

## 2. Background

### Nature and Origins of Reactive Armor

Reactive armor (RA) was first developed during the 1970s as a means of protecting armored vehicles against shaped-charge anti-armor weapons, including Hand Held Infantry Weapons (HHIW) and Anti-Tank Guided Missiles (ATGMs). The same concept can also be applied to protect vehicles against kinetic energy penetrators (KEPs), such as armor-piercing, fin-stabilized, discarding-sabot (APFSDS) projectiles. The essential feature of most RA designs is a layer of explosive material sandwiched between two metal plates. When the hot jet of a shaped-charge (or a KEP) hits this sandwich, it ignites the explosive layer in the middle, causing the two metal plates to fly apart. These “flyer plates” erode and destabilize the jet (or KEP) as it slices through them, thereby reducing its ability to penetrate the base armor of the vehicle.<sup>5</sup>

The first patent for RA was registered in Germany in 1970 by a Norwegian, Dr. Manfred Held, who later worked with the Rafael Armament Development Authority to develop the “Blazer” RA design for Israeli tanks, which first appeared in combat in 1982. The Soviet Union had also been working on its own RA concept and followed suit with its first generation of RA about a year later.<sup>6</sup> Since then the Soviets, and later the Russians, have developed and fielded a variety of improved RA designs for their tanks, including Kontakt-5, which is purported to be effective against a depleted uranium KEP fired from the 120mm gun of a U.S. M1 tank.<sup>7</sup> The United States also developed RA during the 1980s, acquiring RA tiles for Marine Corps M-60 tanks, which were used during Desert Storm in 1991.

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<sup>5</sup>A detailed overview of RA technology was provided by ARL.

<sup>6</sup>R.M. Ogorkiewicz, “Future tank armors revealed: Developments in electric and explosive reactive armor,” *Jane’s International Defense Review*, Vol. 30, No. 5, pp. 50–51, May 1997.

<sup>7</sup>See Jane’s Information Group, “Impenetrable Russian tank armor stands up to examination,” *Jane’s International Defense Review*, Vol. 30, No. 7, p. 15, July 1997.

## Application to Light Armored Vehicles

The earliest forms of RA were only appropriate for heavy tanks because of the structural strength needed to bear the weight of the tiles and endure their exploding force. But as the technology improved during the 1980s, the prospect of applying it to protect lighter vehicles became more feasible. In particular, the use of better explosive materials made relatively lightweight RA tiles more effective and less susceptible to unintentional ignition. In the late 1980s, the U.S. Army acquired Rafael-designed RA tiles for its Bradley Fighting Vehicle (BFV). About 50 vehicle sets of these first-generation, or A0, BFV tiles were deployed for use in Somalia in 1993. The Army is now in the process of procuring a total of 178 sets of an improved A1 version of these tiles from General Dynamics Ordnance Systems (GDOS), which is in partnership with Rafael. As of March 1999, 74 sets of the new A1 tiles have already been delivered, with the remaining 104 expected by the end of 1999.

Some of the U.S. Army's M113s—its aged but numerous armored personnel carrier (APC)—perform operational roles that might expose them to attack by shaped-charge weapons, so these vehicles could also benefit from the added protection that RA tiles could provide. The BFV A0 and A1 tiles are not ideal for the M113, as the modifications necessary to apply these tiles to the vehicle would add significant extra weight. In particular, extra backing armor would be required to adapt these tiles for use on the M113. More generally, there are serious concerns about the relatively heavy weight of RA tiles, due to the M113's limited payload capacity.

In 1998, to explore the potential benefits of applying RA to U.S. M113s, two possible M113 tile candidates were tested in the D650 Tank Automotive-armor Research, Development Engineering Center (TARDEC) Foreign Technical Testing program, which was conducted by the U.S. Army Test and Evaluation Command (TECOM) at its Aberdeen Test Center (ATC).<sup>8</sup> One of the tiles evaluated was a design developed by Rafael for an Israeli M113 variant.<sup>9</sup> The other tile evaluated in the D650 test was a design developed by the French firm Societe Nationale des Poudres et Explosifs (SNPE), which is also marketing a similar design for the French AMX-30 light tank and the Russian BMP-3 APC. Both of these options are similar to current BFV tiles in terms of weight and performance, and they would include extra passive backing armor to reinforce the base armor of the M113.

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<sup>8</sup>Detailed information on the D650 test was provided by ARL.

<sup>9</sup> A photograph of an Israeli M113 with Rafael RA tiles is shown in Ogorkiewicz, 1997.

## Changes in the Threat Environment

Not surprisingly, new anti-armor weapons are emerging that are designed specifically to counteract RA by using a “tandem” warhead, which includes a smaller precursor in addition to the main shaped charge. The precursor charge detonates the explosive layer of the RA early to enable the main shaped charge to penetrate more easily. Tandem warheads have already begun to appear on both ATGMs and HHIWs.<sup>10</sup> As these advanced threats become increasingly prevalent, armored vehicles will need greater protection against them.

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<sup>10</sup>A large selection of existing tandem HHIW designs are discussed in T.J. Gander, “Shouldering the burden of last-ditch defense,” *Jane’s International Defense Review*, Vol. 30, No. 4, pp. 57–62, April 1997; for a similar discussion of ATGM designs, see Jane’s Information Group, “Keeping up with the tank hunt,” *Jane’s Defence Systems Modernisation*, March 1997.