U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMY RESEARCH LABORATORY

Hypersonic Materials
HTMDEC Applicant's Day

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RECALL: ARMY WEAPON COMPONENTS

Guidance

- Sensors: visible/infrared imagers, antennae, accelerometers, gyroscopes, magnetometers
- Electronics: power/signal conditioning, radios
- Real-time processors
- Control mechanisms: electromechanical actuation of aerodynamic and/or impulsive control to steer vehicle
- Power supplies: thermal batteries, super-capacitors

Lethal mechanism

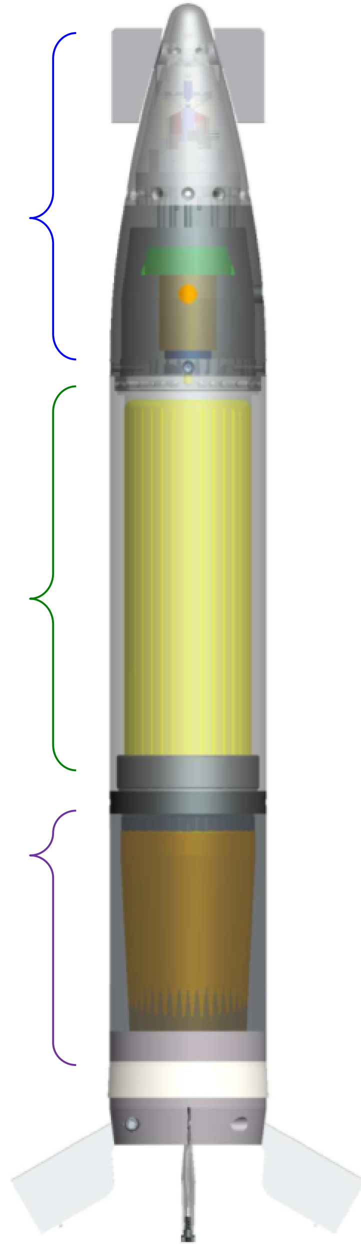
- Blast-fragmentation warhead: fuzing/ignition, high-explosive, metal case
- Shaped-charge/explosively-formed penetrator: fuzing/ignition, high-explosive, ductile metal liner (e.g., trumpet)
- Kinetic energy penetrator: high-density metal rod/slug

Post-launch propulsion

- Solid-rocket motor: ignition, nozzle/pressure vessel, propellant
- Air-breathing propulsion (ramjet): ignition, inlet/grain/mixing/nozzle, propellant

Structures

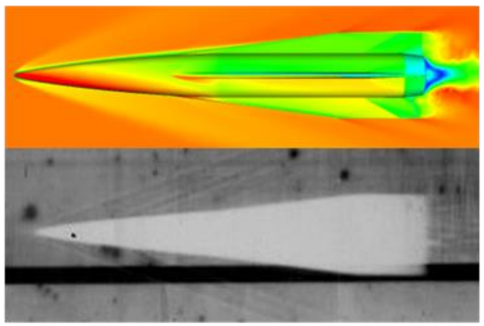
- Mechanical, thermal, electro-magnetic, aerodynamic functionality and weapon packaging (e.g, size/weight) constraints
- Joints, gun rifling engraving bands, gun gas obturators, sabots, launcher interfaces (e.g., rail, tube), stability and control surface deployment features



STRUCTURAL MATERIAL CLASSES OF INTEREST

Putting the pieces together…
Sealants, coatings, joining methods

Strong, light and cheap
Generally consists of carbon-carbon composites or ceramic-matrix-composites.



Structural acreage and thermal protection

Sensor Windows

Leading Edges

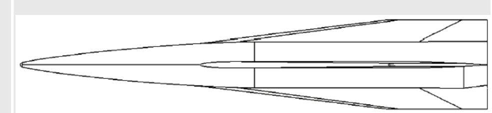
Strong, transparent, low-emissivity
Material determined by sensor.
Position determined by the material.
Generally ceramic in nature.

Performs at high temperature, erosion resistant
Refractory metals and ceramics.
May be coatings, bulk parts.

MATERIALS DISCOVERY FOR ARMY WEAPONS
- SUMMARY NEEDS -

Objective: Rapid discovery of material candidates that may expand the performance envelope

Means: Coordinated computational research, machine learning and automated processing to rapidly identify candidate materials for experimental scale-up.

Metric	Objective	Comments
Launch (mechanical) load	• **>100,000 Gs over 10ms peak set-back launch load** • 10% peak set-back over 0.1ms set-forward launch load	Yield strength vs plastic strain better than steel and aluminum aerospace alloys (e.g., 7075, 6061)
Flight (thermal) load	• **> 1600^{o}C temperatures** • > Mach 6 at sea-level through >20km flight conditions*	* Additional government-provided details (e.g., steady and transient heat flux, shear and normal surface loads on vehicle and control surfaces, etc.) outside scope of unclassified 6.1 research
Launch and flight load	• **>20,000 Gs over 10ms peak set-back launch load** • 10% peak set-back over 0.1ms set-forward launch load • > 1600^{o}C temperatures • > Mach 6 at sea-level through 20km+ flight conditions*	* Additional government-provided details (e.g., steady and transient heat flux, shear and normal surface loads on vehicle and control surfaces, etc.) outside scope of unclassified 6.1 research
Weapon packaging	• **Conic, ogive, and cylindrical body shapes with sharp noses** • Thin, swept stabilizing and control surfaces with sharp leading edges	

SUGGESTED FURTHER READING

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5. Miracle, D. B., & Senkov, O. N. (2017). A critical review of high entropy alloys and related concepts. *Acta Materialia*, *122*, 448-511.
6. Raccuglia, P., Elbert, K. C., Adler, P. D., Falk, C., Wenny, M. B., Mollo, A., ... & Norquist, A. J. (2016). Machine-learning-assisted materials discovery using failed experiments. *Nature*, *533*(7601), 73-76.
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