
U.S. Army Research, Development and Engineering Command

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

# 2009 Tactical Wheeled Vehicles Conference

## "Beyond 2025 – Insights and Possibilities for Future Technology Applications"

*John M. Miller, Director*
*U.S. Army Research Laboratory*

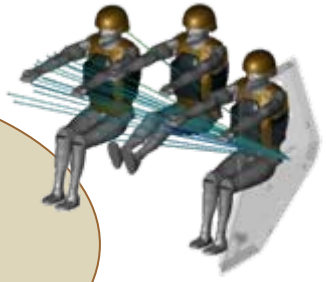
UNCLASSIFIED

# Elements of Integrated Protection Design

Vertical Impulse Experimental Facility

Experimentation

Survivability Analysis

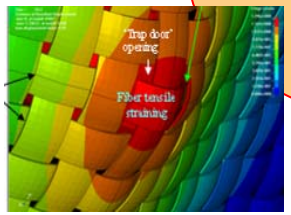


High-Fidelity Analysis with Physical Realism

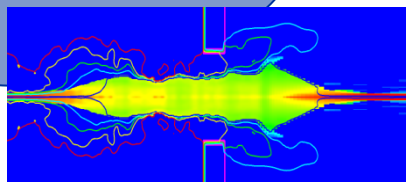
HPC

Materials

Mechanisms




Dynamic Load on Composite Weave



Simulation of Current through Copper Wire Between Charged Plates

Manufacturing

Hot Press for Ceramics Processing

# Tactical Truck Armor Evolution
## — ARL Contributions to Armor Kits —

### Expedient Armor Solutions (2003-2006)

M1114 Add-on Armor Kit

M1114/M1151 Interim Fragment Kit 5

**ARL Working in Concert with TACOM and TARDEC Delivered Critical Technology for Improved Armor Designs to the Program Manager Tactical Vehicles**

### OEM Integrated Armor Kits (2006-2008)

M1151with Fragment Kit 5

FMTV A1R LSAC

### OEM Designed Removable Armor Kits (2009)

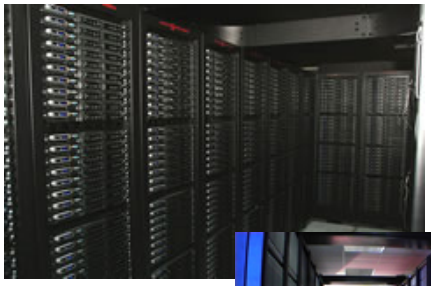
ECV2 with Fragment Kit 5

FMTV A1P2

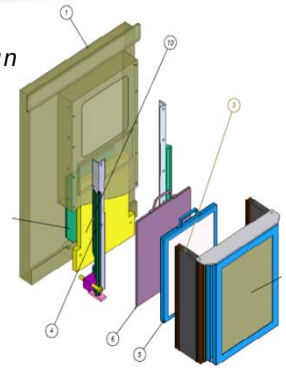
HEMTT A4

M915A5

# State-of-the-Art Computing and Experimentation for Rapid Development

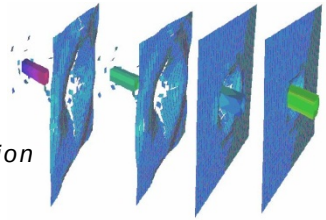



Design

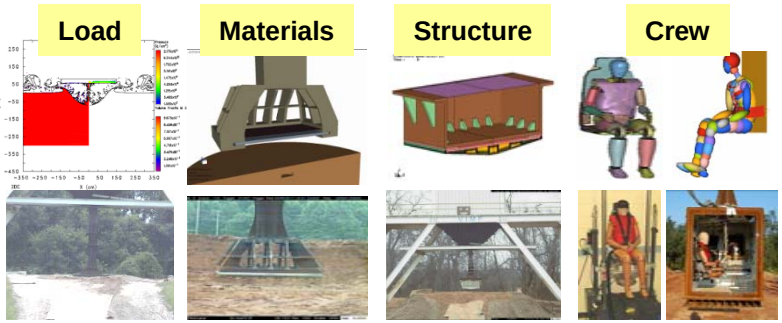


Experimental Facility

Prediction



Vertical Impulse Measurement Facility

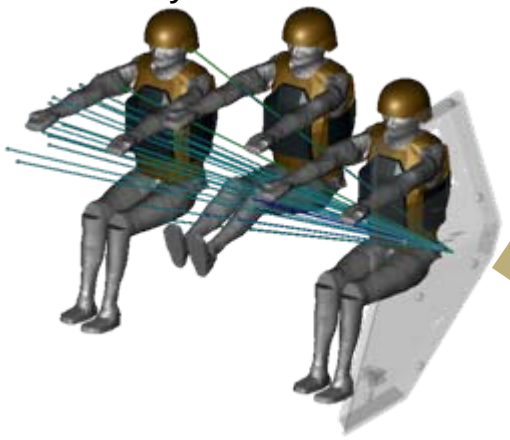



Underbody Kits for Current OPS Needs

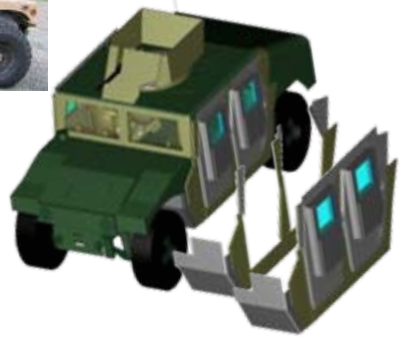
Frag Kit 6 Fielded in Theater in under 4 months

## Ballistic analysis of TWV from a soldier-centric perspective to minimize casualties

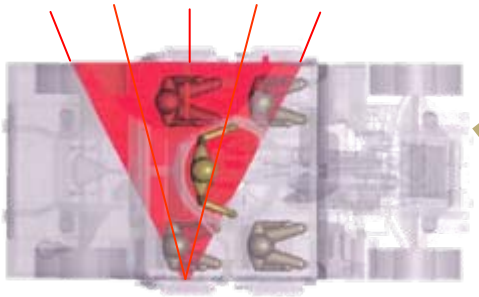
High-Fidelity Analysis with Physical Realism

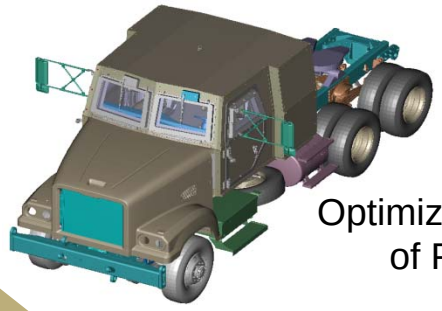


Protection Validation



Parametric Investigations





Optimized Integration of Protection

## Development Driven by Need for Lightweight, Multifunctional, Damage Tolerant, Producible Materials

### TODAY

#### Ceramics

SiC-X
$B_4C$-X

#### Metals

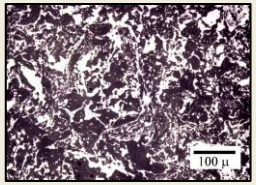
Steel - RHA, HHA
Titanium
Al – 5083,2519

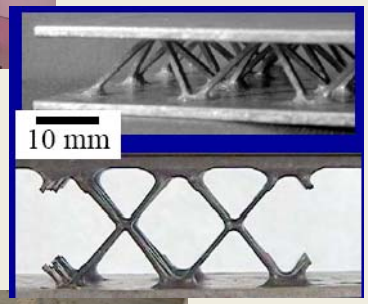
#### Composites

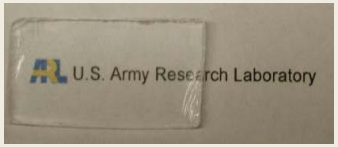
S2 Glass epoxies
S2 phenolics
Kevlar epoxies
Kevlar phenolics
UHMWPE

#### Transparents

Glass-Polymer
Interlayers
Polymers




### TOMORROW

#### Ceramics

SiC-XY
$TiB_2$-X
$B_4C$-XY
Nano-B4C
Alumina-Spinel

#### Metals

Steel - UHHA
Ti – Low cost processing
Al – 5059, 2139
Nano-Al MMC (Trimodal alloy)
Mg
Engineered Structures

#### Composites

Thermoplastics
Hybridized structures
Integrated coms and power

#### Transparents

Glass-Ceramic
Spinel
AlON
Sapphire

# Materials by Design for the Future



***Today:***

***Independent models with gaps between length and time scales***

***Future:***

***Seamless materials modeling across length and time scales enabling turn-key materials design***

***Design tools that encompass advanced mechanism based simulations***

***Pay-off:***

***Faster insertion, lower costs***

**Systems**

$10^{0}$-10m

**Finite Element Methods**

**Material Assemblies**

$10^{-2}$m

**Micromechanics**

**Continuum**

$10^{-4}$m

**Meso-scale**

**Micro-scale**

$10^{-6}$m

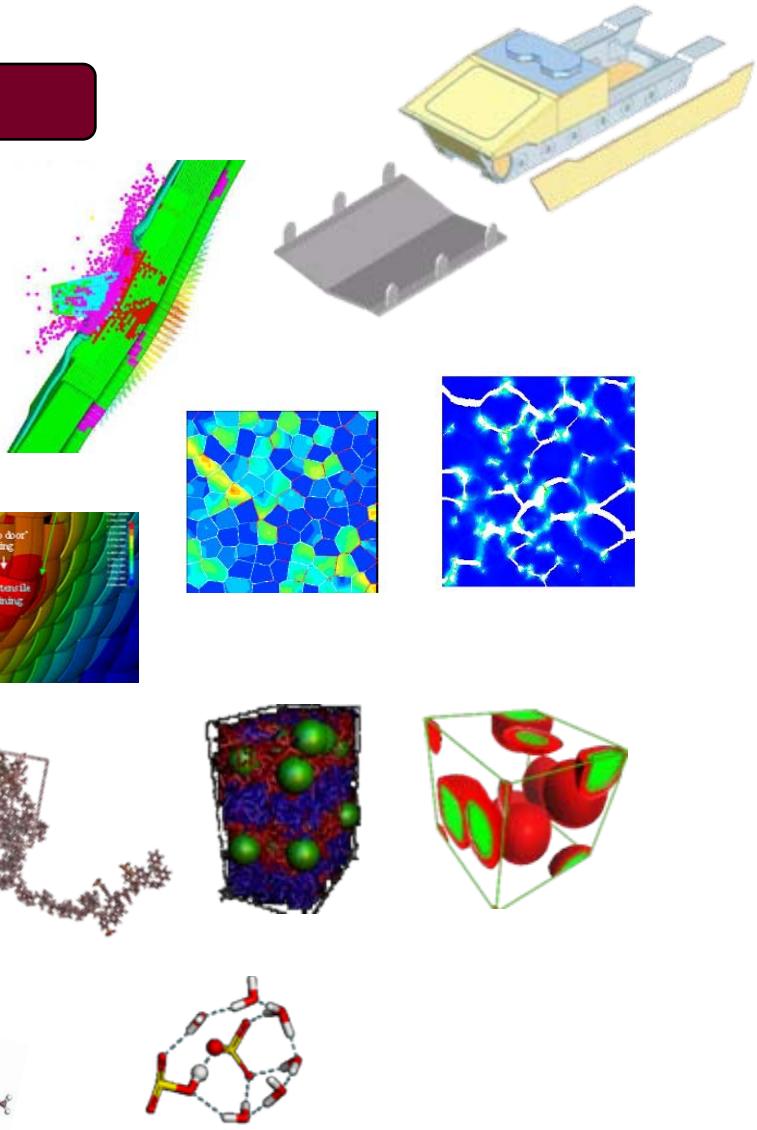
**Molecular Dynamics**

**Collections of Molecules**

**Quantum Mechanics**

$10^{-9}$m

**Atoms / Molecules**

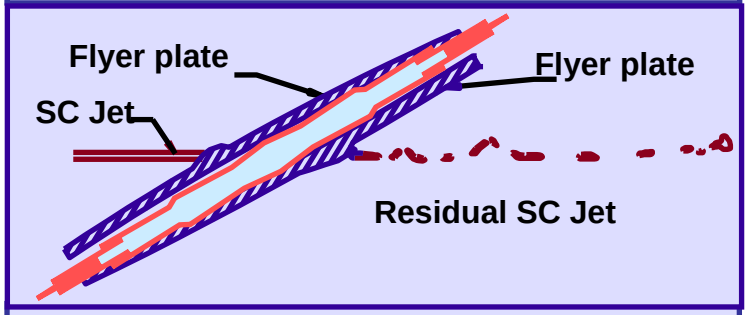


# Novel Mechanisms – The Enablers of Tomorrow



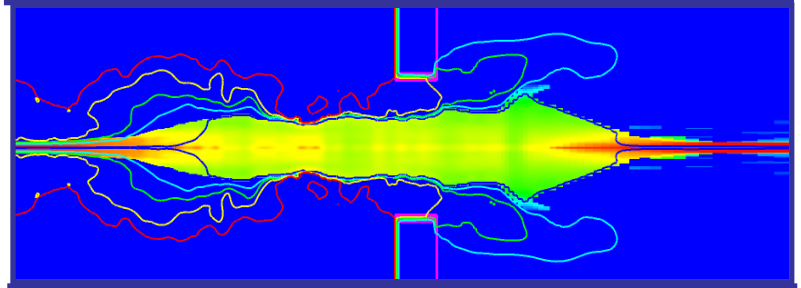
**Non Energetic Reactive Armor (NERA)**
**Non Explosive Reactive Armor (NxRA)**
**Self Limiting Explosive Reactive Armor (SLE)**
**Explosive Reactive Armor (ERA)**
**Advanced Armor**
**Electromagnetic Armor (EM)**
**Active Armor**

**Explosive-driven reactive mechanisms**

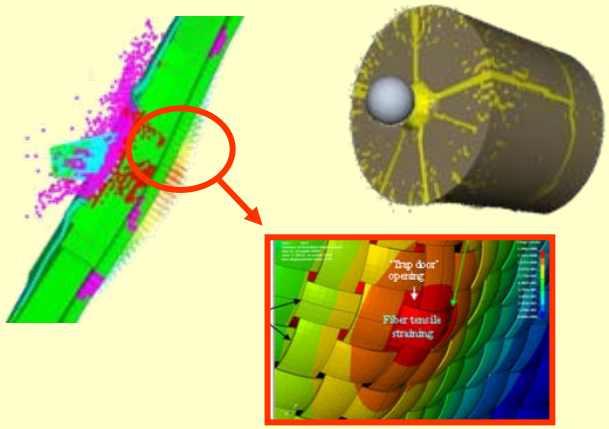



**Advanced detonation physics**

**Novel uses for pulsed power**

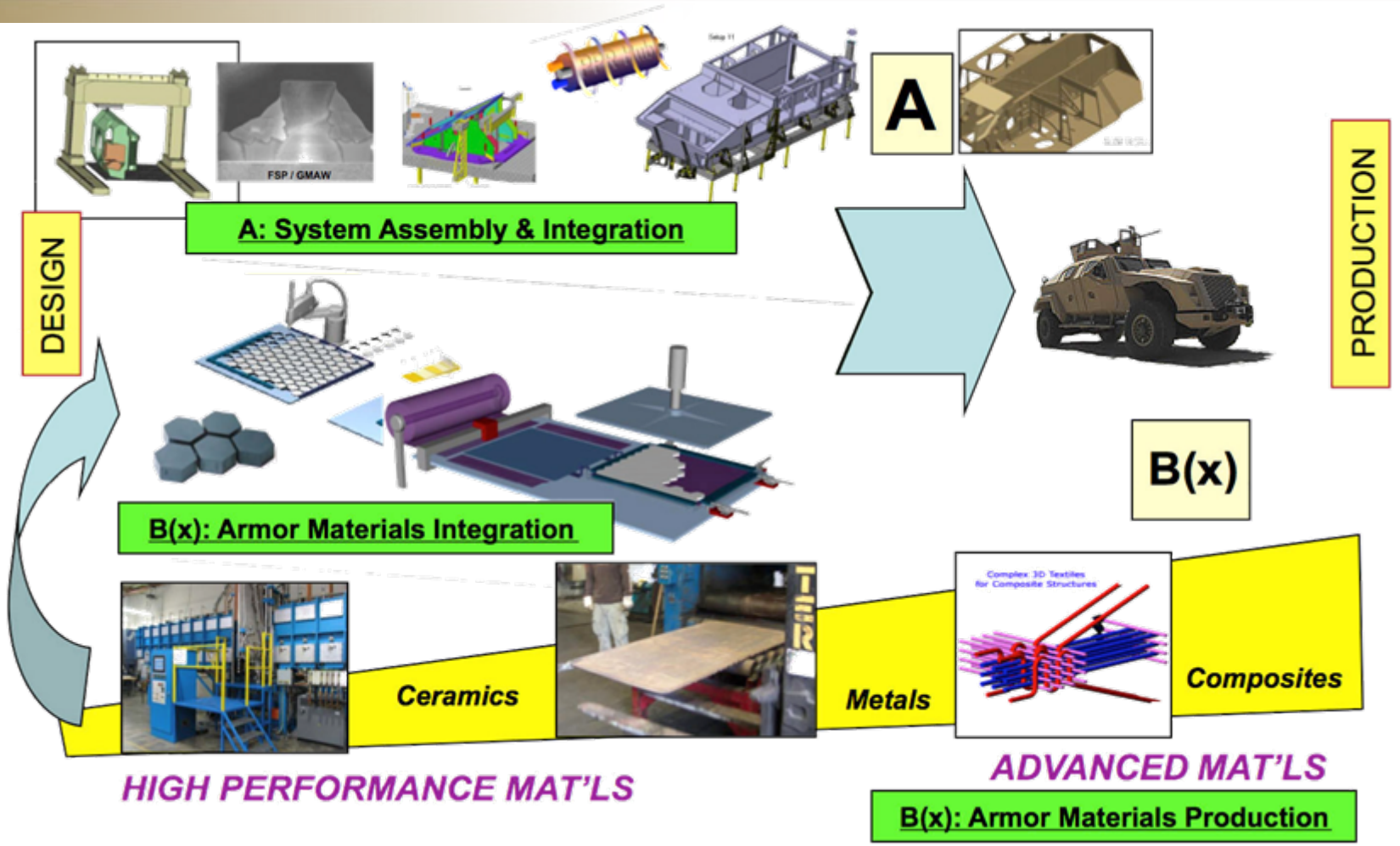


**Conductive wire passing between two charged plates with holes (plot of current streamlines and material densities)**




**Exploitation of complex material behaviors via HPC resources**

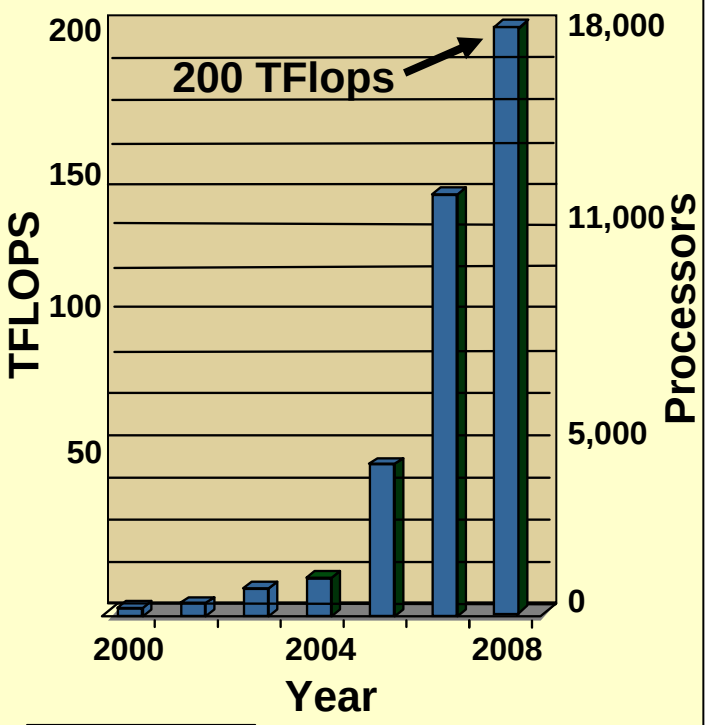
*Future Armor Solutions will utilize Novel Complex Defeat Mechanisms*




*Armor and Armor Materials Research are Directly linked with ManTech Efforts to Ensure Rapid Transition of Technology to Production and Fielding*

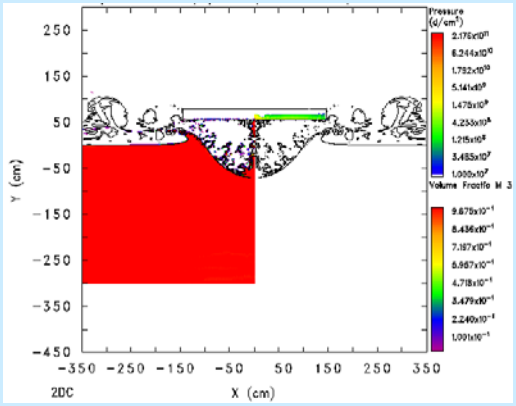
# Independent, high-resolution analyses optimize TWV designs today.

## ARL MSRC Growth in Teraflops

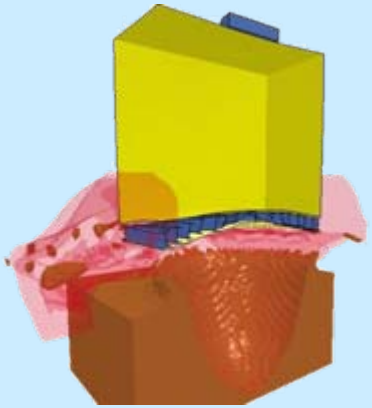



## Mine Blast Analyses

**Circa 2004:**
O($10^4$) cells / elements
2D symmetric
Simplified geometry




**Today:**
O($10^6$) cells / elements
3D with shells / beams
Simplified vehicle geometry



# High Performance Computing Enables Multi-Discipline, Integrated Analyses



Compute Capacity Scale (FLOPS)

Exa

Peta

Tera

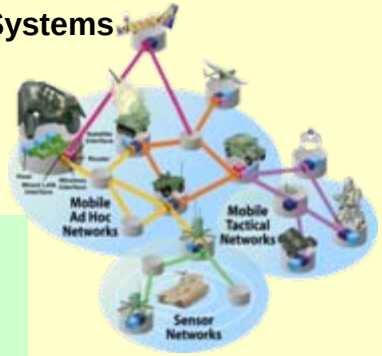
Giga

Mega

Year 1985 1995 2005 2015 2025

**Multi-Discipline, Integrated Models & Simulations to Optimize Vehicle Survivability**

**Modeling Battlefield Effects for Systems of Systems**



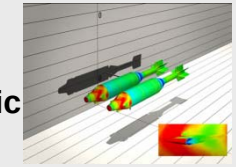

**Dynamic Hologram**

**Multi-Disciplinary Analysis and Optimization**

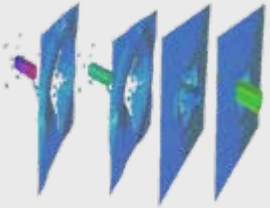
**Battlefield Network Modeling & Optimization**

**Cognitive Response & Design**

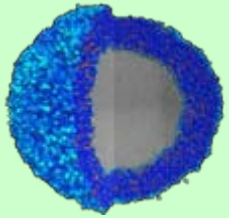
***Digital*** **Virtual Aerodynamic Range**



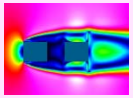
**Advanced Armors**



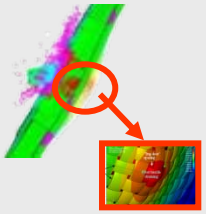
**New Materials**



**Multi-Component Projectiles/Missiles**

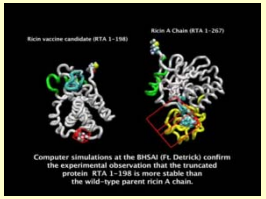


**Complex Material Behaviors**

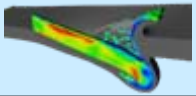


**Micro-Autonomous Systems**

**Vaccines**

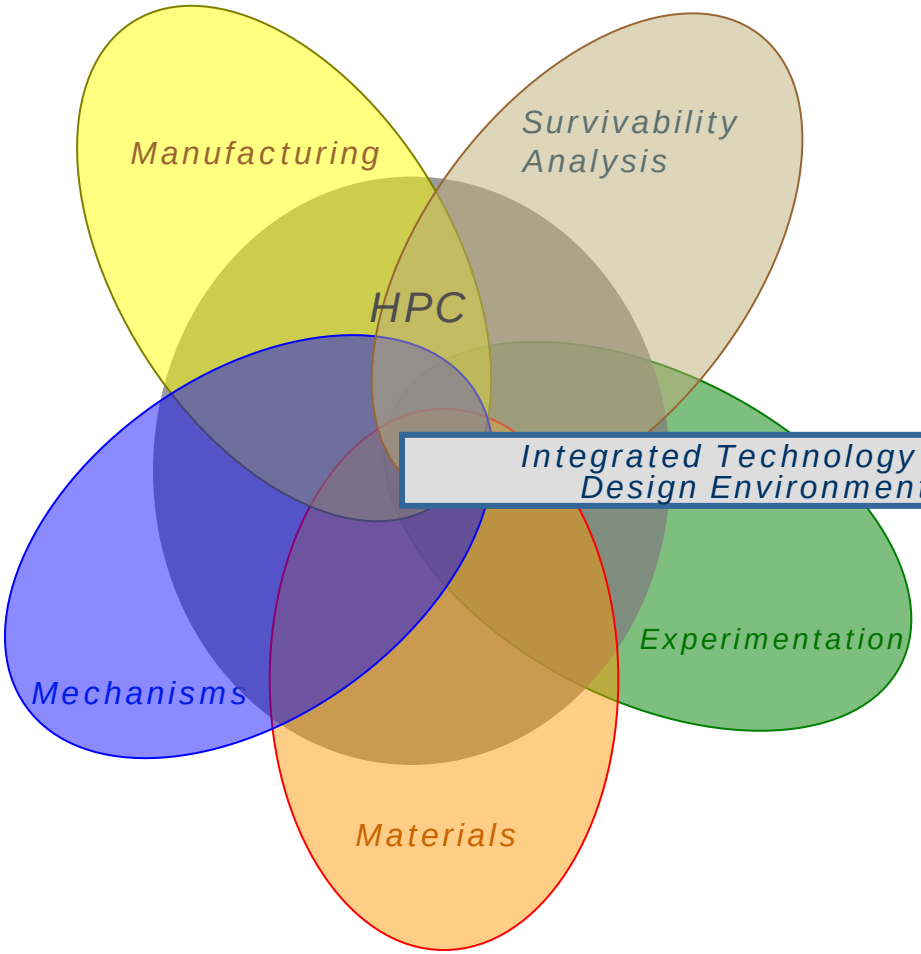



**3D Armor Penetration**

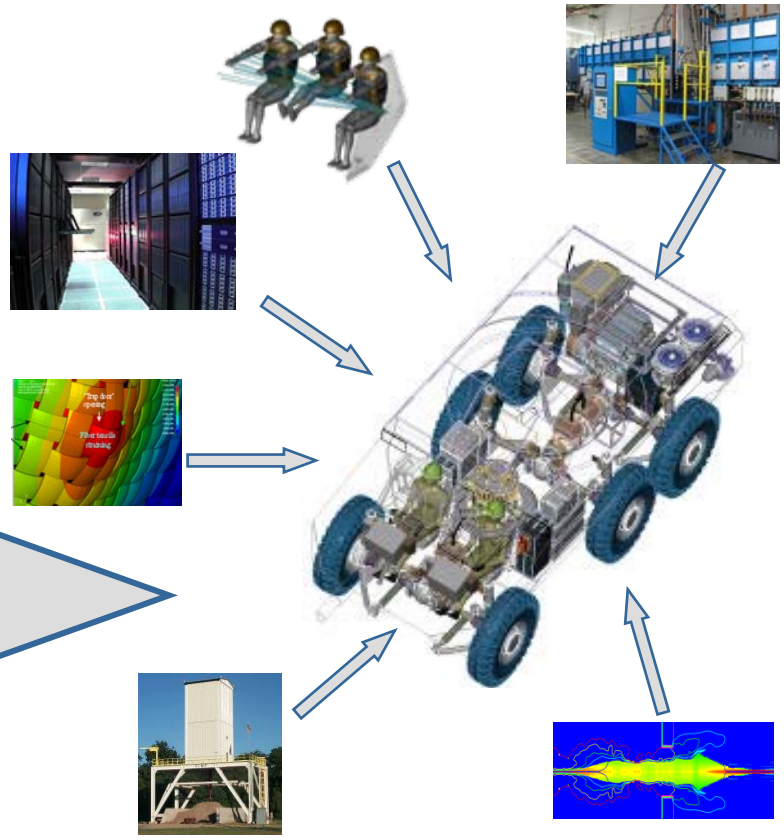


**Proof-of-Concepts**

# The Future of Integrated Protection Design




Integrated Technology and Design Environment



Optimized
Ultra-Light Weight
Survivable
TWV