



August 20, 2021

U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND

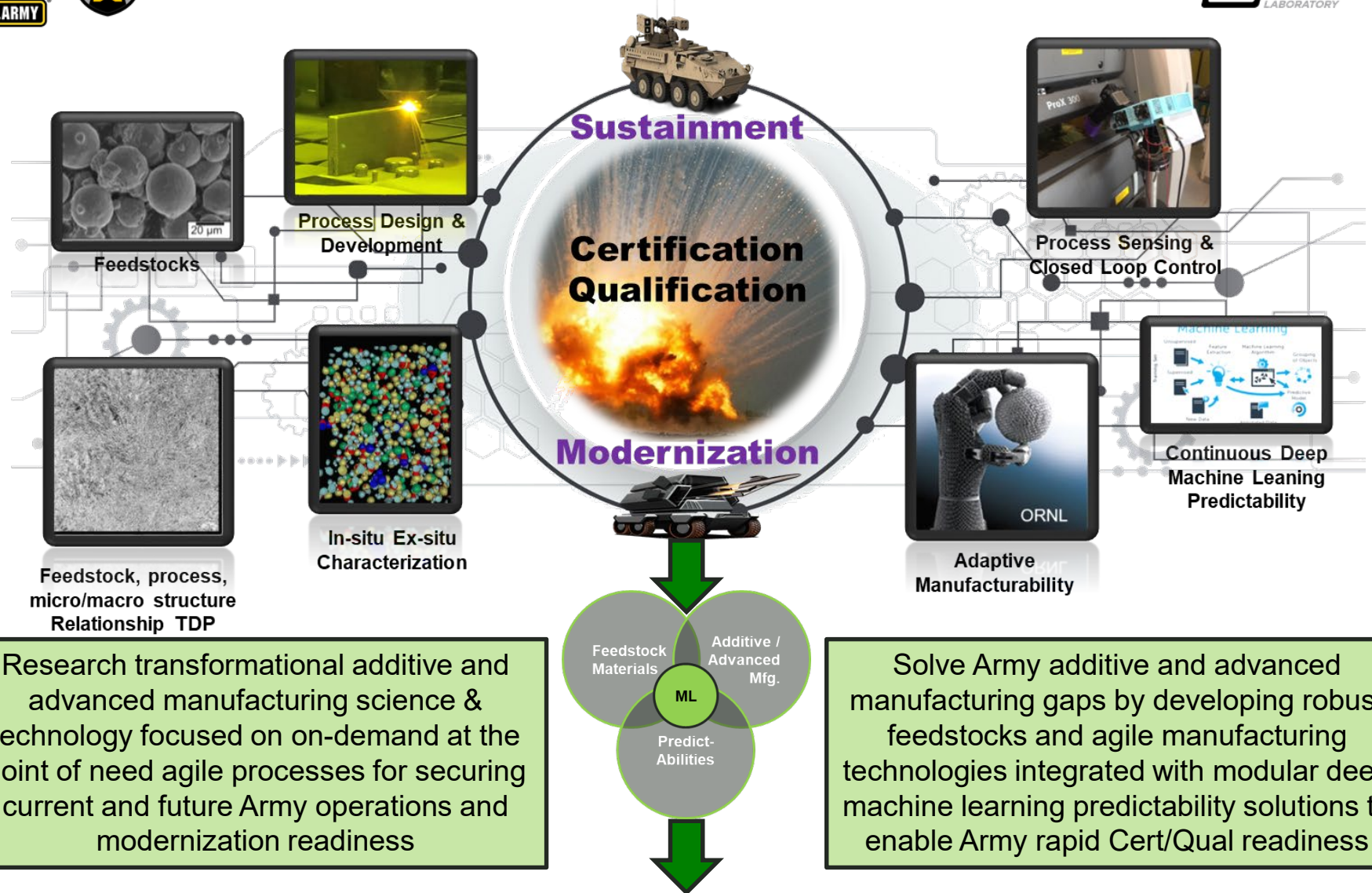
Science of Additive Manufacturing for Munitions (SAMM)

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ARL Additive Manufacturing S&T



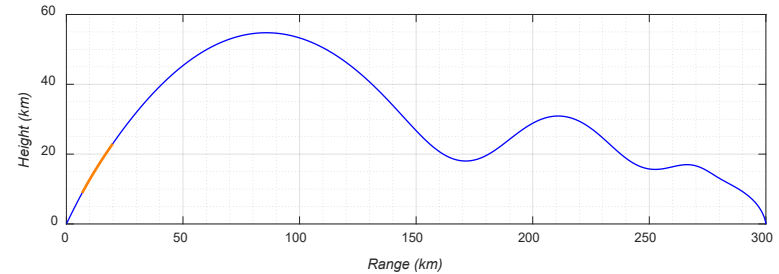
Enabling Agile On-Demand at the Point of Need Manufacturing Readiness



Long Range Precision Fires (LRPF)



Weapon/gun propulsion: M109 self-propelled howitzer test bed, 58-caliber Extended Range Cannon Artillery armament, XM654 propellant supercharge



Hybrid AM

High-G Electronics Integration for:

- *Fuzing*
- *Guidance, Navigation and Control (GNC)*
- *Communication*

Design Science

- *Integrated antenna design*
- *Efficient electronics package to volume*
- *Materials driven design for function and survivability*

Metals AM

- Printed Frag Plates
 - *Ultra-High strength steels*
 - *Custom alloys for high ductility*

Design Science

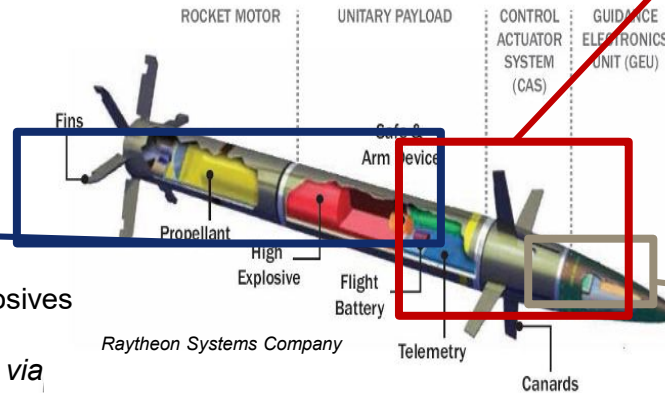
- Tailored mechanical properties

Energetics AM

- Novel printable propellants or explosives
 - *Higher energy density*
 - *Control performance profile via structure*

Design Science

- *Tailored geometries to optimize performance*
- *High G-survivable grain*



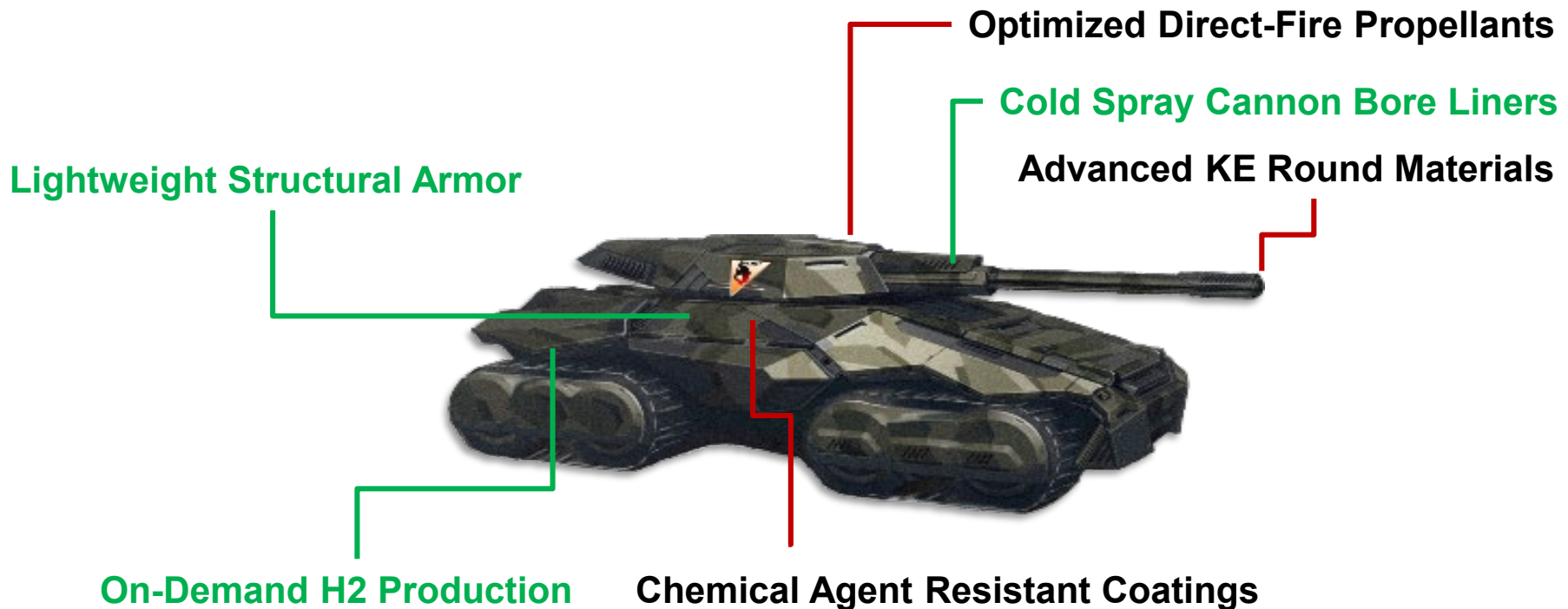
Raytheon Systems Company



NEXT GENERATION COMBAT VEHICLE (NGCV)



Develop combat vehicles that integrate other close combat capabilities in manned, unmanned, and optionally-manned teaming that leverages semi-autonomous and autonomous platforms in conjunction with the most modern firepower, protection, mobility, and power generation capabilities necessary to ensure that our future combat formations can fight and win against any foe, in any environment.





ARL ENERGETIC AM FOCUS AREAS



Goals of Energetics AM

- **Gun Propellant** – increased progressivity, muzzle velocity (novel porosity profiles)
- **Rocket Propellant** – tailored burn profile (graded prints)
- **Explosives** – multimaterial printing

Challenges

- **Formulation** – High energy formulation, high solids loading, energetic binders
- **Manufacturing** – Printing of high viscous pastes with resolution < 100 μm
- **Performance** – mech. properties to withstand high g-forces, enhanced combustion

Feedstock Development

- **Binders** – energetic, better mech. properties (MPs), tailored for energetic solid
- **Particle surface science** – better processing and MPs

Manufacturing

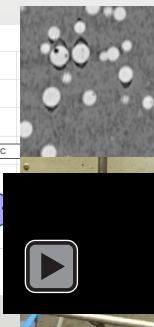
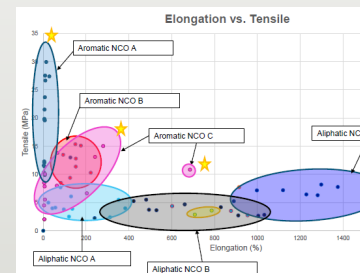
- **Enables multiple binder chemistries**
- **Improved resolution** – vibration assist and particle surface mod.

Modeling

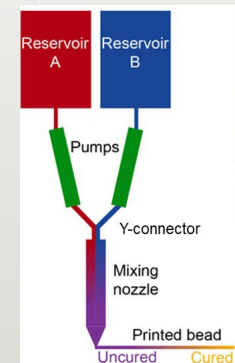
- **AM geometries**
- **Topology Optimization**

Supports NGCV and LRPF Priorities

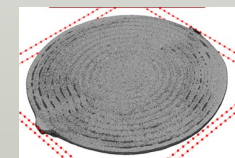
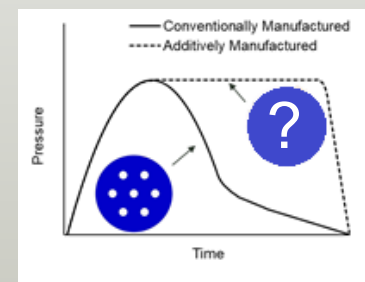
Feedstocks



Manufacturing



Modeling



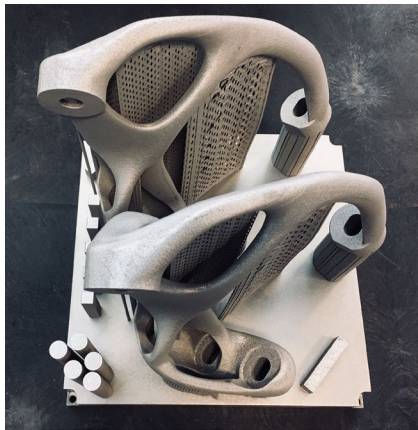


METALS AM RESEARCH THRUSTS



Feedstock development

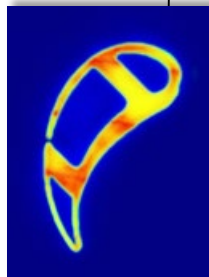
- Ultra high strength steels
- High strength lightweight alloys: aluminum and magnesium
- Refractory metals (W and WHA)
- Low cost feedstocks



Next gen. capabilities

Modeling and Simulation

- Multi-scale modeling tools
 - AM builds
 - Microstructure prediction
 - Performance prediction
- Constitutive models for high strain rate response of AM metals

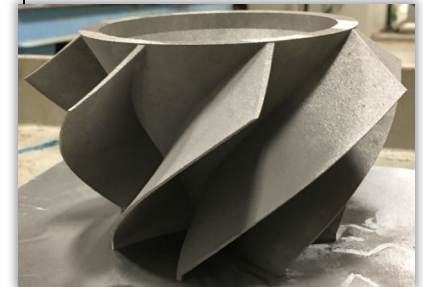


Digital tools for enabling rapid qual.

- AI/ML tools for alloy design
- AI/ML tools for process data analytics
- In-situ process monitoring sensors and data analysis
 - Optical
 - Thermal
 - Acoustic
 - X-ray
- Generation and management of material data to support development of specs and standards

Expeditionary Manufacturing

- Recycled feedstocks
 - RHA
 - Stainless steel
 - Aluminum
- AM for repairs
 - DED
 - E-beam PBF
 - Additive friction stir



Replacement parts to support mission readiness



HYBRID ELECTRONICS - S&T DEEP DIVE SNAPSHOT



Technical Approach:

- Developing hybrid electronics solutions for integration of sensor circuits and fuzing directly onto 3D structures
- Design next generation structures through plasma-treated feedstock
- Optimize reliability through simultaneous design, modeling, and additive manufacturing of the structures
- Test research concepts in harsh environments; high-g forces
- Leverage micro and nano-x-ray CT for materials properties to validate modeling and test results

Payoff / Deliverables:

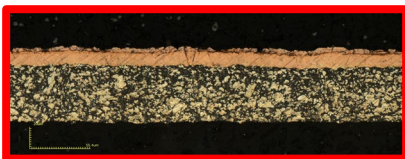
- Multi-axis-multi-sensor, fuzing platform to develop high-G
- 3D Optical sensors array for Seekers: CCDC-AvMC, CCDC-AC missile and munitions
- Integrated 3D hybrid manufacturing processes for future LRPF applications
- Transition to the US Industrial Base for scale manufacturing to support long-term Army/CFT missions.

Studying Material properties and “harsh environment” testing

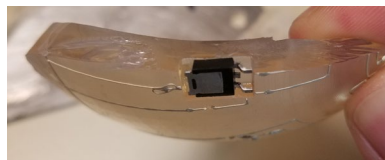
Plasma-treated Stock Polymers



CT Scan – cross-overs



High-g Test: structure and circuits

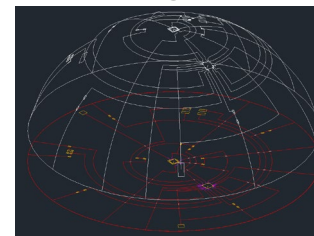


AM technique: complimentary WMRD SEDD capabilities)

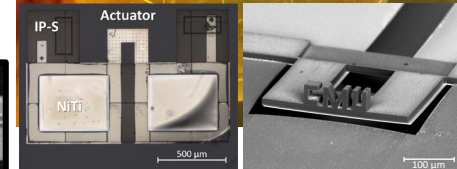
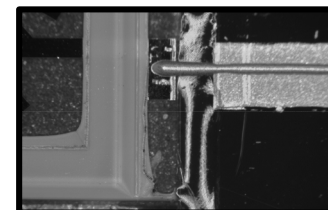
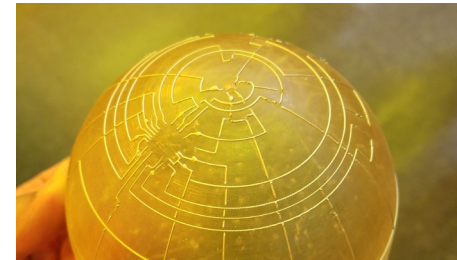


Novel 3D Hybrid Devices, Fuzes

Design



Print, Sensors, Fuze



Process Research



SUMMARY – OPPORTUNITIES FOR BASIC RESEARCH



- **Army-specific Feedstock/Material Development**
 - Energetics AM: 3D-printable polymers/binders, energetic simulants, energetic ingredients, surface science of energetics
 - Metals AM: AM specific feedstock alloys, lower cost
 - Hybrid AM: Conductive AM materials (metal-polymer chemistries), organo-metallic chemistries to reduce to metals, high density dielectrics and semiconductors
- **Manufacturing Technologies**
 - Process monitoring (sensors, diagnostic tools)
 - Multi-axis, multi-process, multi-material manufacturing
 - Robotic kinematics, path planning
 - AI/ML analytics and control systems
 - Software design – g-code editing/slicer
- **Modeling**
 - Efficient multi-scale, multi-physics modeling and design
 - Robust design algorithms (incorporating stochastic material, manufacturing, processing conditions)
 - Integration of AI/ML models with physics-based models (hybrid models)