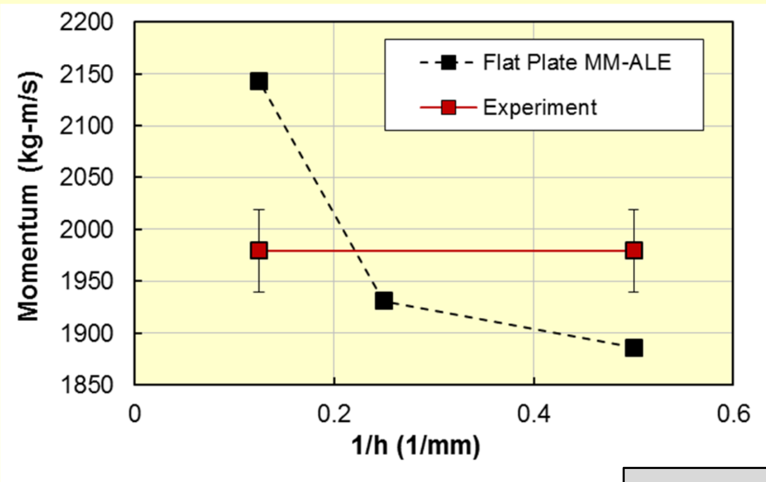
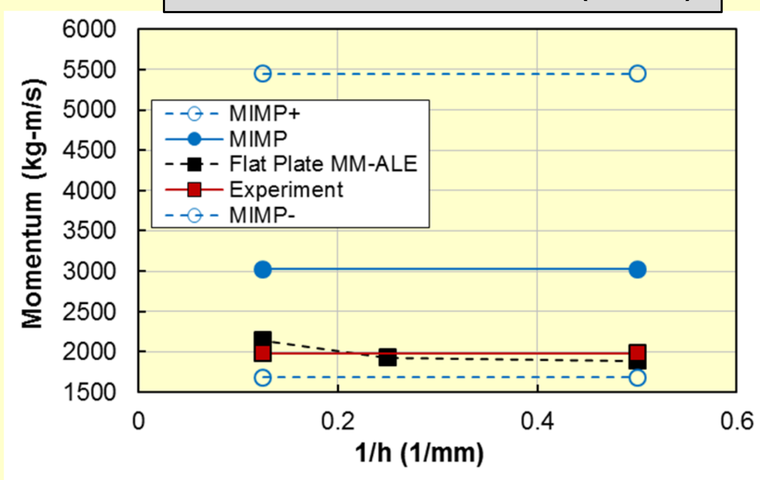
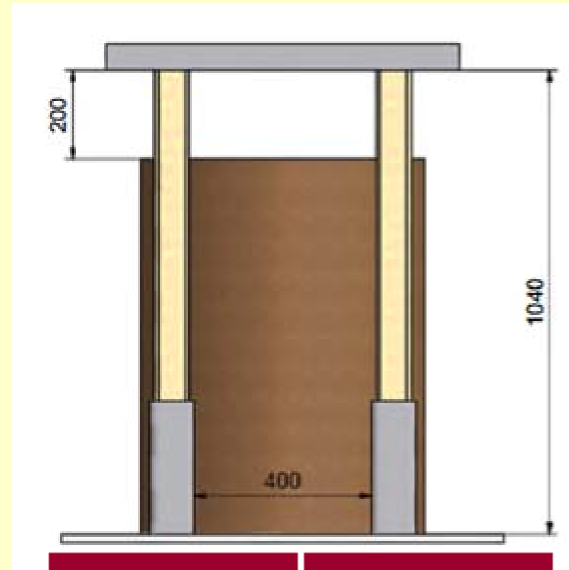
LSTC Developer: Todd Slavik

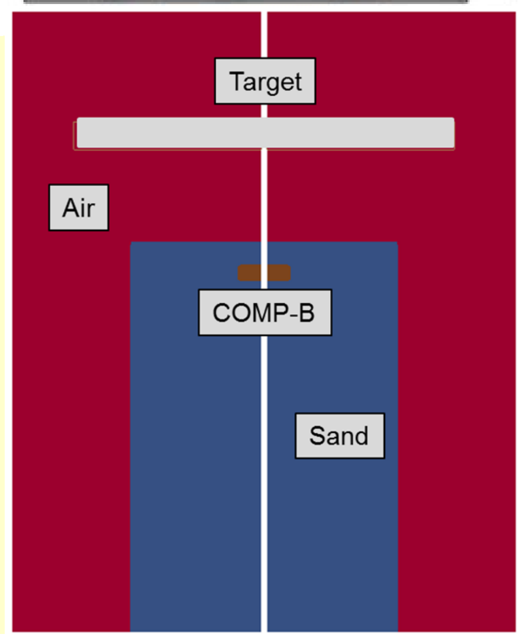
SwRI BURIED CHARGE TESTS



MIMP/1.8 < MIMP < 1.8(MIMP)







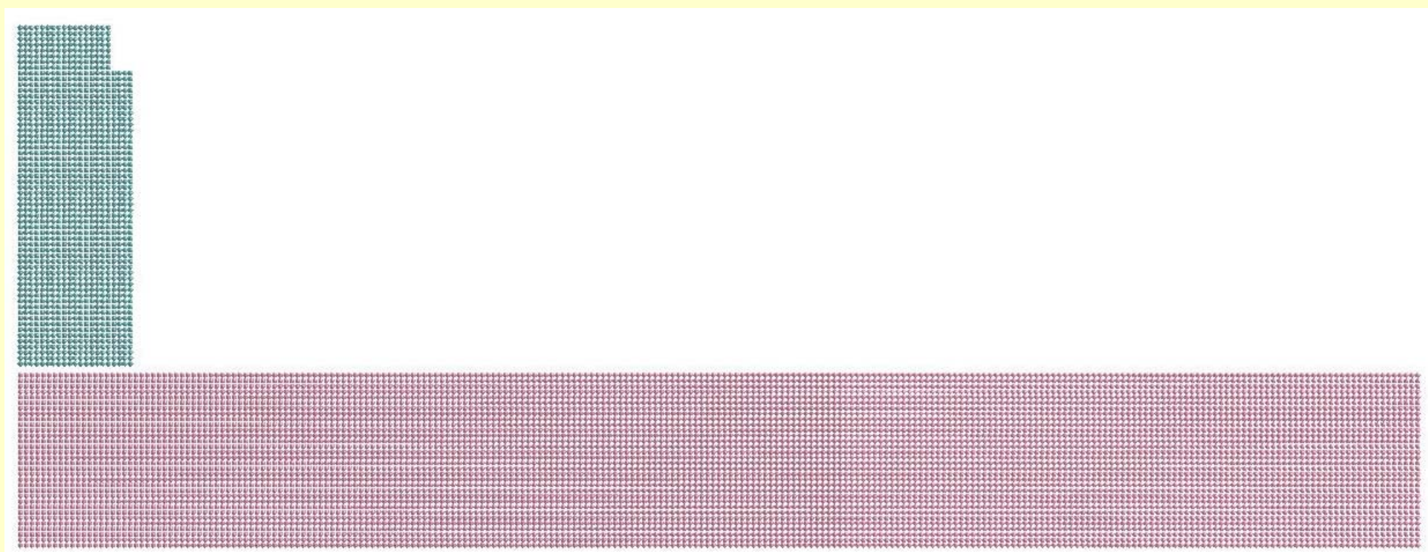
Anderson, C.E. Jr., T. Behner, and C.E. Weiss (2011), "Mine Blast Loading Experiments," *International Journal of Impact Engineering*, Volume 38, page 697-706.

*CONTROL_SPH

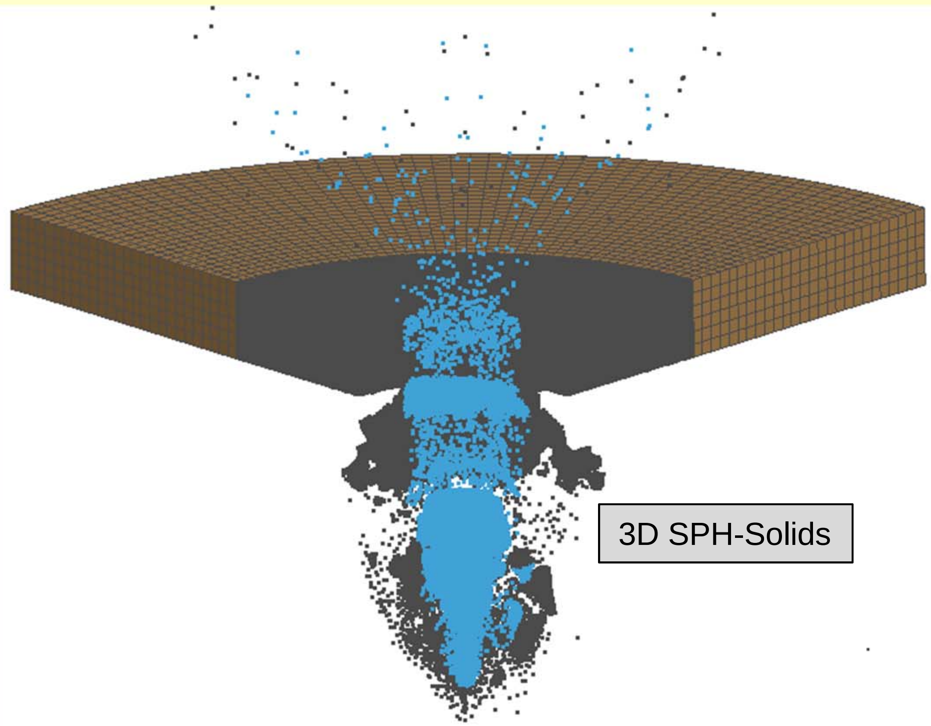
*CONTROL_SPH

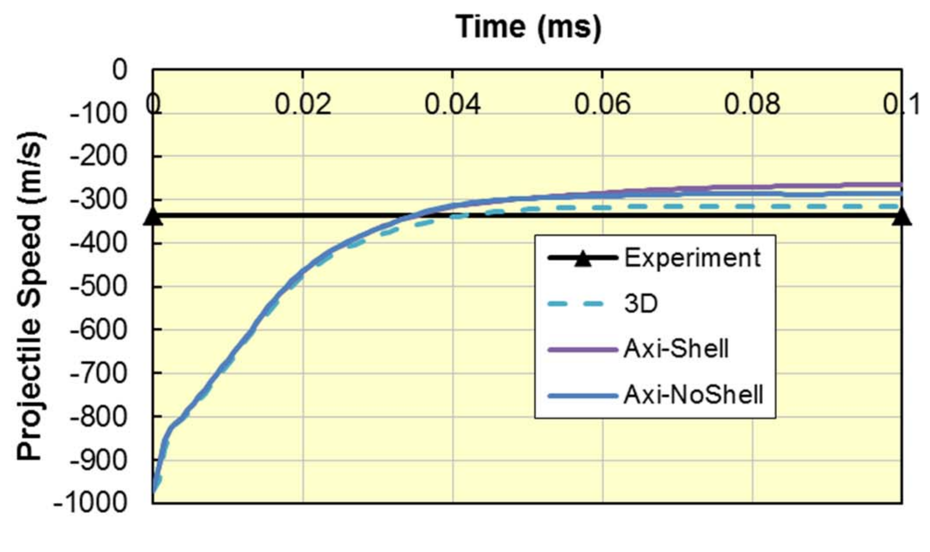
```
$
*CONTROL_SPH
$     NCBS     BOXID        DT      IDIM    MEMORY      FORM       START      MAXV
         1       000                  -2      -150         1
$     CONT     DERIV       INI     ISHOW     IEROD     ICONT       IAVIS
                                                                       1
$
```

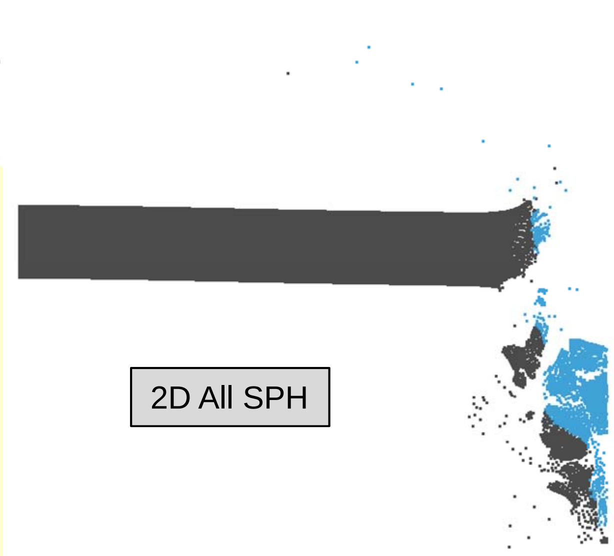
IDIM = -2 Axisymmetric
IDIM = 2 Plane Strain

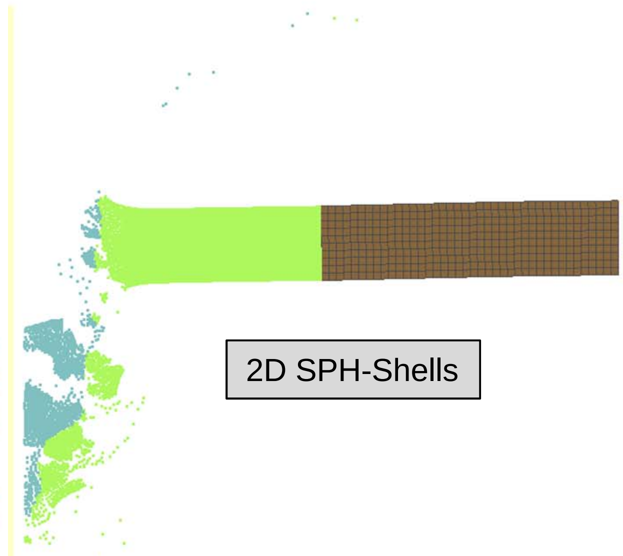


*CONTROL_SPH









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*CONTROL_ADAPTIVE_SOLID_TO_SPH

*CONTROL_ADAPTIVE_SOLID_TO_SPH

***DEFINE_ADAPTIVE_SOLID_TO_SPH**

```
$   IPID  ITYPE     NQ  IPSPH   ISSPH  ICPL   IOPT
  40100       1       2     301      201       1       1
```

IPID	ID of the solid part or part set to transform.
ITYPE	IPID type: EQ.0: Part ID, NE.0: Part set ID.
NQ	Adaptive option for hexahedral elements. EQ. 1: Adapt one solid element to one SPH element, EQ. 2: Adapt one solid element to 8 SPH elements, EQ. 3: Adapt one solid element to 27 SPH elements.
IPSPH	Part ID for newly generated SPH elements.
ISSPH	Section ID for SPH elements.
ICPL	Coupling of newly generated SPH elements to the adjacent solid elements: EQ. 0: Failure without coupling (debris simulation), EQ. 1: Coupled to Solid element.
IOPT	Coupling method (for ICPL=1 only See Remark 3): EQ. 0: Coupling from beginning (used as constraint between SPH elements and Solid elements), EQ. 1: Coupling begins when Lagrange element fails.

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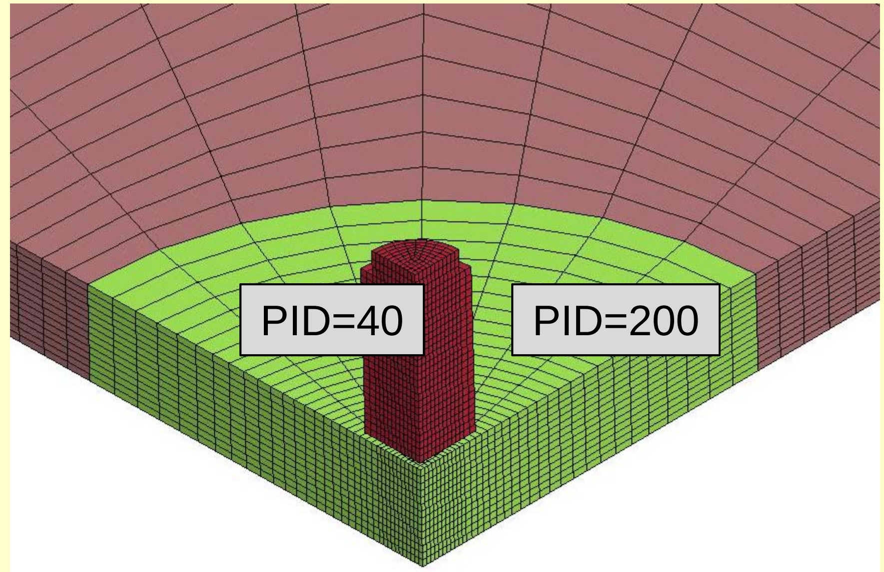
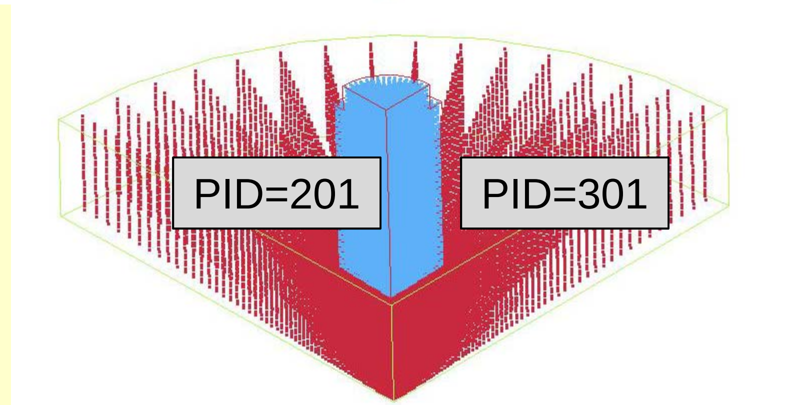
LSTC Developer: Jingxiao Xu

*CONTROL_ADAPTIVE_SOLID_TO_SPH

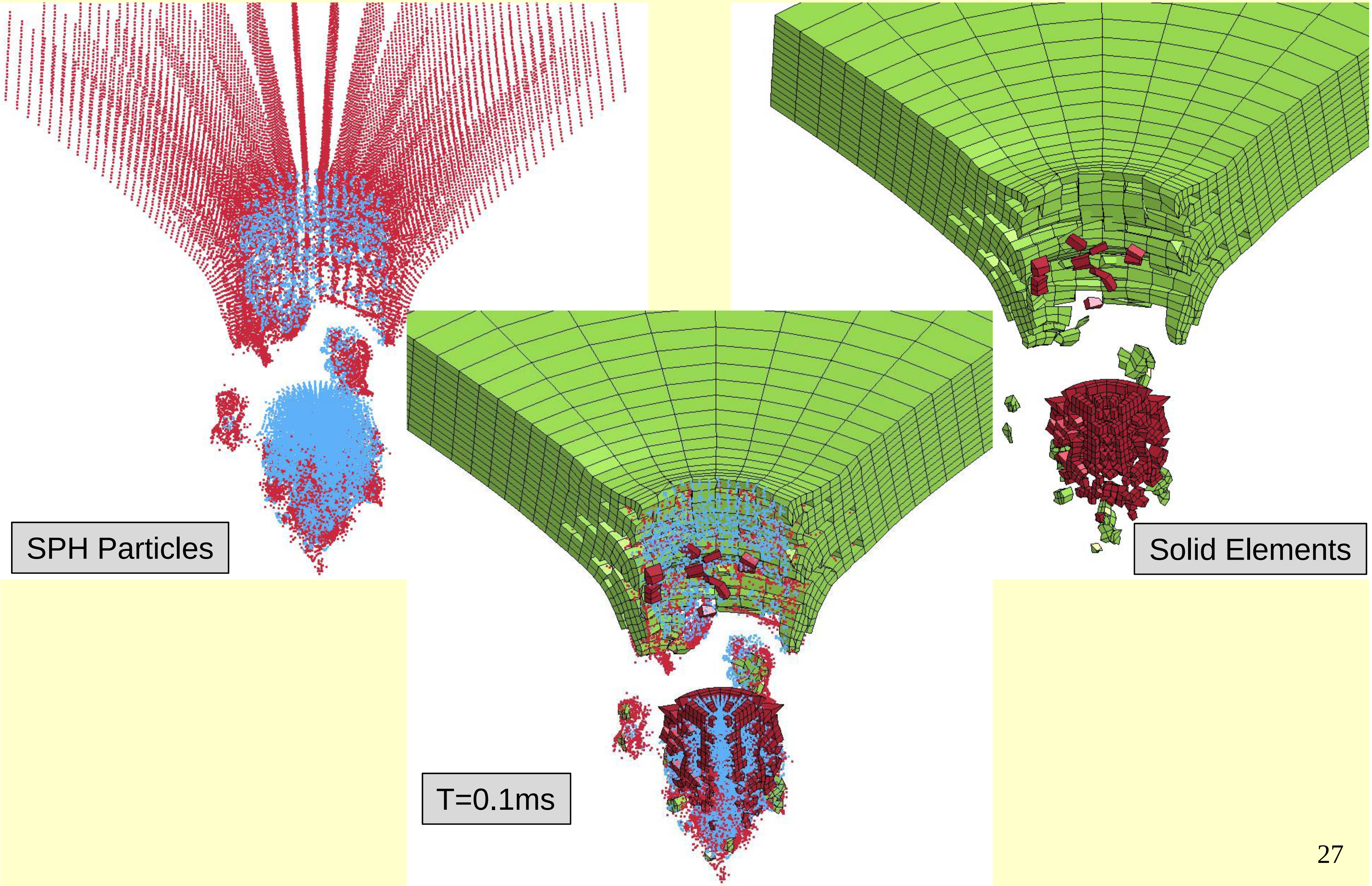
```
Projectile:
*DEFINE_ADAPTIVE_SOLID_TO_SPH
$  IPID  ITYPE    NQ  IPSPH   ISSPH  ICPL   IOPT
     40       0      2     201     201      1      1
$
Inner Target:
*DEFINE_ADAPTIVE_SOLID_TO_SPH
$  IPID  ITYPE    NQ  IPSPH   ISSPH  ICPL   IOPT
    200       0      2     301     201      1      1
$
$
*SECTION_SPH
$  SECID   CSLH   HMIN   HMAX   SPHINI
     201    1.20   0.200     4.00    0.00
$
*PART
  Generated Projectile SPH Particles
$    PID   SECID    MID   EOSID    HGID    GRAV
     201     201   26061    6061
*PART
  Generated Inner Target SPH Particles
$    PID   SECID    MID   EOSID    HGID    GRAV
    301     201   26061    6061
```



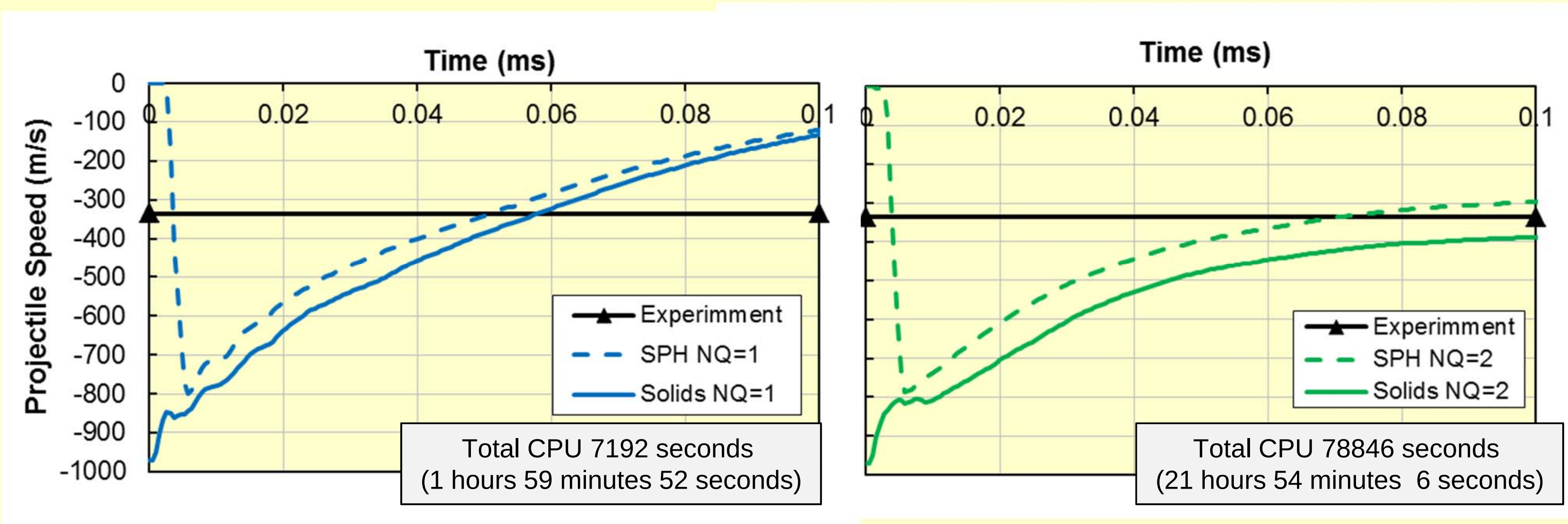


LS-DYNA generates the SPH particles using the specified NQ parameter.

*CONTROL_ADAPTIVE_SOLID_TO_SPH



*CONTROL_ADAPTIVE_SOLID_TO_SPH



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No Attempt was made to run the NQ=3 case: Solids to 64 SPH

SUMMARY

BLAST

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***ALE_REFINE -** *Static or Adaptive*

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- Surface Burst
- Height of Burst

***INITIAL_IMPULSE_MINE** – *Buried Charges*

PENETRATION

***CONTROL_SPH** – *2D Solver:*

- IDIM=-2 Axisymmetric
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***CONTROL_ADAPTIVE_SOLID_TO_SPH**

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