

# **Protecting Future Platforms: Modernization, Innovation, and Implementation**

Robert W Schumitz

April 2019



The INL is a U.S. Department of Energy National Laboratory  
operated by Battelle Energy Alliance

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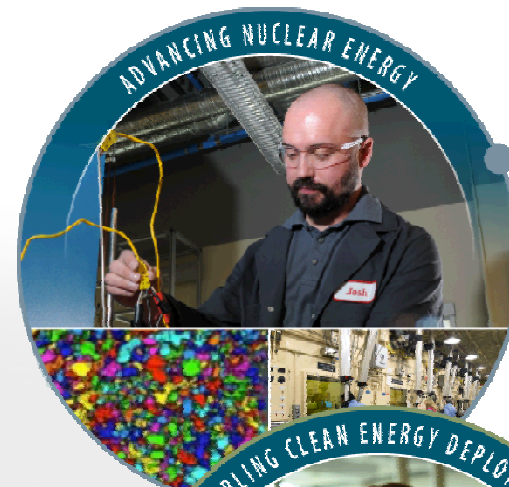
**Idaho National Laboratory  
Idaho Falls, Idaho 83415**

**<http://www.inl.gov>**

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# Protecting Future Platforms: Modernization, Innovation, and Implementation

**Robert Schumitz**  
Director, Defense Systems



**2019**

**Future Ground Combat Vehicles**

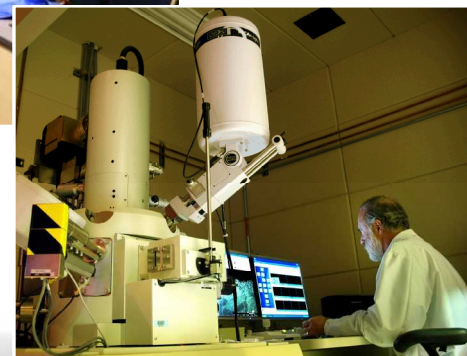
**April 29, 2019**

[www.inl.gov](http://www.inl.gov)



## ***INL's Position – Nationally***

- **A network of 17 DOE national labs**
- **The Nation's lead lab for Nuclear Energy research and development**
- **A major center for National Security and Clean Energy**



National Labs are “Capability Machines” that rely on unique capabilities

They innovate to solve multi-disciplinary problems of national interest

They do what Universities and Industry Can't, Won't or Shouldn't do



Research in the National Interest that  
**Maintains U.S. Competitiveness & Security**



# INL is Positioned to Address the World's Most Challenging Problems in:

## ADVANCING NUCLEAR ENERGY

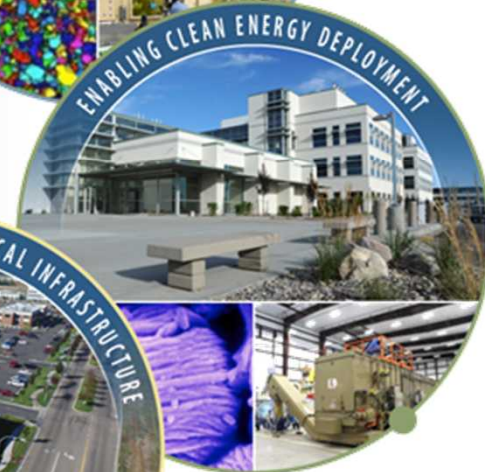
- Ensuring long-term reliability of light water reactors
- ***Peaceful and secure use of nuclear technology***
- Rapid translation of innovation to the nuclear industry
- Enabling deployment of nuclear systems in the modern energy context

## ENABLING CLEAN ENERGY DEVELOPMENT

- Developing, demonstrating, and facilitating clean energy system transitions
- Accelerated deployment of next generation transportation systems
- Advanced sustainable and efficient manufacturing for U.S. competitiveness

## SECURING & MODERNIZING CRITICAL INFRASTRUCTURE

- ***Critical infrastructure protection at the nexus of power, controls, cyber, and wireless***
- ***Delivering innovative products that enable defense, intelligence, and public safety***
- Advancing environmental security and sustainability

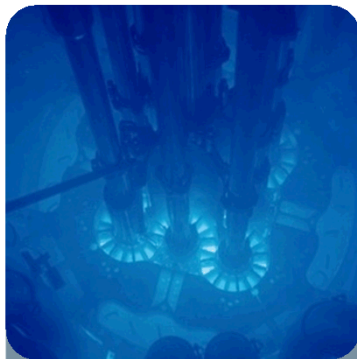


# *INL's Directorates are Organized to Align Capabilities to R&D, Demonstration, and Deployment*



## **Nuclear S&T**

- Advanced reactor design and optimization
- Nuclear fuels and materials
- Fuel cycle technologies
- Light water reactor fleet sustainability



## **Advanced Test Reactor**

- Steady state neutron irradiation of materials and fuels
  - Naval Nuclear Propulsion Program
  - Industry
  - National laboratories and universities



## **Materials & Fuels Complex**

- TREAT – Transient pulse testing
- Analytical laboratories
- Post-irradiation examination
- Advanced characterization
- Fuel fabrication
- Space nuclear power, isotope technologies



## **Energy & Environment S&T**

- Advanced transportation
- Environmental sustainability
- Clean energy
- Advanced manufacturing
- Biomass



## **National & Homeland Security S&T**

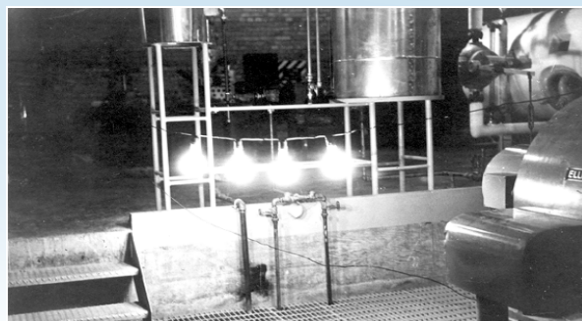
- Critical infrastructure protection and resiliency
- Nuclear nonproliferation
- Physical defense systems



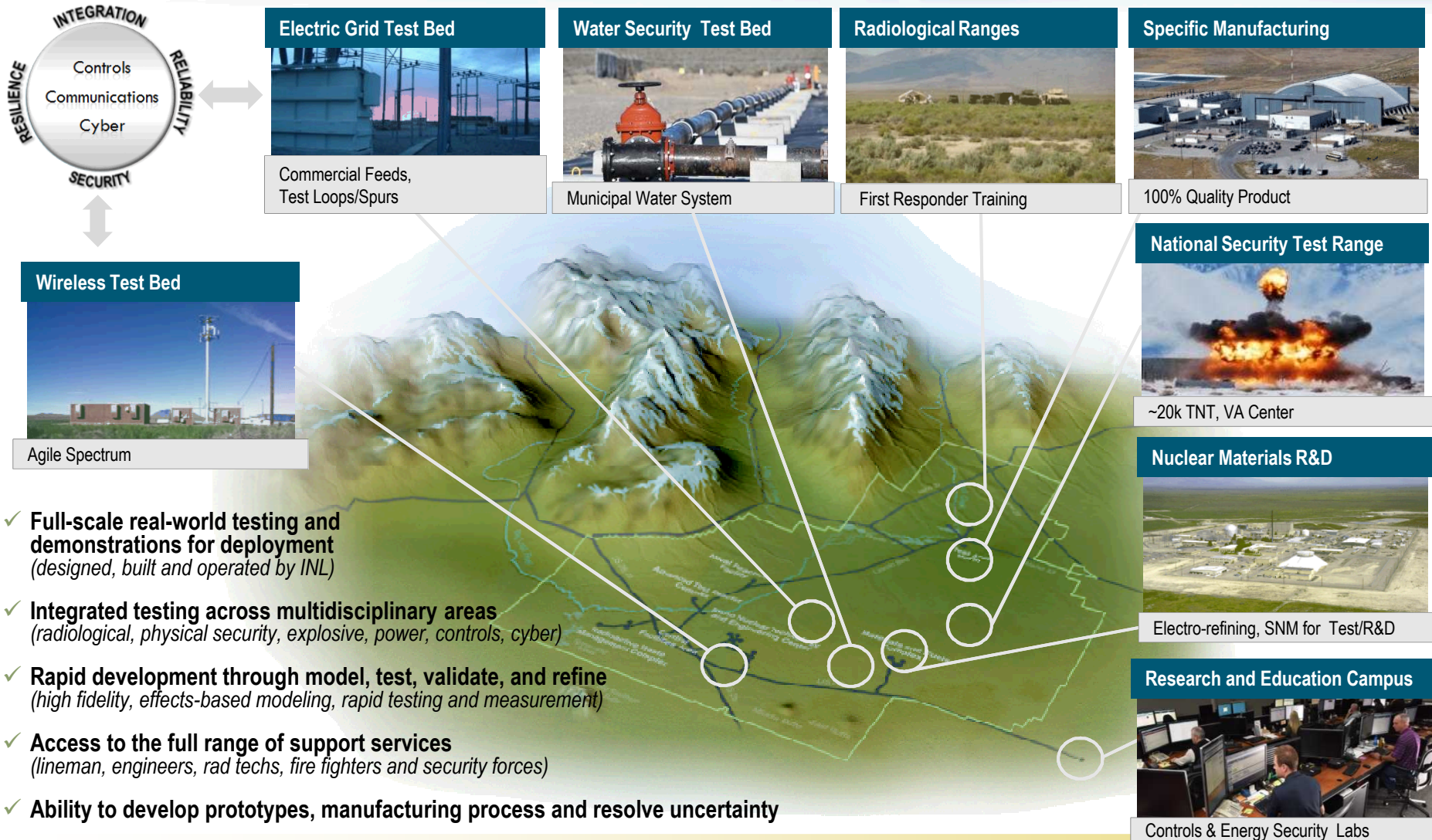
## ***INL – The History of Supporting National Security***

- Testing naval large caliber guns
- National Reactor Testing Station 1949, INEL 1974, INEEL 1994, INL 2005
- Fuel cycle development and demonstration – reprocessing
- Design construction testing and operation of 52 unique nuclear reactors, including Navy's Nautilus Submarine Prototype (S1W) Reactor
- Specific Manufacturing Capability (SMC) 1982

Research – Development – **Demonstration** – Deployment



# Unique National Security Infrastructure and Capabilities





# INL's Advanced Design & Manufacturing (ADM) Initiative



**Increase performance and economic competitiveness** of materials for harsh environments and advanced energy production systems

**Advance secure design and manufacturing processes** for energy generation, energy management, space and defense systems

Enable discoveries and advances in harsh environment materials, instrumentation and energy technologies of tomorrow by improving upon state-of-the-art processes through adaptation, analysis, development and integration of new or novel techniques.



Process Discovery

Refinement &  
Intensification

Deployment

*Improve U.S. leadership in Science,  
Engineering and increase U.S. Industry  
Competitiveness*



## ADM Research Areas & Pillars

### Advanced Design & Manufacturing

Focus on advancing secure design and manufacturing processes for materials & components in harsh environments

Nuclear  
Energy

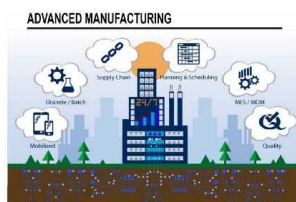
Energy  
Management

Space &  
Defense  
Systems

Process  
Discovery &  
Development

Secure Digital  
Design &  
Manufacturing

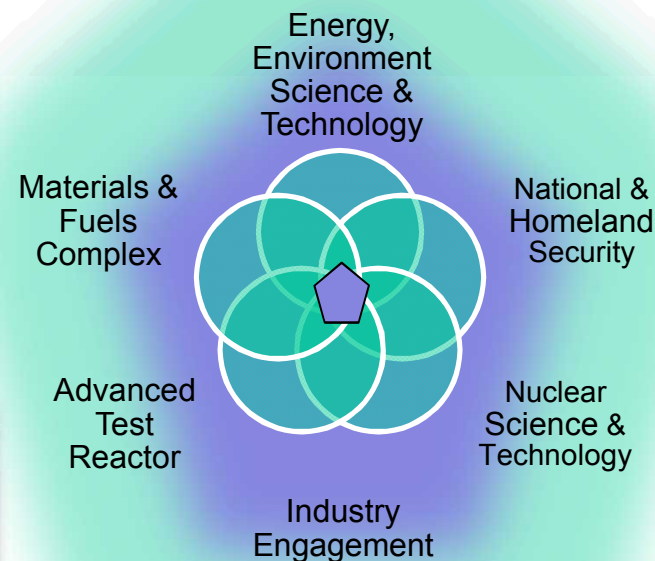
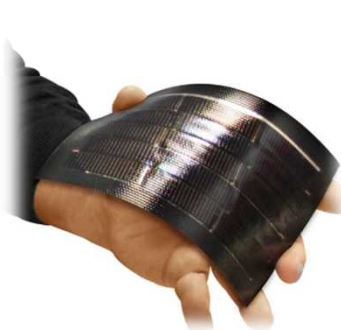
Intensification &  
Scale-up





## ADM Motivation

- The future energy value chain will rely on the use of high efficiency, high performance, multi-functional and intelligent materials.
- These new materials either need to be created and/or production processes need to be scaled and/or intensified.
- Many of these materials will operate in extreme and harsh environments.
- INL Advanced Design & Manufacturing methods and process R&D will enable and accelerate the nation's access to these vital materials.



# Mission: Materials for National Defense

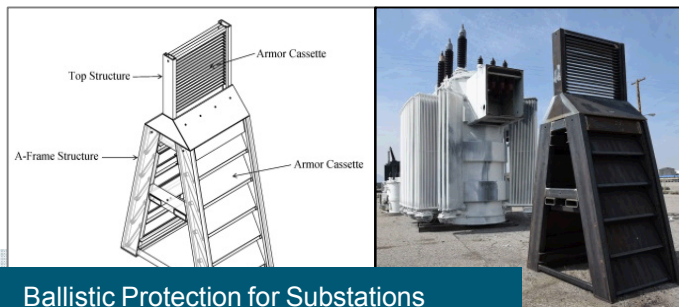
## Ensure U.S. technical superiority in materials science and armor-related defense systems

- ✓ Designated U.S. Army Abrams Armor Center of Excellence
- ✓ Advanced modeling and simulation
- ✓ Large scale explosives and ballistics test range
- ✓ Materials science and energetics
- ✓ Nationally recognized vulnerability studies



SMC

Energetics Testing



Ballistic Protection for Substations



Henry Chu



NSTR

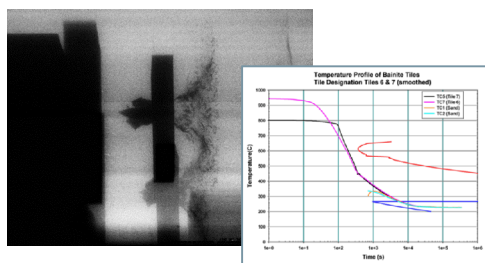
# Initiatives and R&D Focus Areas for Defense Solutions

Initiatives

## SMC



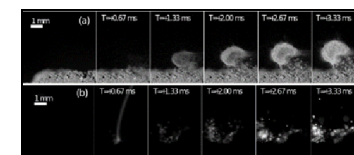
## New Light-weighting Armor Solutions



## National Security Test Range



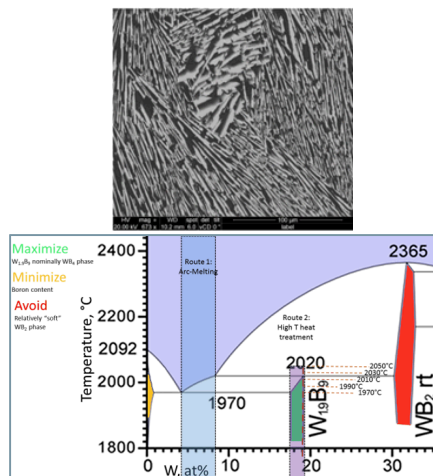
## Collaborative Environment Tool and Energetics Applications



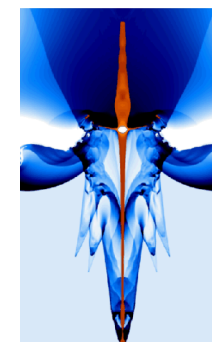
Critical R&D



## Survivability Enhancements to Abrams Survivability Suite



## Material-by-Design via First Principal For Extreme Environments



## Impact Physics, Material System Performance and Terminal Ballistics Computation and Modeling



## ***Lethality Solutions***



## ***Representative 30 - 57 mm Armor-Piercing Kinetic Energy Projectiles***

### **30 x 165 mm (Russian)**

- 2A42 AP-T BT with 400g steel core, muzzle velocity:960 m/s.
- 2A42 APDS-T BP with 304g tungsten projectile, muzzle velocity:1120 m/s

### **30 x 170 mm**

- L14A3 with 300g tungsten core, muzzle velocity:1170m/s

### **35 x 228 / 50 x 330 mm (Rh 503 cannon, 35/50 Bushmaster III)**

- APFSDS with 388/640g projectile, muzzle velocity:1417/1600 m/s

### **37 x 252SR (Russian)**

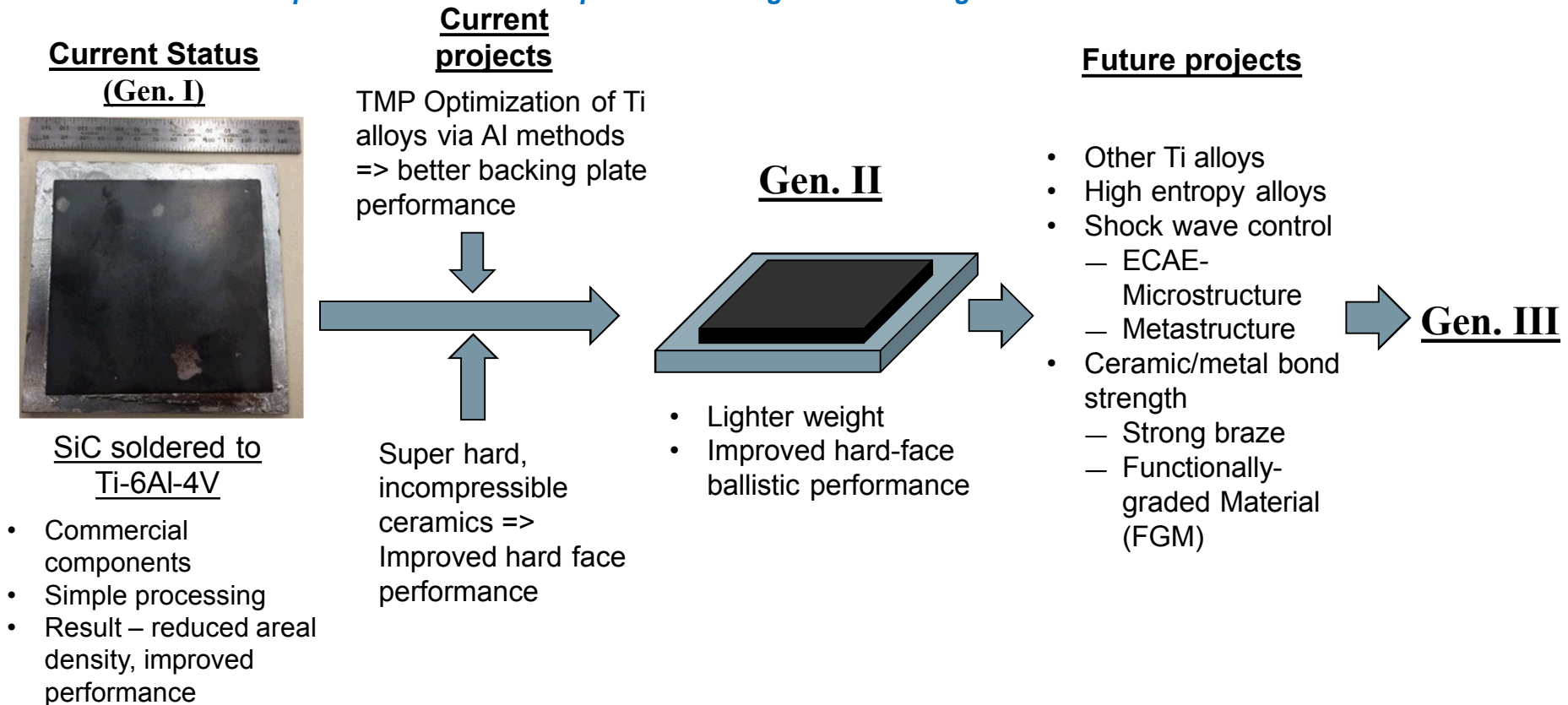
- BR-167 (steel)/BR-167P(WC) AP-T with 760/610g, muzzle velocity:850/955 m/s. Penetration (@zero obliquity): 56/97mm.

*Source of information:*

1. *Jane's Ammunition Handbook*
2. *Soviet Cannon – A Comprehensive Study of Soviet Guns and Ammunition in Calibres 12.7 mm to 57 mm.*

# Integrated R&D Approach for Advanced Armor System Development

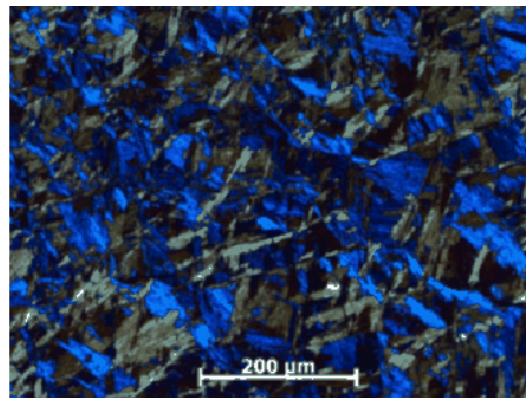
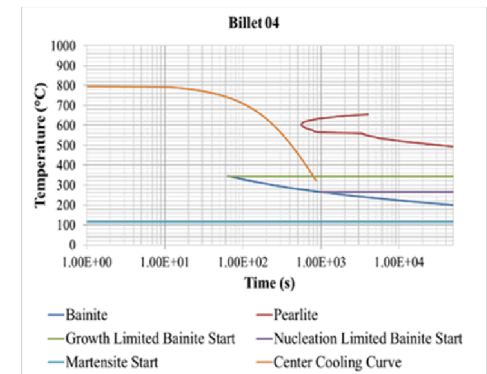
*Projects in the past, present and future portfolio systematically address various armor material and system design issues to allow continuous improvement of ballistic performance against elevating threats.*





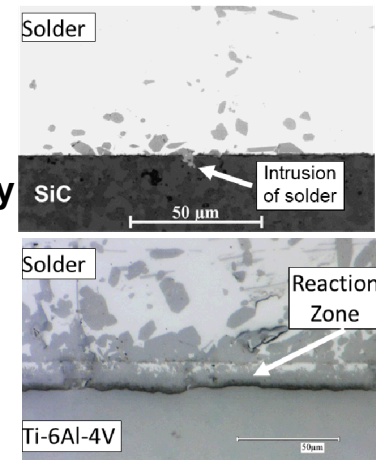
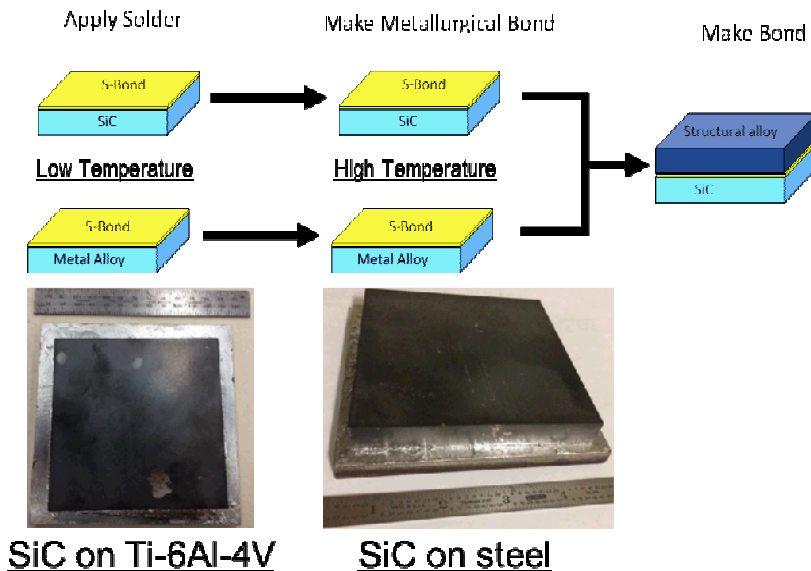
# Next Generation Armor Steel (NGAS)/bainitic armor steel LDRD

- Successfully develop a novel air-cooled/quenched process to manufacture uniformly-hard (RC 50-54) and strong bainite-based steel with thick (2.5") section suitable for medium to heavy armor application



# High-Performance Survivability Solution Via Metallurgical-bonded Ceramic to Metal Structure

- Developed process to solder/braze ceramic tiles to titanium and steel alloys.
- Strong metallurgical bond offers efficient impact load transfer via higher shear strength, and stiffer structure overall and lateral confinement that increase erosion dwell time.
- Demonstrated significant reduction in areal density (weight) against high-lethality threats.

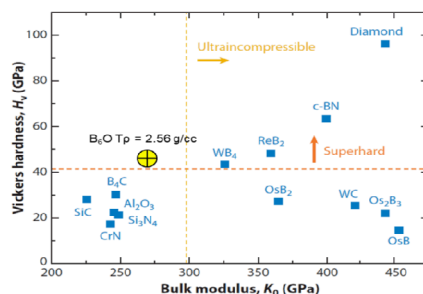


**SiC soldered to Ti-6Al-4V**

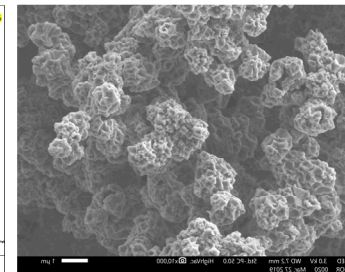
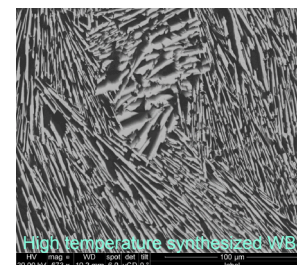
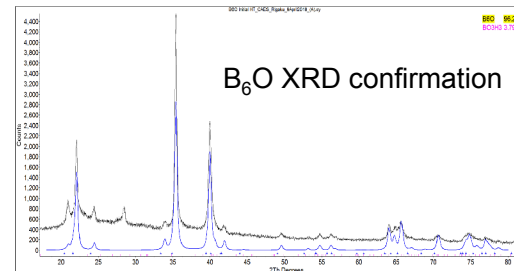
# Synthesis and Spark Plasma Sintering of Super-hard and Ultra-incompressible Ceramics

## Focus Materials

1. Boron suboxide ( $B_6O$ ,  $B_{12}O_2$ ):
  - Density  $\sim 2.56$  g/cc
  - Bulk Modulus  $\sim 270 \pm 12$  GPa
  - Hardness  $\sim 45$  GPa Hv
2. Tungsten Tetraboride ( $WB_4$ )
  - Density  $\sim 8-9$  g/cc
  - Bulk Modulus  $\sim 325$  GPa
  - Hardness  $\sim 41$  GPa Hv

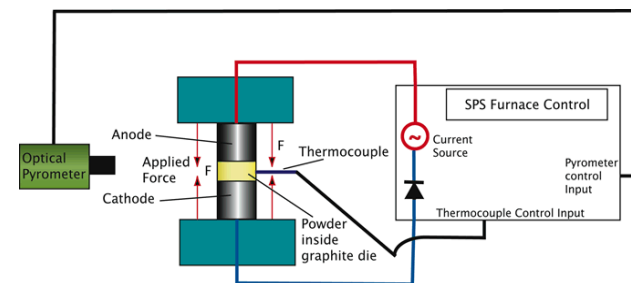


Graph adapted from Kaner et al, *Ultra-incompressible, Superhard Materials*, Annu. Rev. Mater. Res. 2016 46:465-85



## Powder synthesis and spark plasma sintering (SPS) fabrication methods

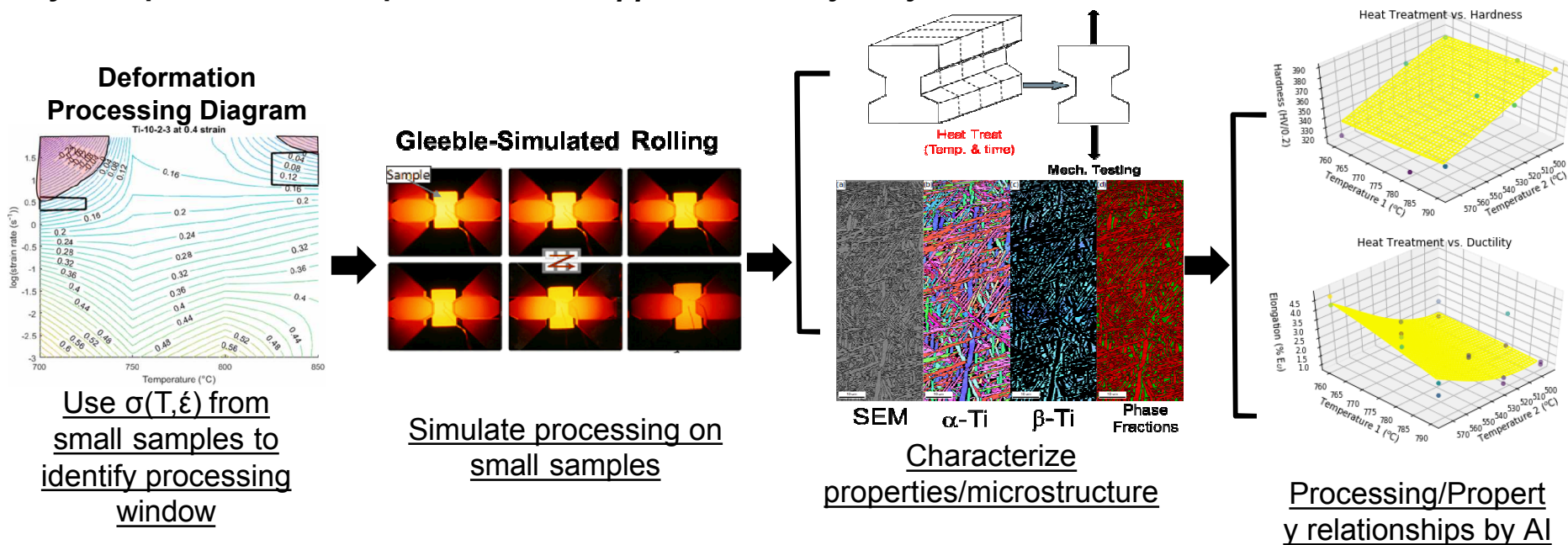
- Powder synthesis via high temperature synthesis ( $WB_4$ ) and chemical reaction ( $B_6O$ )
- Bulk consolidation via Field Assisted Sintering Technology (FAST)/ Spark Plasma Sintering (SPS) methods
- SPS parameters & schedule assisted by real-time synchrotron X-ray imaging of in-situ consolidation process and multi-physics-based M&S





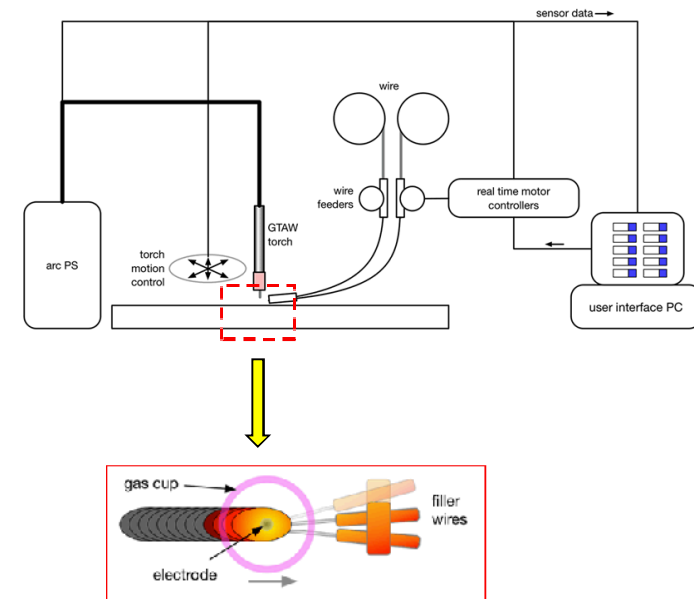
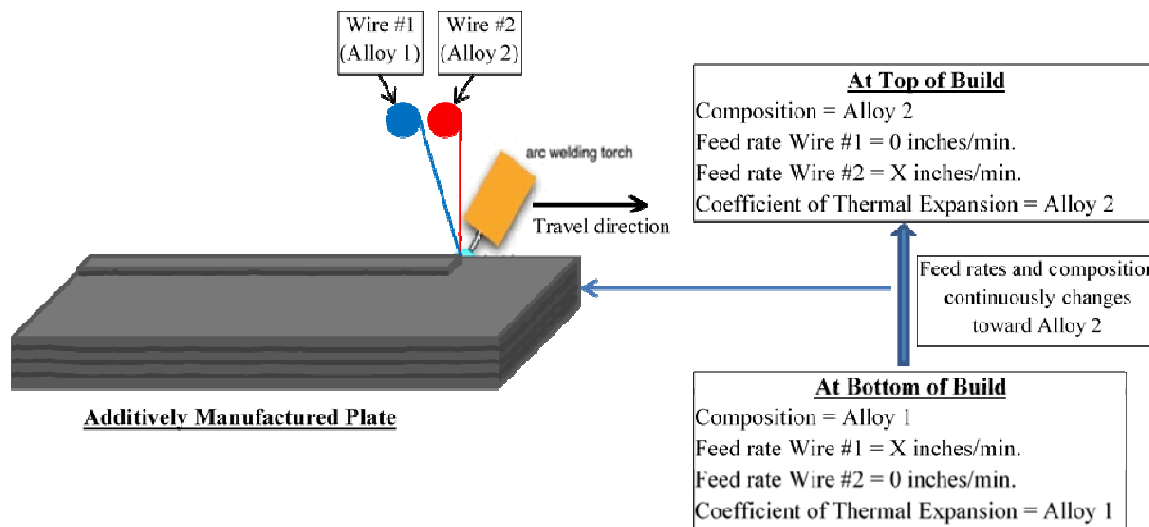
# Process Optimization of Ti Alloys for Armor Applications

- Commercial and emerging Ti alloys need process optimization specifically for armor applications.
- Need to understand and predict the influence of thermomechanical processing parameters on microstructure and ballistic performance
- Develop AI methods as a cost-effective, science-based approach to rapidly identify TMP parameters to yield optimum ballistic performance – *applicable to any alloy*



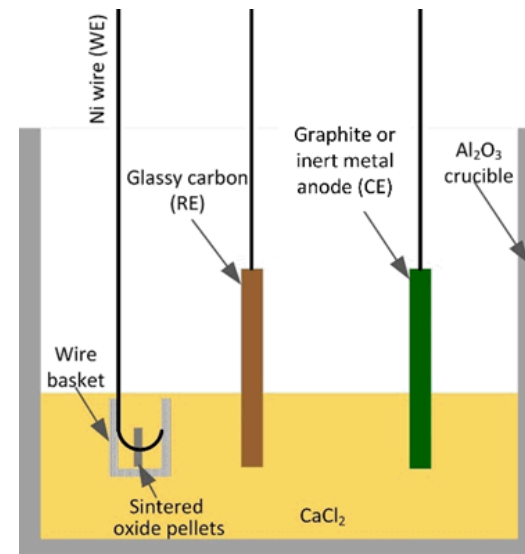
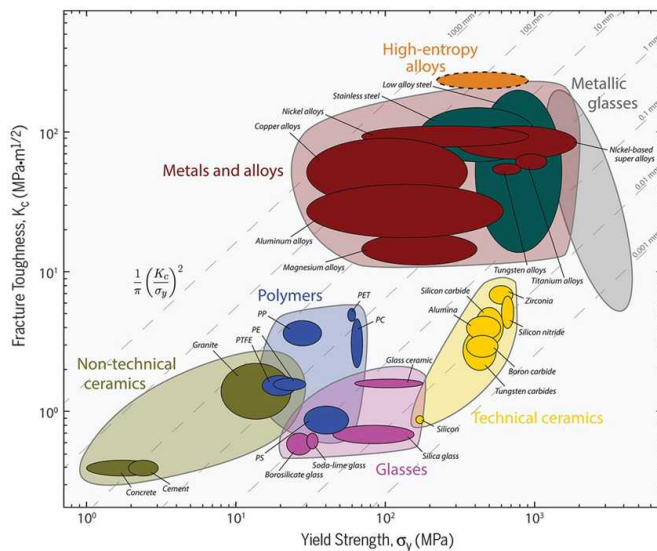
# New Advanced Material and Process Technology R&D Planned

- Development of an advanced multi-wire arc additive manufacturing (m-WAAM) process to fabricate functionally-graded (FG) alloys. For example, fabrication of armor system with graded hardness or as graded interface for joining highly-mismatched (differences in thermal expansion and contraction) materials.



# New Advanced Material and Process Technology R&D Planned (continued)

- Design and process development of low-density, high-strength and high-toughness High Entropy Alloy (HEA).
- Novel electro-deoxidation (EDOX) process to produce ultra-clean non-segregated HEA starting powders.





# INL National & Homeland Security – RDD&D Capabilities



**Control Systems  
Cybersecurity**



**Electric Grid  
Resilience**



**Wireless Communications  
& RF Modeling**



## Continual Focus on the Nation's Grand Challenges



**Nuclear Forensics/  
Ultratrace Detection**



**Nonproliferation/  
Safeguards**



**Emergency Training  
& Response**



**Armor  
Development**



**Materials &  
Energetics**

