TOW 2B SYMPATHETIC

DETONATION CONTAINER

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Presented by:

ROBERT BARNABI
NSWC DD
DAHLGREN, VA (USA)

MICHAEL A GLICK
BAE SYSTEMS
STAFFORD VA (USA)

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Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

1.0 INTRODUCTION

1.1 BACKGROUND

The current TOW 2B missile container is a reusable wooden box encased in a Faraday Cage to preclude ESD into the missile as shown in Figure 1. The TOW 2B WSESRB review board, conducted in May 2004, resulted in several recommendations to the Program Manager, Anti-Armor Systems (PM AAS) regarding TOW 2B explosive safety. WSESRB recommendations included investigating the possibility of decreasing the sympathetic detonation (SD) probability of containerized TOW 2B missiles, as well as decreasing the missiles susceptibility to hazards of other effects caused by exposure to the electromagnetic spectrum (ESD/HERO) and moisture. As a result of the WSESRB recommendations, PM AAS initiated efforts to procure a TOW 2B missile container that satisfies WSESRB recommendations.

Figure 1: Current TOW 2B Wood Shipping Container Provides No Sympathetic Detonation or HERO

1.2 WARHEAD MODELING APPROACH

The TOW-2B missile poses a unique challenge to insensitive munition (IM) compliance for sympathetic detonation (SD) in that its warheads may be aimed directly at neighboring warheads as shown in Figure 2. The warhead produces an explosively-formed-penetrator (EFP) that can cause sympathetic detonation even at large separation distances. In order to provide guidance for the design of packaging to mitigate this SD mechanism, three-dimensional simulations were performed at the U.S. Army Research Laboratory. In each of the simulations, the explosive fill of the acceptor warhead was treated as inert, and the pressure loading it received was used to estimate whether or not detonation propagation would occur. These simulations showed that the formation of the EFP could be interrupted using aluminum bars (referred to as disruptors) in proximity to the exterior surface of the missile's launch tube.

When this was accomplished, the pressure levels in the acceptor remained well below those expected to produce detonation. Further simulations were conducted to explore the conditions under which EFP disruption occurs. Parameters considered include the positioning of the disruptor(s), the shape of the container, and the presence of foam inside the container. Prevention of SD caused by the EFP solves only one part of the problem. Direct propagation due to warhead and rocket motor blast may also need to be addressed.

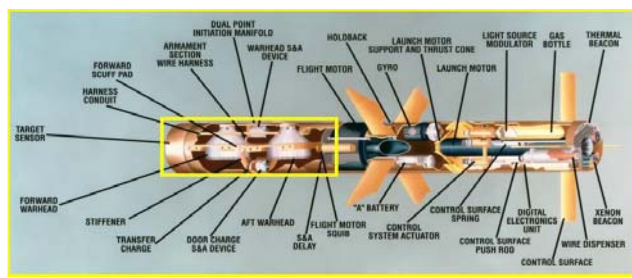
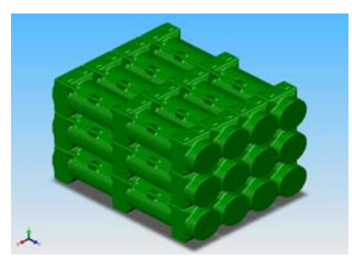


Figure 2: TOW 2B Missile with Warhead section and palletized configuration



Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

1.3 USMC ATD Approach

The USMC conducted several Advanced Technical Demonstrations (ATDs) to ensure that the new TOW 2B missile container will reduce the effects of SD and protect the missile from ESD and HERO. During the initial phase, modeling was used to model the effects of the EFP during an unplanned external event resulting in SD. The SD modeling was conducted by the US Army's Picatiny Arsenal and confirmed by testing at the Naval Air War Center China Lake (NAWC CL).

Another phase of the program demonstrated that a flexible bag could be fabricated to protect the missile for the effects of ESD and HERO while the missile was not in the container and loaded in the ammunition racks being readied to go ashore. The testing conducted at Redstone Technical Test Center and NSWC-DD during this portion demonstrated the successful suppression of ESD and HERO effects on the TOW 2B missile.

The next phase of the USMC effort will incorporate the ESD/HERO protection and the SD mitigation together to develop and manufacture a lightweight re-usable container that will be retrofitted on to all the USMC TOW 2B missiles. This program is currently expected to be complete, with full qualification by 2007.

2.0 WARHEAD MODELING

2.1 Approach

Three-dimensional simulations of donor-acceptor pairs of TOW 2B warheads were performed with the CTH shock-physics solver (Hertel et al. 1993). CTH provides capabilities for modeling dynamics of multidimensional systems with multiple materials, large deformations, and strong shock waves. It is an ongoing project of the Sandia National Laboratories.

CTH simulations typically run until a specified amount of problem time has elapsed or until a difficulty with the physical state at some point in the problem domain causes the computational time step to drop below a specified minimum value. Although CTH includes several explosive shock initiation models, these are calibrated to predict explosive response to simple planar shock waves. The shock loading in the present case is complex and representation of the acceptor as inert allows the pressure history in the impacted portion of the acceptor to be monitored. An educated guess at the acceptable pressure level (1 GPa) was used as a standard.

The simulations were conducted in two phases. Phase I was intended to answer three questions:

1) What is the behavior in the baseline configuration (without mitigation)?

2) Can EFP formation be disrupted under the constraints of the system?

3) If EFP disruption is successful, what is the effect on acceptor loading?

In Phase II, details of the disruptor and container designs were considered. These include the positioning of the disruptor, the shape of the container, and the presence of foam within the container.

2.2 Simulations

The simulation configuration includes representations of the warhead case, explosive, and liner, as well as the missile skin and the launch tube. Only one of the two warheads in each missile is considered. A section of the missile extending 50mm above and below the warhead is included. A

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

programmed-burn initiator is used to detonate the donor warhead in design mode. The acceptor loading is monitored at 5 Lagrangian points (tracers) imbedded in the aft portion of the acceptor explosive where the highest pressure is experienced. Different containers and a variety of disruptor bar configurations between the donor and acceptor were simulated.

In Phase I, the container was represented as a rectangular steel box with 3/32-inch-thick walls. Three simulations were performed. In the first simulation, the 11-inch container dimension was used without disruptors. It ran for 380μs. The EFP formed and penetrated through the acceptor warhead. Pressures in excess of 3 GPa were produced. This is expected to initiate the acceptor charge. In the second simulation, 2-inch-thick rectangular aluminum bars attached to the inner surface of the 11-inch-wide container were added. These bars are in close proximity to, but not quite touching, the outer surfaces of the launch tubes. The bar width is sufficient to subtend an angle from the center of the donor missile that shields the acceptor. The simulation ran for 400μs. In this case, the bars successfully disrupt the formation of the EFP. The pressure in the acceptor warhead is reduced substantially, remaining below 0.2 GPa. Under these conditions, the acceptor warhead is not expected to detonate. In the third simulation, the same 2-inch-thick rectangular aluminum bars are attached to the inner surface of the 14⅔-inch-wide container. This leaves a larger space between each bar and the adjacent launch tube. The simulation also ran for 400μs. Under these conditions, disruption of EFP formation fails. The EFP penetrates the aluminum bar and the acceptor warhead. The initial pressures are about as high as in the baseline case, but the late-time pressures are lower. The mitigation, in this case, is deemed inadequate to prevent acceptor detonation.

Clearly, only the nearer of the two disruptor bars is required to stop the EFP from forming. Use of a single bar would mean less added weight. A simulation was performed to address the question of whether such a single bar is effective. The bar was thickened a little to fill the entire space between the launch tube and the container. The simulation ran 350μs. The EFP formation is disrupted, but the acceptor is impacted first by material from the container wall and subsequently by the remains of the disruptor. This produces two pressure spikes of a little less than 2 GPa each. This is above our 1 GPa criterion data on the explosive indicates that it takes 10 Gpa to cause a detonation reaction.

More realistic container designs use generally cylindrical shapes. A simulation in which the successful bar design was adapted to an 11-in-diameter circular-cylindrical shell container (with the same wall thickness used for the square container) was conducted. In this case, curved bars were used to fill the space between the outer surface of the launch tube and the inner surface of the container and to subtend the appropriate angle. This simulation ran to 350μs. The results are similar to those achieved with the rectangular container. The EFP is effectively disrupted and the pressure does not exceed 0.2 GPa, as shown in Figures 3A and 3B.

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

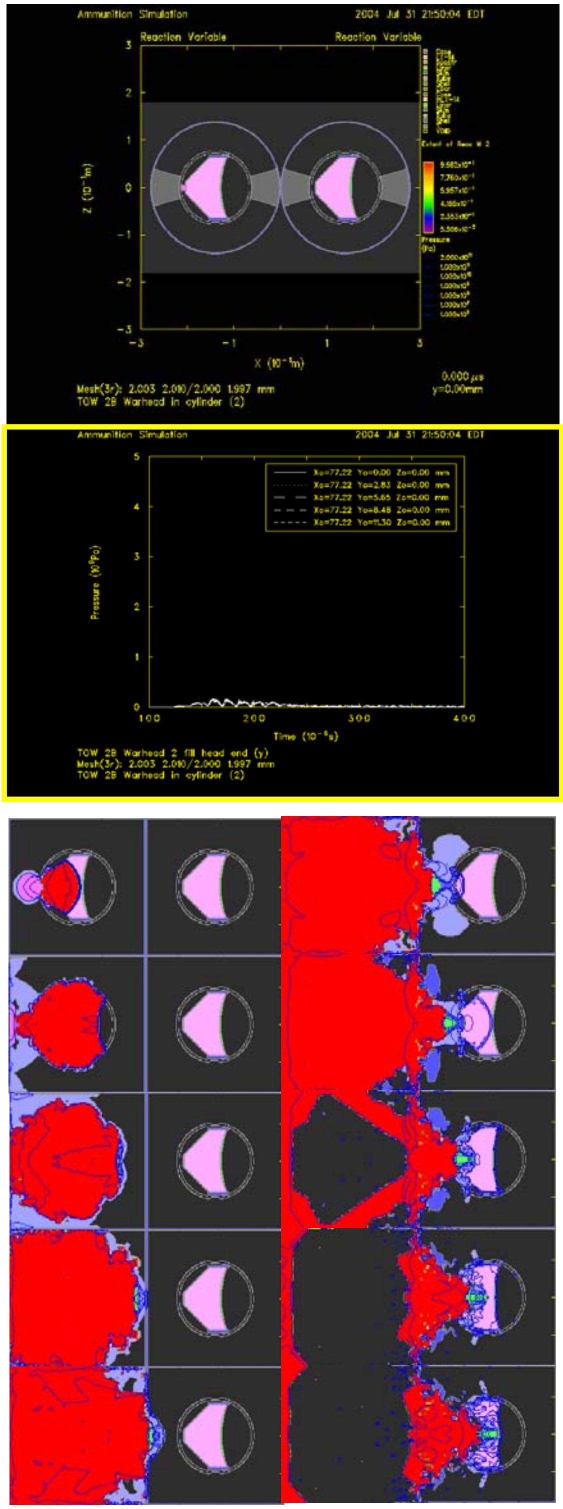


Figure 3A & 3B: CHT Model Output Shows Pressure Level Below Acceptable Detonation Limits

Low density foam fills within the container are used to stabilize its contents. The extent to which this influences the results was addressed in a simulation in which the cylindrical container was filled with foam to the outer surface of the launch tube. The foam was modeled as porous polyurethane. This representation is numerically more temperamental and the simulation failed after 220μs. The pressures at the maximum peak are almost identical, while subsequent peak pressures appear a little lower in the presence of foam.

3.0 TESTING

3.1 Approach

The USMC provided TOW 2B missile assets to the Navel Air Warfare Center-China Lake (NAWC-CL) for prototype testing of the interrupter. The purpose of the testing was to validate the modeling conducted and to demonstrate that the formation of the EFP could be stopped utilizing the interrupter concept and prevent SD to adjacent missiles. A total of four (4) tests were conducted during this phase to validate the modeling and show that the SD of adjacent missiles could be prevented. These tests concentrated on the warhead section only and did not account for the launch and flight motors. The test configuration is shown in Figure 4.

The test containers were manufactured by NSWC-DD and shipped to NWWC CL along with the foam overpack and the missile Launch Tube Assembly (LTA). The test containers were designed based on preliminary packaging studies conducted by the Navy's PHS&T center in Earle, NJ, and the modeling that was conducted by the US Army's Picatinny Arsenal.

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

Figure 4: Sympathetic Detonation Test Configuration

3.2 BASELINE TESTING

The initial test conduct was to establish the baseline effects of SD when the TOW 2B missiles were stacked in a normal shipping configuration on a pallet. The test results indicate that the two (2) Acceptor warheads were initiated normally and that the EFP formation ignited the donor warheads resulting in the formation of all four (4) EFP from the two (2) donor warhead assets, Figure 5. Once the baseline was established, additional testing was conducted to compare various interrupter configurations to the baseline.

Figure 5: TOW 2B Baseline Test Configuration

3.3 DUAL INTERRUPTER TESTING

The second series of testing was to evaluate the dual interrupter concept. The modeling predicted that this concept would inhibit the formation of the EFP and prevent the SD of the donor warheads. The testing was conducted in the same configuration as the baseline with the donor warheads initiated directly above the acceptor warheads.

The results of the test showed that the donor warheads were initiated successfully and the interrupters prevented the initiation of the donor warheads, Figure 6. The witness plates show where the two (2) donor warheads impacted the plate and deposited material from the non-initiated warheads. Additionally there was no evidence of penetration of the EFP through the witness plate.

Figure 6: Dual Interrupter Test Configuration and Witness Plate

3.4 SINGLE INTERRUPTER TESTING

Due to weight constraints of the total system, missile, and container, testing was conducted to determine if a single interrupter could be used and still successfully prevent the initiation of the acceptor warheads. The test set up and

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

results are shown in Figure 7. The results indicated that a single interrupter could be used in the prevention of SD, thus reducing the interrupter weight by 50% and allowing for more design flexibility. The interrupter was found within 25 feet of the witness plate and again there was no evidence of penetration of the EFP through the witness plate.

Figure 7: Single Interrupter Test Configuration and Witness Plate

3.5 Single Interrupter Orientation Testing

The model indicated that the interrupters had to be in line in order for the interrupters to function properly. This design increases the logistics effort and results in a container design that must align all the warheads and interrupters in a given orientation. Figure 8 shows how the containers may be stacked which would result in a palletized load where all the warheads and interrupters were not aligned.

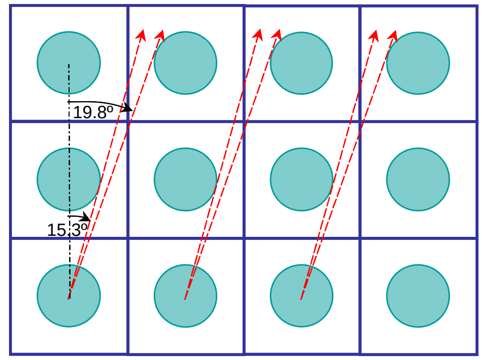


Figure 8: Palletized TOW 2B Containers with Warheads Not Aligned

This test was conducted to show that the single interrupters did not have to be aligned in order to prevent the initiation of the acceptor warheads. The test setup and results are shown in Figure 9. The testing resulted in successful prevention of SD of the adjacent warheads. The witness plates shows that the EFP formation was inhibited and no evidence of penetration of the EFP through the witness plate.

Figure 9 Single Interrupter With Interrupters and Warheads Not Aligned

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

4.0 SUMMARY

Three-dimensional simulations were performed to provide guidance for the design of packaging to mitigate SD caused by the TOW-2B EFP. In each of the simulations, the explosive fill of the acceptor warhead was treated as inert; and the pressure loading it received was used to estimate whether or not detonation propagation would occur.

These simulations show that the formation of the EFP can be prevented using aluminum bars (referred to as disruptors) in proximity to the exterior surface of the missile's launch tube. When this is successful, the resulting pressure levels in the acceptor remain well below those expected to produce detonation. Additional simulations were conducted to explore the conditions under which EFP disruption occurs. Parameters considered included the positioning of the disruptor(s), the shape of the container, and the presence of foam inside the container. The results indicate that disruptors must be paired in the missile container in order to prevent container-wall and disruptor launch and effectively reduce acceptor pressure levels. It was also demonstrated that container shape and the presence of foam have little influence. Prevention of SD caused by the EFP solves only one part of the problem. Direct propagation due to warhead and rocket motor blast should also be addressed.

5.0 USMC FUTURE PROGRAM PLANS

The USMC has plans in place to conduct a full development program for the container, which will incorporate both SD and ESD/HERO mitigation for the TOW 2B missile during shipping and storage. The program schedule is shown in Figure 10. The USMC has issued a Request for Proposal (RFP) and is in the process of issuing several concept container demonstration contracts. During the demonstration portion, the containers will be evaluated for performance under limited environmental conditions and ESD/HERO. The USMC will then down select to one contractor to proceed into a full-scale System Design and Development (SDD) contract.

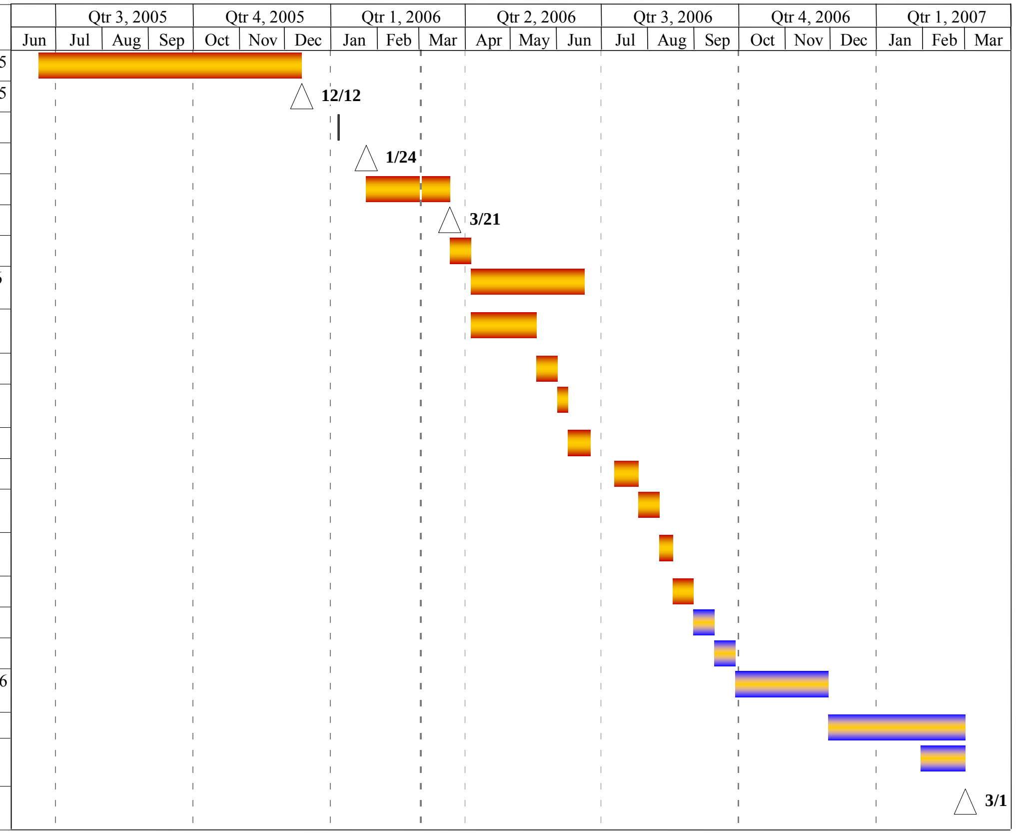
During the SDD phase, the container will be tested to all the natural and induced environments (MIL-STD-810), ESD/HERO (MIL-STD-468), and SD testing (MIL-STD-2105). After the completion of the SDD contract, the USMC plans on entering a low rate initial production (LRIP) and retrofitting the current USMC inventory of TOW 2Bs with the ESD/HERO bag and the container with the SD and ESD/HERO incorporated.

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554

TOW Container SDD Phases

Task Name	Start	Finish
Prepare Final RFP	Mon 6/20/05	Mon 12/12/05
Release Final RFP	Mon 12/12/05	Mon 12/12/05
Conduct Bidders Conference	Fri 1/6/06	Fri 1/6/06
Vendors Proposals Due	Tue 1/24/06	Tue 1/24/06
Source Selection Process	Wed 1/25/06	Tue 3/21/06
Contractor Selection	Tue 3/21/06	Tue 3/21/06
Contract Negotiation	Wed 3/22/06	Tue 4/4/06
Container Design and Development	Wed 4/5/06	Mon 6/19/06
Coupon Design and Development	Wed 4/5/06	Thu 5/18/06
Coupon Manufacturing	Fri 5/19/06	Thu 6/1/06
Coupon Shipping & Delivery	Fri 6/2/06	Thu 6/8/06
Coupon Testing	Fri 6/9/06	Fri 6/23/06
Container Manufacturing	Mon 7/10/06	Tue 7/25/06
Container Free Fall Drop Testing	Wed 7/26/06	Tue 8/8/06
Container Stacking Strength Test	Wed 8/9/06	Thu 8/17/06
Phase 1 Quicklook report	Fri 8/18/06	Thu 8/31/06
Container Downselect	Fri 9/1/06	Thu 9/14/06
Contract Negotiation	Fri 9/15/06	Thu 9/28/06
Design & Manufacture 25 Containers	Fri 9/29/06	Wed 11/29/06
Container Qual Testing	Thu 11/30/06	Thu 3/1/07
Container POP Certification	Wed 1/31/07	Thu 3/1/07
Container Qualification Complete	Thu 3/1/07	Thu 3/1/07



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Denotes Phase 1 effort

Denotes Phase 2 effort

Figure 10: Program Schedule

Robert Barnabi
USMC Anti-Armor Project Engineer
NSWC Dahlgren Division

Michael Glick
Subject Matter Expert
BAE Systems
25 Center St.
Stafford, VA 22554