

# Survivability



GVSETS

GROUND VEHICLE SYSTEMS ENGINEERING & TECHNOLOGY SYMPOSIUM  
& ADVANCED PLANNING BRIEFING FOR INDUSTRY

NDIA  
Michigan

## EXPLOSIVE REACTIVE ARMOR (ERA) ENCLOSURE SIMULATION

V. Babu, M. Vunnam, Shawn Klann, Charles Filar (GVSC)



- Objective
- Overview of ERA enclosures
- Test & M&S setup
- Results & discussion
- Future work





## ❑ Objective

- ✓ To develop M&S models to simulate ERA enclosures loadings and response
- ✓ Establish correlation to the tests
- ✓ Measure Stresses and subsequent damage on adjacent enclosures and tiles

## ❑ Accomplishments

- ✓ Developed ERA enclosures M&S capability
- ✓ Successfully correlated the M&S responses to the test



# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

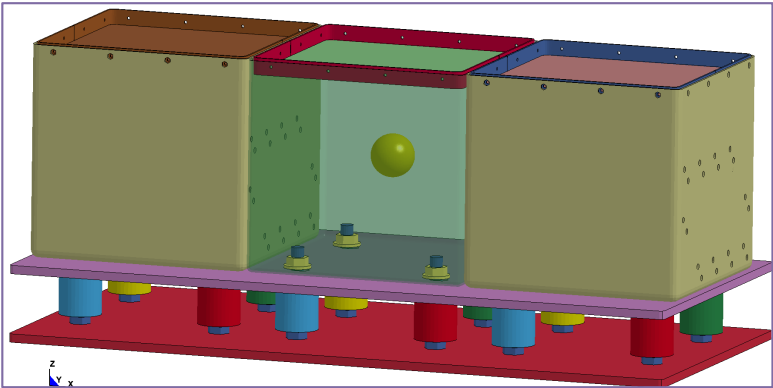


## - Enclosures Specs and Charge Position



Test Enclosure

- Enclosures dimensions 13" x 13" x 13"
- The C4 charge is placed at the center of the middle tile and detonated
- The C4 charge simulates the blast loadings of an ERA ballistic event



M&S Enclosure

<u>Material</u>	<u>Thickness</u>
Steel (304 Stainless)	0.0625" (1.5875 mm)
Titanium (Ti-6-4)	0.125" (3.175 mm)
Aluminum (6061-T6)	0.125" (3.175 mm)
Fiberglass (S2 + Epoxy)	0.165" (4.191 mm)



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## - Enclosures Specs and Charge Position

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- ❑ Most of the material properties are derived from publicly available literatures  
References are provided in the paper
- ❑ Since the C4 is hand packed, its detonation velocity is approximately is 7% less at 7600 m/s than the ideal value of 8193 m/sec.

	Density (kg/m <sup>3</sup> )	C-J Pressure (Pa)	Detonation Vel (m/s)	Energy/volu me (J/m <sup>3</sup> )
Theoretical	1600	2.60E10	8193	9.10E10
As tested	1600	2.60E10	7600	9.10E10



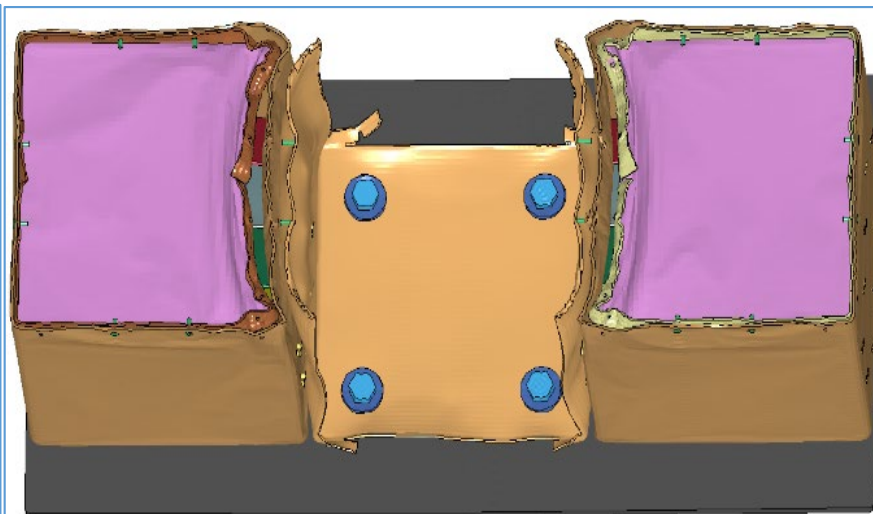
# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

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## - AL 6061-T6 Post Test Deformation



Test – Al 6061-T6



M&S - Al 6061-T6

- Deformation and rupture of Al 6061-T6 between test and M&S compares well.



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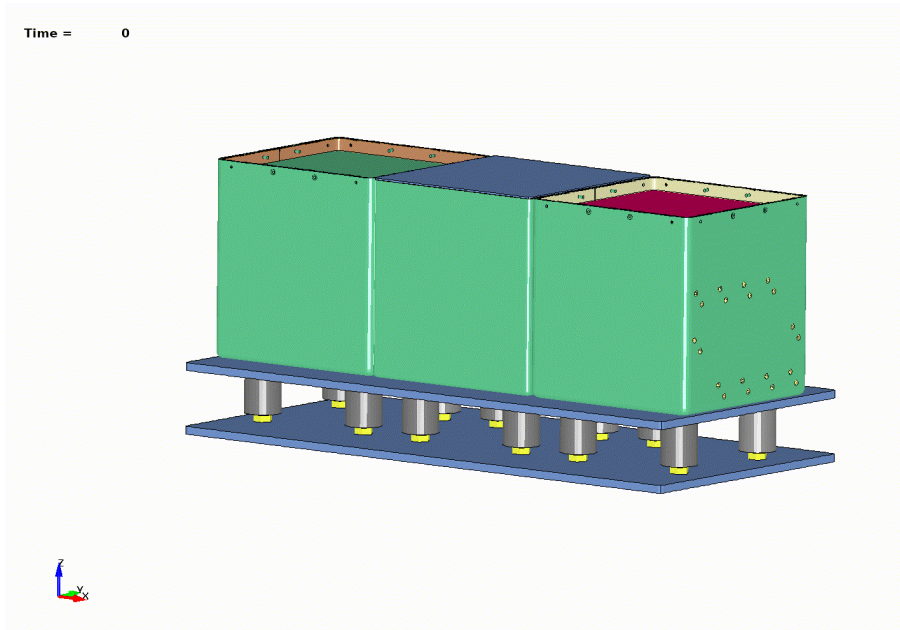
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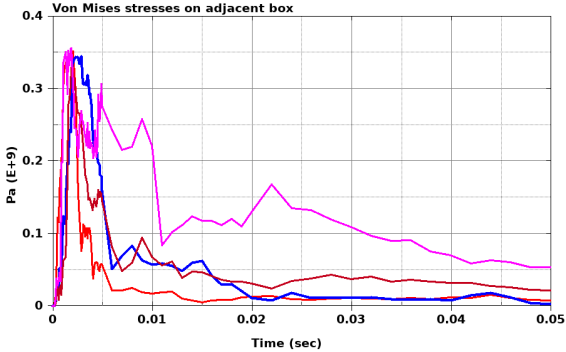
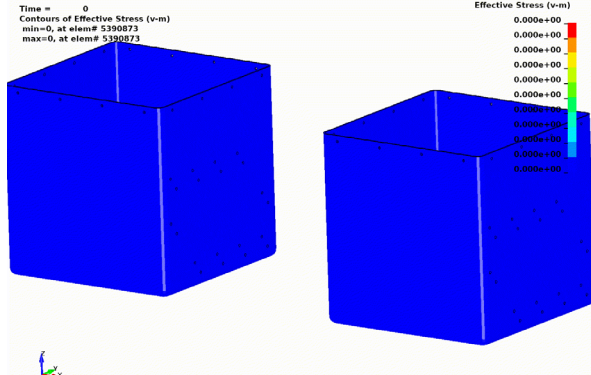
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## - AL 6061-T6 animation & stresses

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M&S - Al 6061-T6 Stresses



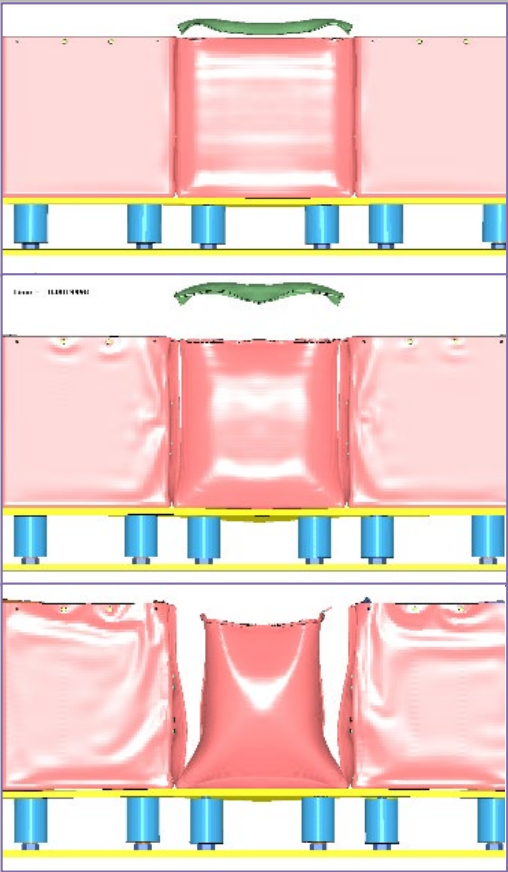
Peak stresses on the adjacent tiles are around 350 Mpa and plastic strains are below 6%



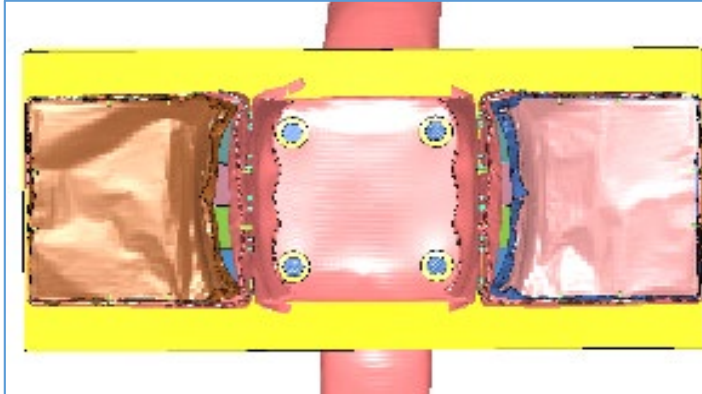
# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

## - AL 6061-T6 Post Test Deformation

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Test



@ 50 ms

M&S

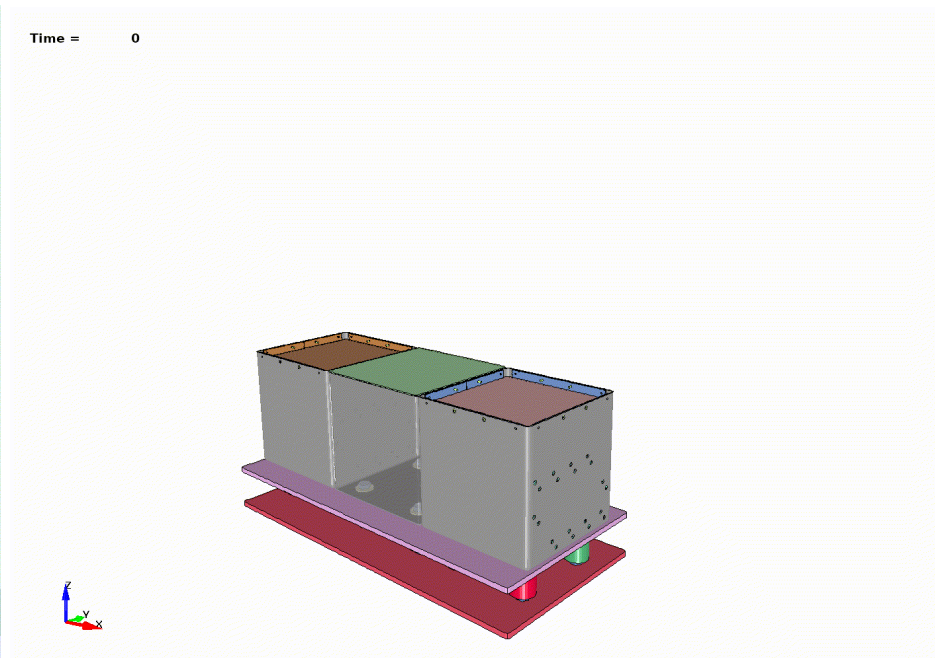
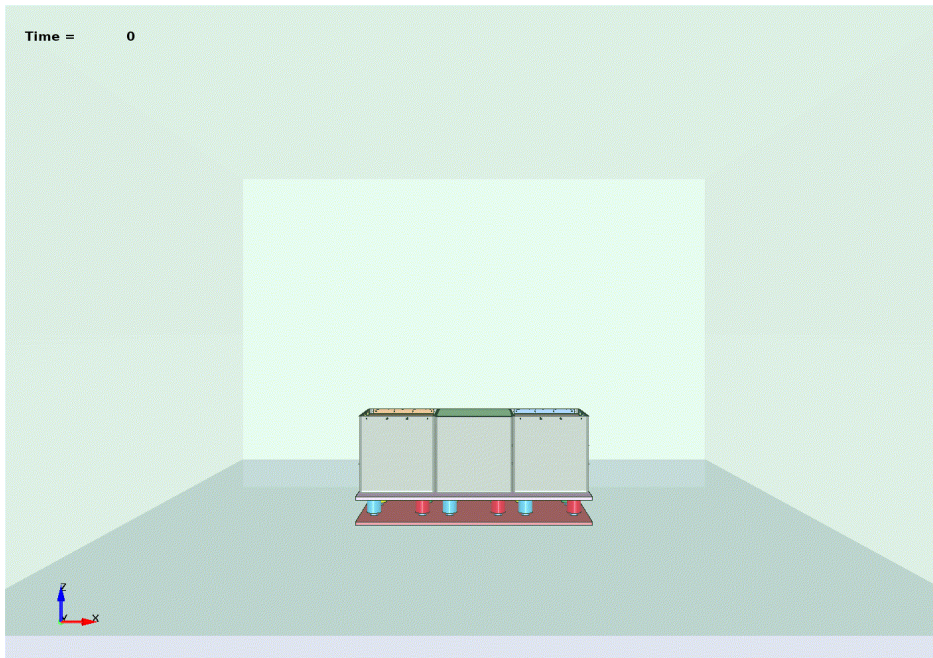
- Deformation and rupture of Ti-6-4 between test and M&S



# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

## - Ti-6-4 (Ti6Al4v) animation

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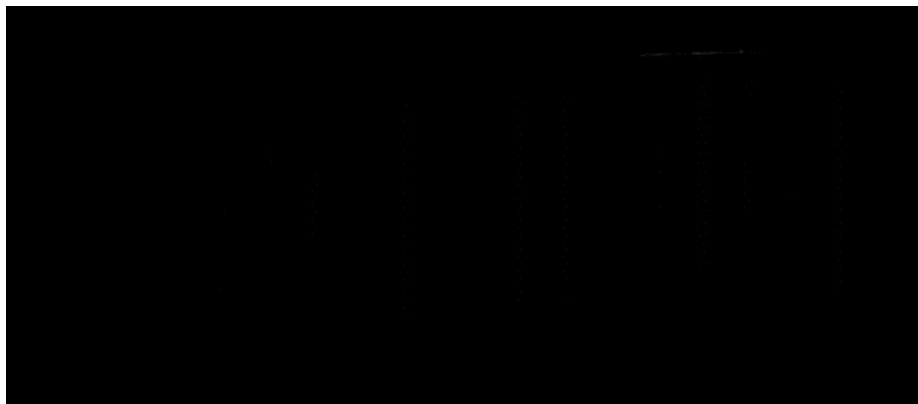
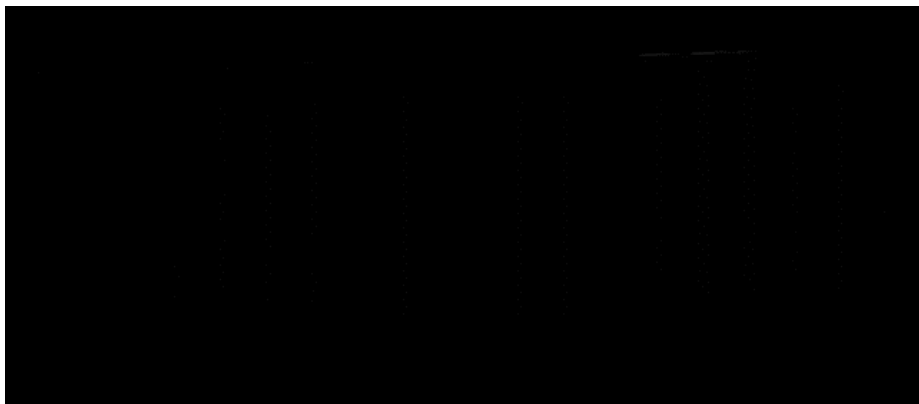
- All the initial stored energy of C4 (26 Mega Joules ) converted into internal and kinetic energy of structures and air



# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

## - Test Videos

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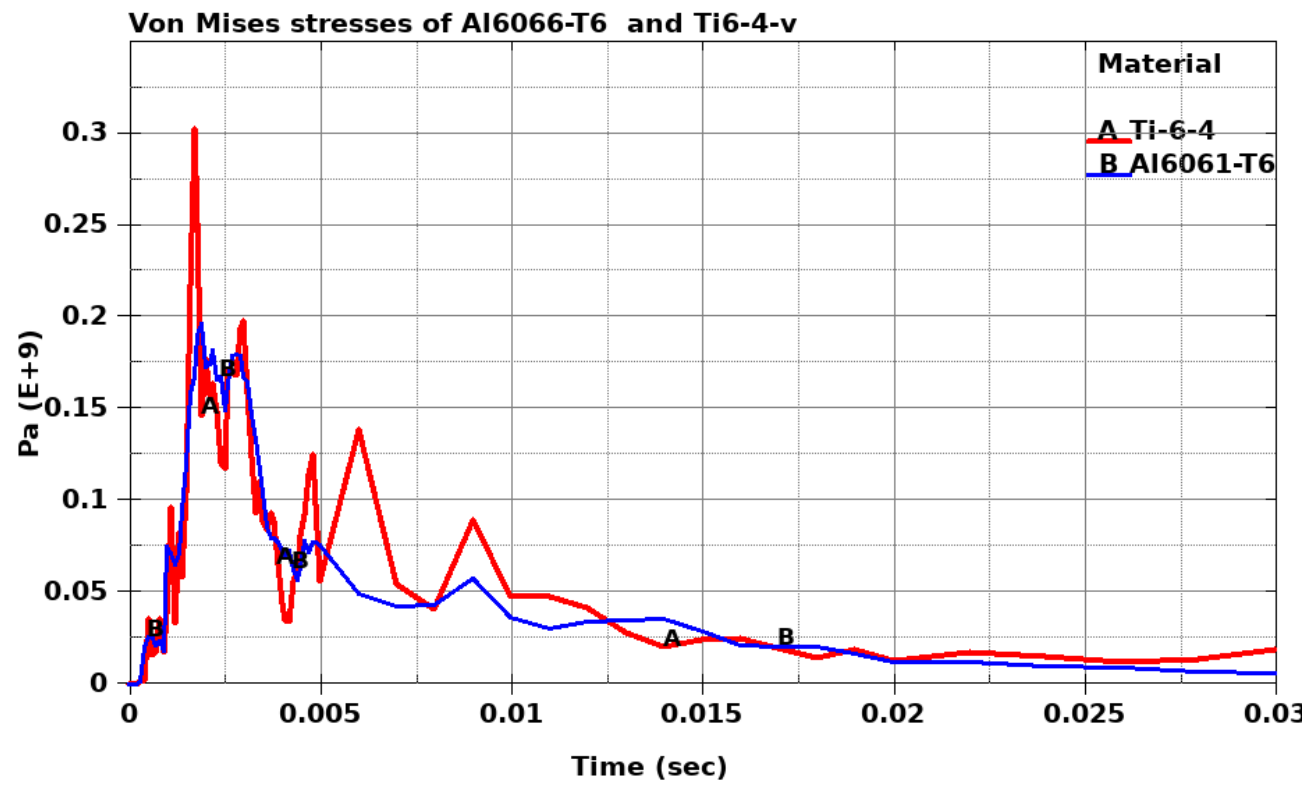
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## - Stresses on adjacent boxes



☐ Stresses on the adjacent boxes are very similar pattern, except that Ti-6-4 shows higher Von-Mises stresses.

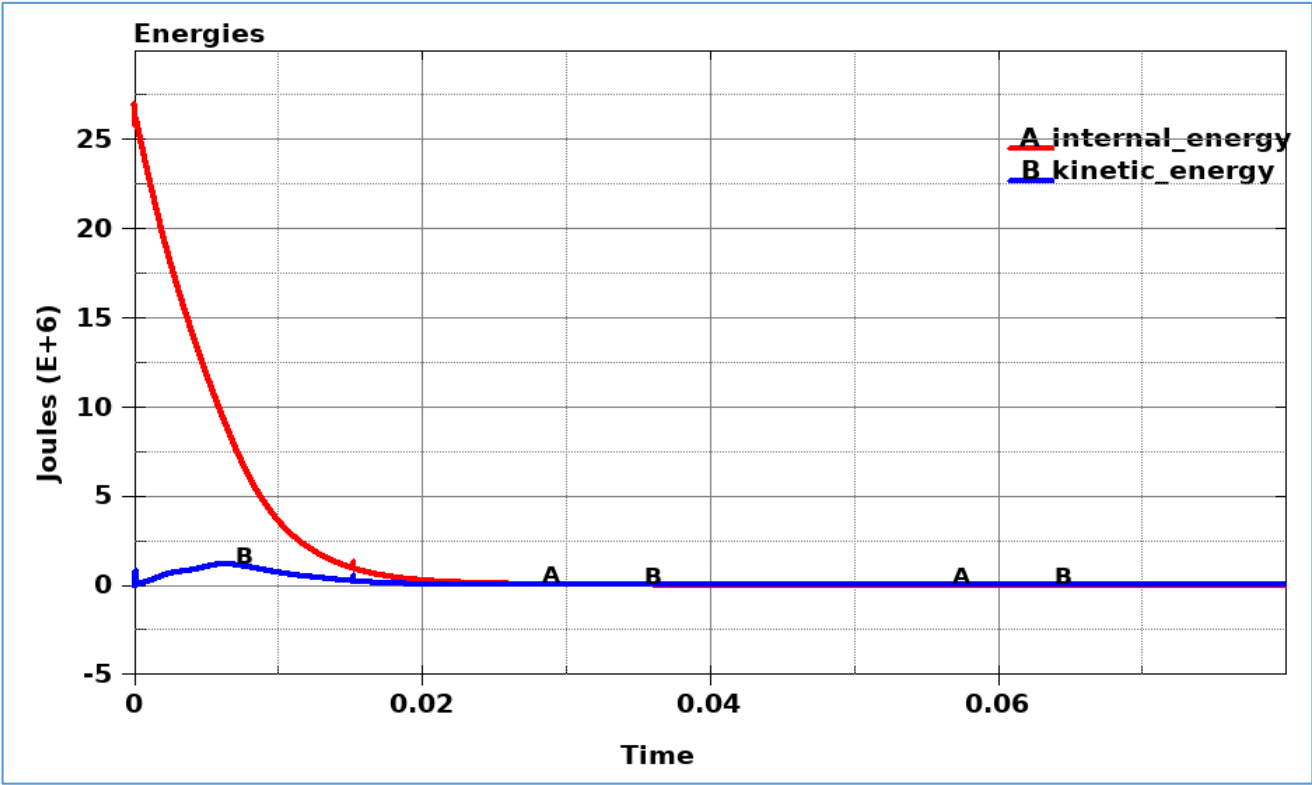


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## - Energies



- Initial stored energy of C4 is 26 Mega Joules
- All the initial stored energy is converted into internal and kinetic energy of structures and air

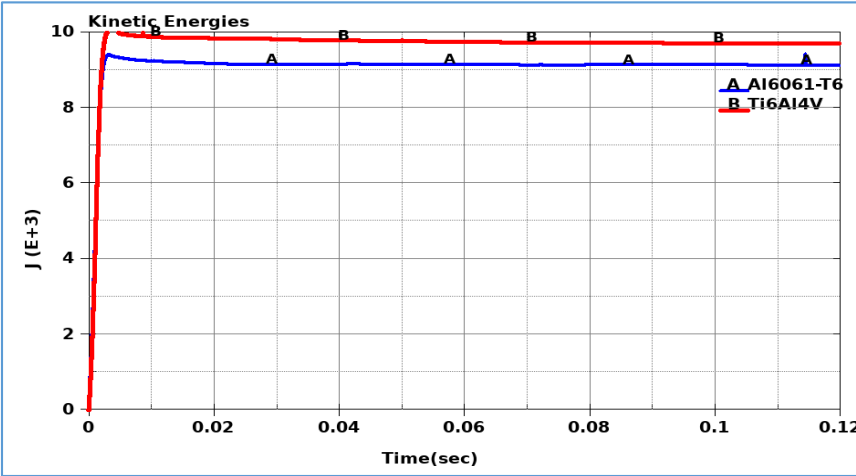
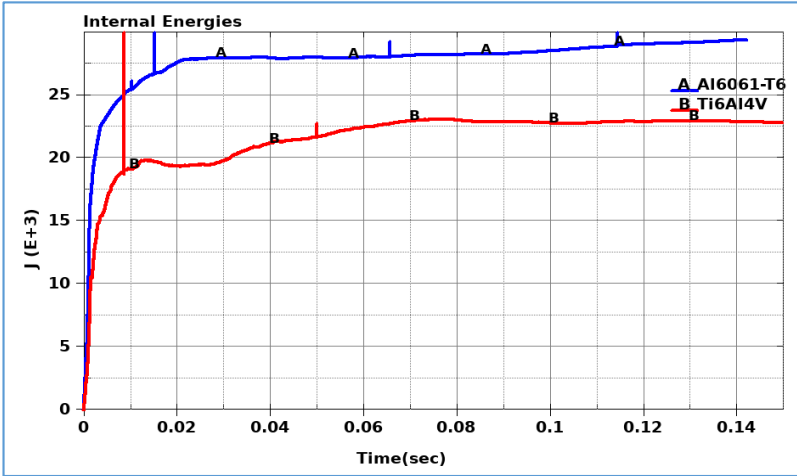


# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

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## - Energies

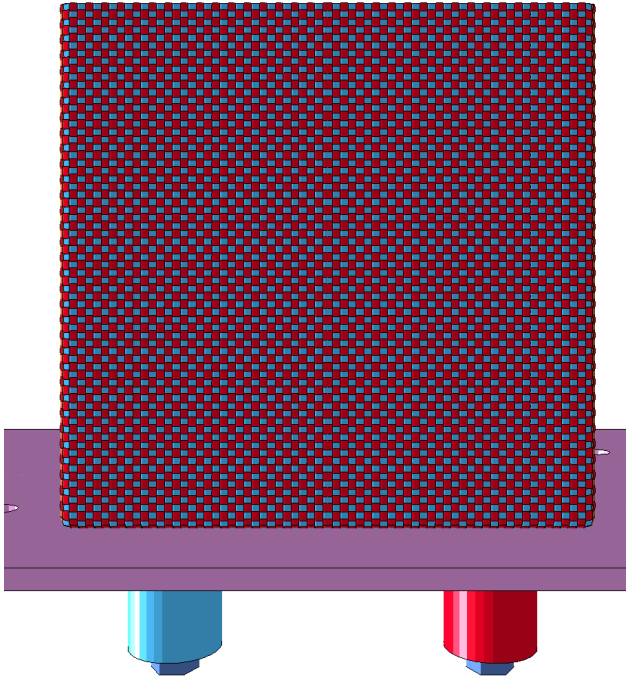
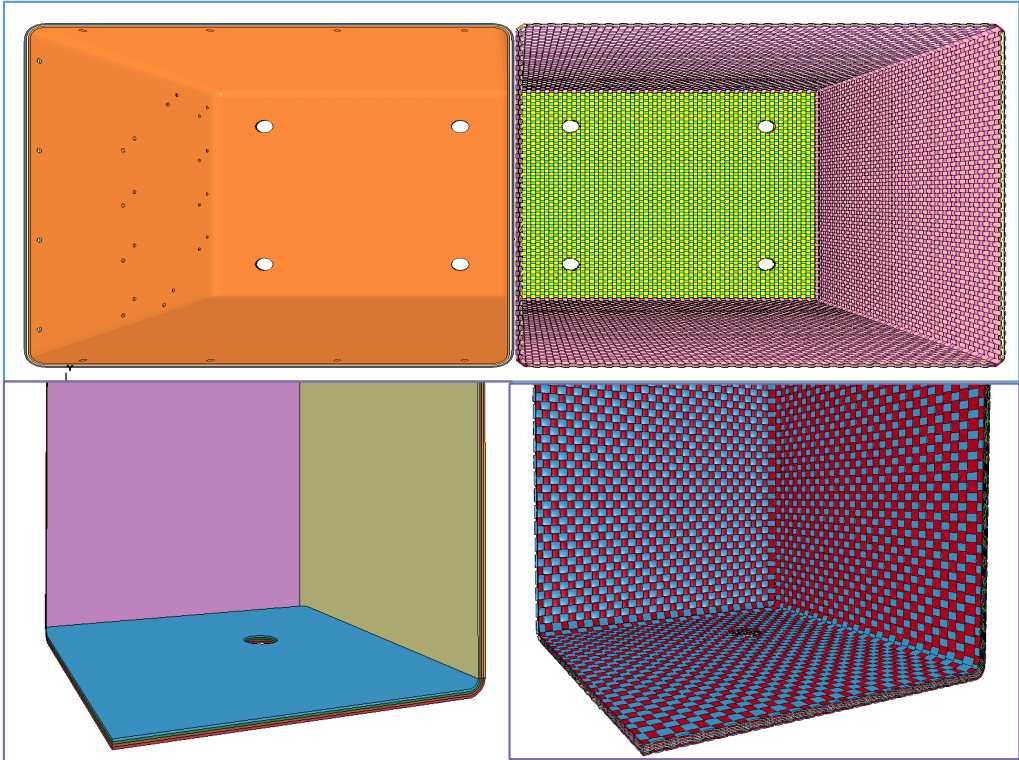


- Energy absorbed by the structure is less than 1/10<sup>th</sup> of the initial stored C4 energy
- Rest of the energy is dissipated in air



# EXPLOSIVE REACTIVE ARMOR ENCLOSURE SIMULATION

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- ❑ S2/Glass composite enclosures is modeled with two approaches
  - ✓ As a composite material
  - ✓ As a woven layered fabric with epoxy





- **GVSC Survivability has conducted blast tests for four different enclosure design utilizing different materials**
  - ✓ *304 stainless steel, Al 6061-T6, Ti6Al4v and S2/Glass-epoxy composite for explosive reactive armor*
- **M&S models were developed to simulate the enclosure boxes and compared to the test results**
- **S2/Glass-epoxy model is still in development phase**
- **M&S capability will help to evaluate alternate enclosure materials and identify light weight material solution quickly with minimal cost and saves significant development time**
- **Develop an end-to-end model for ERA so that integration of new ERA tile designs can be evaluated quickly**

