Reactive Fragment Warhead for Enhanced Neutralization of Mortar, Rocket, & Missile Threats

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PROBLEM STATEMENT

Troops on the ground and lightly armored and unarmored vehicles are highly vulnerable to attack by short-range weapons, including mortars, rocket-propelled grenades, and missiles. These threats, which are, after small arms, the most numerous class of weapons on the battlefield, are not effectively countered by the usual means for protecting against small arms: entrenchment, fieldworks, and light armor. As a result, these weapons have claimed a large number of casualties among Coalition Forces in the ongoing war.

Active Protection Systems (APS) are being developed to provide protection against these threats. These function by firing a projectile containing an explosive warhead that detonates to project high-velocity fragments that neutralize the incoming threat. In this SBIR project, we are developing reactive materials to be used in the projected fragments to make them more effective than the inert fragments (typically steel) currently under consideration.

Fragments of reactive materials provide an additional threat-neutralization mechanism. Whereas inert fragments must perforate the threat's warhead with a substantial residual velocity to insure neutralization (detonation or deflagration of its explosive), a reactive fragment needs only to reach that explosive, in which it initiates a reaction by means of its great thermochemical energy (heat). Reactive fragments can thus be smaller and more numerous, which increases the probability of hitting the threat, and need to be projected only with enough velocity to perforate the threat's casing, which reduces the amount of explosive that must be carried by the APS. Finally, reactive fragments can be engineered to burn up in the air before they have traveled only a short distance, which reduces the radius over which undesirable collateral damage or injuries can occur.

WHO CAN BENEFIT?

Attack by rockets, mortars, and missiles is a persistent problem facing our troops deployed in hostile territory. Protection from these short-range threats will prevent many casualties. Active Protection Systems have been developed for use on land vehicles, mainly light and heavy armor, but potentially could be fielded to protect unarmored vehicles, infantry, and naval vessels. While the Army has taken the lead in the development of APS, the Navy and Marine Corps have an interest, and the Office of Naval Research and the Naval Surface Warfare Center have dedicated considerable funding and resources, including toward the incorporation of reactive materials to enhance performance.

High-strength reactive materials have numerous other applications, several of which we are actively developing, including:

- lethality enhancement of **anti-air fragmentation warheads**, by projecting reactive material inside the target's airframe to cause catastrophic structural damage. The photograph at the top shows a full-scale test of the Reactive Material Enhanced Warhead co-developed by DE Technologies and NSWC-Dahlgren under an ONR Advanced Technology Demonstration (ATD) program. We are also supplying reactive materials to both prime contractors (General Dynamics and Alliant Techsystems) of the Air Force's Battleaxe Program.
- lethality enhancement of **shaped-charge warheads**, by projecting reactive material into the penetrated target for greater behind-armor effects. Under ONR funding, we are currently developing a shaped-charge warhead incorporating a reactive-material liner for the Compact Rapid Attack Weapon (CRAW) torpedo.
- lethality enhancement of **penetrating warheads** (bombs), by incorporating reactive materials as replacement for part of the penetrator's usually inert body. Under another SBIR Program, sponsored by DTRA, we are developing structural (very high-strength) reactive materials for use in a bunker-busting missile or projectile.
- non-explosive energetic **gun projectiles**, by replacing the usual explosive load with the much less hazardous yet equally lethal reactive material. Reactive materials afford the possibility of an explosiveless projectile for the (propellantless) Electromagnetic Gun under development by ONR.

BASELINE TECHNOLOGY

Current Active Protection Systems (APS) operate by firing a projectile containing an explosive warhead that detonates to project high-velocity fragments that neutralize the incoming weapon. The fragments, which are composed of inert metals such as steel or tungsten, must penetrate the warhead with sufficiently high residual velocity to initiate its explosive by impact shock. This requires large fragments projected at very high velocity, which increases warhead size and explosive mass and limits the number of fragments that can be carried and projected. Heavy fragments travel for great distances and can cause undesired collateral damage and injuries to friendly troops and non-combatants.

Full-scale test of Northrop-Grumman's Integrated Army Active Protective System (IAAPS), featuring the inert-fragment explosive warhead designed and built by DE Technologies. When the projectile reached the location of the dark cloud, the warhead was detonated, to project the pattern of inert-metal fragments visible on the left.

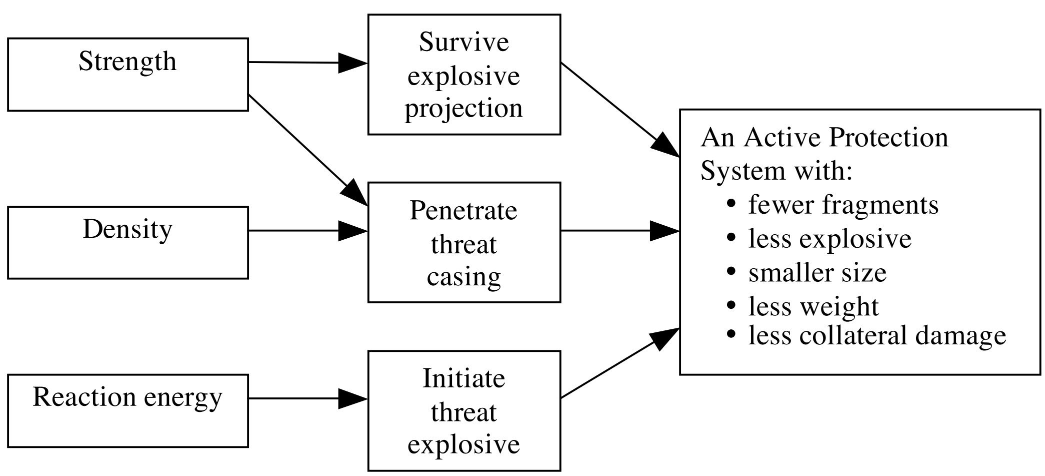
TECHNOLOGY DESCRIPTION

The goal of our SBIR project is to marry the reactive-material technology shown in the cover photo with an APS warhead as shown just above. To this end, we are developing reactive materials to be used in the projected fragments to make them more effective at initiating a reaction in the threat's explosive than the inert fragments currently under consideration. Effectiveness of reactive materials is gained by increasing their strength, mass density, and reaction energy. Greater strength increases the material's ability to withstand explosive projection and to penetrate the incoming threat's casing. Greater mass density further improves penetrating power. Greater reaction energy increases the material's ability to initiate a premature reaction in the threat's warhead explosive load.

Reaction energy is provided mainly by chemical reactions between a given material's components but is enhanced by subsequent burning of the resulting products in ambient air. Reactions fall into two classes, *thermitic* and *bimetallic*. In thermitic reactions (similar to the familiar Thermite), an active metal is oxidized by an element drawn from a compound (such as a plastic or resin) of which it is a chemical component; an example is a mixture of aluminum and PTFE (polytetrafluoroethylene, or Teflon), in which the metal is oxidized by fluorine from the plastic. In bimetallic reactions, two dissimilar metals react with each other; an example is titanium and boron, which react to form TiB_2, a ceramic. In both classes of reactions, the white-hot products remain largely solid or perhaps become molten, but there is no great output of gaseous products, which means the materials are non-explosive. Energy output is comparable to that of a high explosive, but in a different form—more purely thermal, with little blast. A roughly similar amount of additional energy is released when the products of the first reaction (such as carbon liberated from the PTFE, or the individual metals in a bimetallic) burn in air. If the products are dispersed in air before this secondary reaction, it will be accompanied by a large blast pressure.

We have demonstrated that we can increase the strengths of reactive materials of the thermitic type through the application of conventional composite-materials technology, including fiber-reinforcement and nano-reinforcement. Conventional reinforcing fibers, such as of graphite and boron, can be oriented to provide material strength and stiffness in desired directions. Reinforcement with the new super-strong nano-fibers—with diameters on the molecular scale of only a few hundred nanometers or less—have proven to be highly effective in increasing the strength and stiffness of many materials. We have successfully incorporated both types of reinforcement into polymer-based reactive materials to yield strengths and stiffnesses improved by a factor of two or more.

We have also produced another family of high-mass-density, bimetallic reactive materials through powder metallurgy. Typically, powders of two or more active metals are mixed and cold-pressed under extreme pressure to create a solid body with high mass density, considerable strength, and high reactivity. When projected at high velocity, fragments of these materials are able to penetrate even the thick steel casings of mortar rounds, after which the component metals react with each other to yield a white-hot release of energy, to prematurely initiate the incoming weapon's explosive charge.



CURRENT STATE OF DEVELOPMENT

Materials of both classes that we have developed have been demonstrated in various types of tests. First, improved mechanical properties of strength and stiffness have been measured in standard laboratory tensile and compressive tests.

Ballistic testing performed by the Naval Surface Warfare Center, Dahlgren Division, and ATK Launch Systems Group demonstrated significant release of thermochemical energy on impact; energies comparable or superior to those of high explosives are typical.

As part of our previous ATD Program, we developed a special explosive-launch test that in a simple and inexpensive device replicates the dynamic loads experienced by fragments projected by a much larger and more expensive full-scale explosive warhead. In such tests, we have demonstrated the ability of our high-strength reactive materials to survive explosive projection while remaining intact. We estimate that this represents achievement of a Technology Readiness Level (TRL) of 4.

By the conclusion of our current Phase II SBIR Program in June 2007, we expect to demonstrate a full-scale warhead that explosively projects intact fragments of a high-strength reactive material. This represents a TRL of 5.

TECHNOLOGY AVAILABILITY

We are seeking funding to adapt this device to a particular delivery system and statically test it against simulated and actual threats, with accompanying further refinements of the performance of our reactive materials. We estimate that this could be accomplished within a $1,000K, 12- to 15-month development effort, to reach a TRL of 6. A further effort would culminate in dynamic tests for basic function and for performance against actual threat munitions.

At this early stage of its development, we are holding various aspects of the technology as proprietary. Much of the technology associated with the material development and integration into a warhead system involves novel approaches and in many instances may qualify for patents of various subject matter. In fact a patent application has been filed covering the previously developed RMEW ATD warhead design and design approach used jointly by DE Technologies and NSWC-Dahlgren.

As the technology matures, we anticipate filing several patents covering our reactive-material development and warhead designs. DE Technologies could produce the reactive material and associated warhead components up through full-scale production, or the technology could be licensed to a suitable fabricator.

REFERENCES

Our technical monitor, Dr. Clifford Bedford (703-696-0437, bedforc@onr.navy.mil), has been enthusiastically supportive of our progress in this SBIR Program.

In mechanical and ballistic tests performed at NSWC Dahlgren by Dr. Richard Ames (540-653-6405, amesrg@nswc.navy.mil), our reactive materials have consistently ranked superior in performance, especially in mechanical strength and post-impact blast effect. Dr.

Ames is also cognizant of our success on the Reactive Material Enhanced Warhead ATD Program.

Our recent design, development and manufacture of the inert-fragment explosive warhead for Northrop-Grumman's Integrated Army Active Protection System (IAAPS) was overseen by Mr. Frank Stoddard (310-814-5243, frank.stoddard@ngc.com).

ABOUT THE COMPANY

DE Technologies is a small engineering firm located in the Philadelphia area, specializing in:

- Explosive warheads
- Impact mechanics
- Computer model development
- Computer simulation
- Composite fabrication
- Ultra-high-precision machining
- Testing and evaluation

Our mission is to provide a full range of services in research and development of explosive warheads and related devices, from conceptualization through qualification testing and production.

DET was established in 1993, incorporating the former Dyna East Corporation (founded 1968) and the former Warhead Development Group of BAE Systems. We have grown into a full-service engineering organization specializing in the design, development, manufacture, and test & evaluation of explosive warheads, kinetic-energy penetrators, and armor protection systems; and the computer-aided design and analysis of innovative metallic and composite structures for both military and commercial applications.

DET is a renowned leader in the field of ballistic design and development. Our capabilities span the entire spectrum of warhead and armor development, from basic research, through design, to the manufacture and evaluation of developed items. Current major projects include:

- advanced reactive material warhead development and munitions design
- analysis and testing for an explosive mine neutralization system
- development of an advanced shaped-charge warhead for the next-generation torpedo
- development of improved penetrators for enhanced penetration-trajectory stability.

Our customers span all branches of the Defense Department, including the Air Force Research Laboratory, Army Research Laboratory, Army Research, Development, and Engineering Center, Army Missile Command, Army Tank Command, Defense Threat Reduction Agency, Naval Air Warfare Center, Naval Surface Warfare Center, Office of Naval Research, Waterways Experimental Station. Our DoE customers include Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National

Laboratory. Commercial customers include AAI, Alliant Techsystems, BAE Systems, Delta Defense, Dow Chemical, DuPont, FMC, Foster-Miller, General Dynamics, Halliburton, Lockheed-Martin, Northrop-Grumman, Raytheon, Talley Defense, and Tracor Aerospace. Foreign customers have included Società Esplosivi Industriali SpA, Oto Melara, SNIA-Viscosa, Raufoss, and the Ballistic Research Laboratory of Taiwan.

For more information on our experience and capabilities, please browse our website at www.detk.com and download our brochure.