Anti Structure Shoulder Launched System – Insensitive Munition Program

H. Kentagens, J. Zhang, D. Heigh (DND)
Y. Schneebaum, T.Eliash, T.Yarom (Rafael)

Abstract

Anti Structure (AS) shoulder launched system is a joint program between RAFAEL and Dynamite Nobel Defence. The launcher is based on the "Davis-Gun" principal in which the projectile's acceleration at launch is balanced by a countermass, resulting in a recoilless weapon. The AS projectile has a solid rocket sustainer motor which compensates for drag and ensures a constant velocity along the flight path. The projectile contains a tandem anti-structure dual mode warhead providing capability against a wide range of urban targets.

It was clear from the outset that the customer required an IM solution so the design of the weapon system included IM strategies as part of the program. The design and development included a graduated and comprehensive IM program.

The development and qualification of the system consisted of the following main IM activities:

- Threat Hazard Analysis incorporating guidelines from the customer requirements to form a test plan in which the most relevant threat scenarios were adopted.
- Warhead explosive selection to meet both performance and safety characteristics.
- Launcher design was developed to incorporate a liquid counter-mass material, a key element of the IM design.
- IM testing was conducted on the sub-components of the system.
- Safety tests conducted on the new explosive materials to characterize them.
- System level IM tests conducted as part of a full weapon qualification program.

The system level IM tests conducted were: Fast and Slow heating, Fragment attack and Sympathetic reaction.

The AS is now qualified and in service with several customers.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

Introduction

Anti-Structure (AS) is a joint program between RAFAEL and Dynamite Nobel Defence for a shoulder launched weapon system.

In the process of development and approval of AS we dealt with the IM issue from day one with a graduated and comprehensive IM activities program.

The development and qualification of the system consisted of the following main IM activities:

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- Warhead explosive selection to meet both performance and safety characteristics.
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- IM testing on the sub-components of the system.
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System Description

AS is a shoulder launched rocket designed to meet the needs of the infantry, especially in urban terrain. The launcher is based on the "Davis-Gun" principal, in which the projectile’s acceleration at launch is balanced by a countermass, resulting in a recoilless weapon. The AS projectile has a solid rocket sustainer motor which compensates for drag and ensures a constant velocity along the flight path. The projectile contains a tandem anti-structure dual mode warhead providing capability against a wide range of urban targets.

The main components of the AS system are:

- The Break–In Charge (BIC) which forms the forward part of the AS.
- The Follow-Through Bomb (FTB) which is located behind the BIC.
- The Sustainer Rocket Motor (SRM) located behind the warheads.
- The Gas Generator (GG) located in the center of the launch tube, between the AS projectile and the Counter-Mass.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

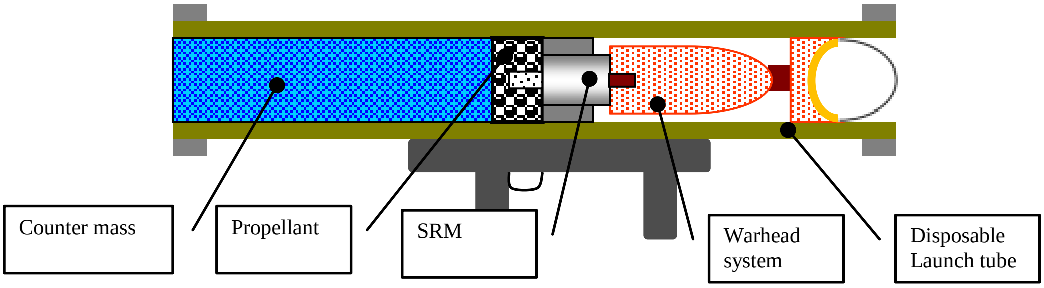

Figure 1– A schematic illustration of the AS shoulder launched rocket

IM Activities Description

IM Process Plan

The assessment methodology of our customer [1] implements a 'whole body of evidence approach' and includes assessment of data under the following areas:

- Assessment of the energetic materials
- Analysis of the weapon system design
- Analysis of the role of packaging
- All Up Round (AUR) testing

We preformed a Threat Hazard Analysis (THA) in order to identify credible threats to our system. During this process guidelines from the customer requirements were adopted to form a test plan / roadmap for system development and qualification.
The roadmap for the IM qualification included:

- Explosive selection and qualification
- Component and sub-system assembly IM tests
- Full system IM tests for the selected IM threats.

The main IM threats identified for the system level were Fast and Slow heating, Fragment attack and Sympathetic reaction.

High Explosive Selection

An increasing demand for insensitive explosives worldwide has resulted in an extensive Research & Development into Insensitive cure cast High Explosive (HE) for various purposes; as a result, the PX-940M and PBXN-110 equivalent formulations were developed at Rafael.

A series of tests were performed as initial qualification for the PX-940 and PBXN-110 IHE, The qualification included:

- Vacuum Stability Test (VST)
- Electrostatic Discharge Sensitivity (ESD)
- Accelerated Storage (Aging)
- Impact sensitivity (Fall hammer)
- Friction Sensitivity Test
- Decomposition Temperature Test
- Large Scale Gap Test (LSGT)
- Bullet Attack (BI) Test

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

In addition, performance tests were also conducted:

- Plate acceleration test – a test designed to measure the brisance of the explosive.
- Open field firings.
- Firings in closed volume pressure chamber.

The setup of these tests is shown in Figure 2 below.

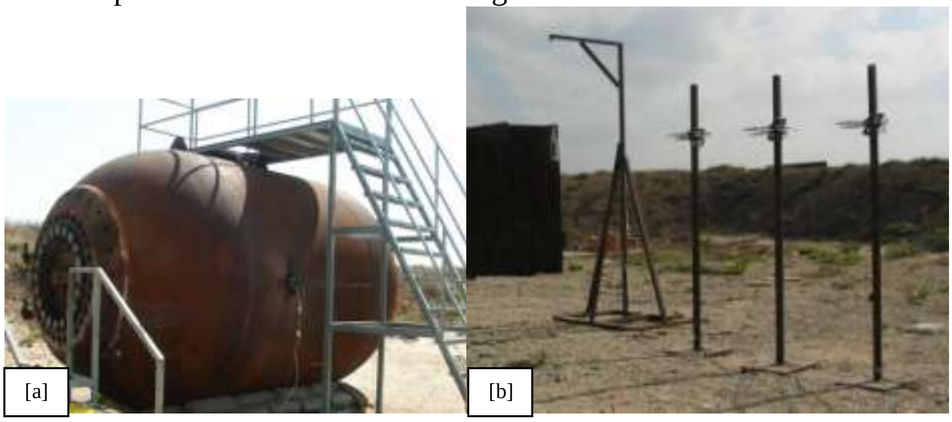

Figure 2 – Explosive performance test setup [a] closed vessel [b] open field

These initial tests helped us select the explosives for the warhead system:
The BIC explosive selected was PBXN-110.
For the FTB we chose PX-940 which showed enhanced blast performance.

Explosive Qualification:

As indicated above, the explosive compositions were already tested in the laboratory with a standard series of qualification tests. In addition, we conducted another set of qualification tests as defined in the Energetic Material Testing and Assessment Policy Committee (EMTAP). These tests included the EMTAP tube tests played an important part of the assessment process. The tests were conducted at the Wehrwissenschaftliches Institut für Werk-, Explosiv- und Betriebsstoffe (WIWEB) laboratories in Germany. In these tube tests the responses give a clear indication of the propensity of the explosive to undergo deflagration to detonation transition (DDT).
Three variants of the tube test were conducted:

- Internal Ignition: The explosive under test is ignited within the tube by means of a charge of propellant. Ten firings were conducted for each formulation.
- Fast Heating: The tube and contents are heated by means of a fuel fire. The time to response is recorded. Again ten firings were conducted for each formulation.
- Electrically Heated: The sample of explosive, confined in a steel tube, was heated at 5°C/minute by an electrical heating tape. Four firings were conducted for each formulation.

All variants of the test involve the same test sample which consists of a steel tube containing approximately 350g explosive with screw-on steel end caps. The tubes are designed so that the wall of the tube fails before the end caps. The degree of fragmentation of the tube is used to assess the relative explosiveness of the composition under test. The proportion of recovered explosive is also used to ascertain the degree of reaction. The results can be compared to other materials tested in the same way in an EMTAP database.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

Figure 3 – PX940 Tube test results

As can be seen in Figure 3, the pressure build-up in the tube caused bursting in a non violent manner in all the three types of tube test (in the PBXNX-110 test one sample reacted more violently).

Sub System Preliminary Tests:

The next stage in our roadmap was to evaluate the system design and test its key hazard sources at a component level.

The tests were selected so that each component was evaluated in its most dangerous scenario.

The tests conducted at this stage were Bullet Attack (BI), Fragment attack (FI) slow heating (SCO) and fuel fire (FCO).

The following table summarises the preliminary tests conducted

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

Test Type / Test Item	FI	BI	SCO	FCO
BIC	Unpackaged Packaged	Unpackaged	Unpackaged	
FTB	Unpackaged Packaged	Unpackaged	Unpackaged	
SRM			Packaged Propulsion sub system test	Packaged Propulsion sub system test
GG				

Table 1 – Sub System level tests

Bullet Attack

The test was conducted in a "stand alone" configuration on the FTB and BIC. The warhead with its booster charge was clamped to an Aluminum whiteness plate and attacked by a single M2, 12,7 mm AP round.
In both cases the warhead disintegrated without any violent reaction.
Figure 4 below shows the test setup and results:

Figure 4 – Component level Bullet Attack test setup and results for FTB [a],[b] and BIC [c],[d]

Fragment Attack

The test was conducted in a "stand alone" configuration on the FTB and BIC.
In the preliminary tests the RAFAEL Modified Fragment Impact test method (MFI) was used. This test method was developed at RAFAEL [2] in order to achieve a simple yet accurate way of accelerating a projectile to the velocities required in the STANAG. The MFI test method uses an EFP charge, which provides a spherical copper projectile of identical weight and velocity required by the STANAG. This approach is based on the assumption that in high velocity impact conditions, the shape and material of the projectile do not play a major role in the impact process, the main component is the fragment energy. The EFP charge and the fragment produced are shown in Figure 5.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

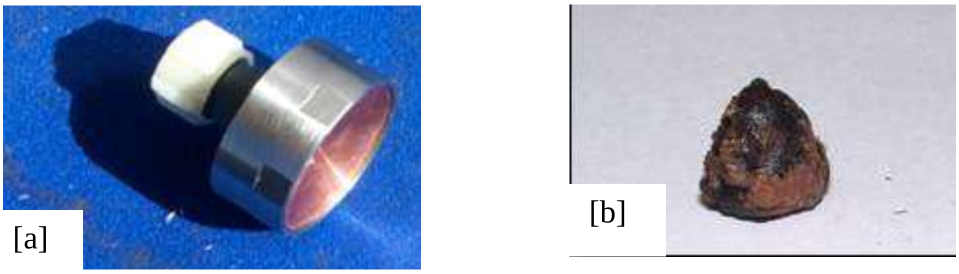

Figure 5– MFI EFP charge [a] and recovered fragment [b].

The warheads were attacked with an EFP projectile travelling at 1830 m/sec in the unpackaged and packaged configuration.
Both warheads exhibited a burn reaction in the packaged configuration, however the BIC detonated in one of the unpackaged tests.

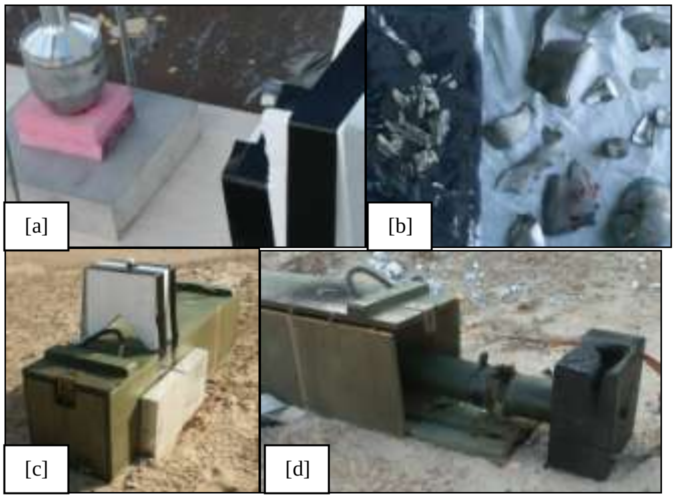

Figure 6 – Component level Modified Fragment Impact test setup and results for unpackaged BIC [a],[b] and packaged FTB [c],[d]

The significance of the composite launch tube and packaging to decelerate the fragment to a safe level is evident in the modified fragment impact test. The fact that the package contained all the warhead remains also helped in analyzing the test results.

Slow Heating

The test was conducted in a "stand alone" configuration on the FTB, BIC and propulsion system.
The warheads were tested individually and unassembled. Both showed a burn reaction at temperatures above 180ºC

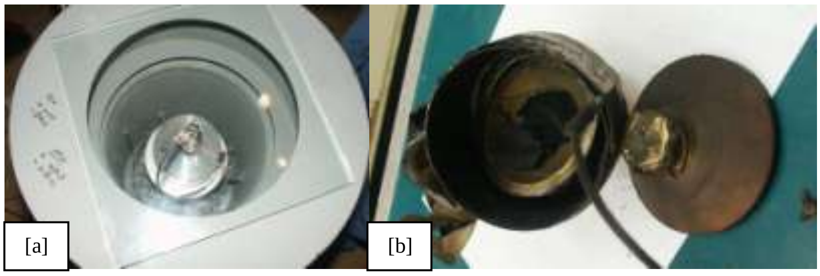

Figure 7 – BIC component level slow heating test setup [a] and results [b]

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

Since the propellants react at lower temperatures our focus was turned to the propulsion system. The propulsion system is based on the "Davis-Gun" principal in which the projectile's acceleration at launch is balanced by a countermass. The design approach was to ensure that the countermass had burst and dissipated before any reaction in the propellants occurs. This was achieved through the use of a proprietary liquid countermass.

A preliminary countermass design was put to the test with a dummy-projectile and live propellants. The propellants reacted at approximately 135ºC but did not propel the system more than a few meters.

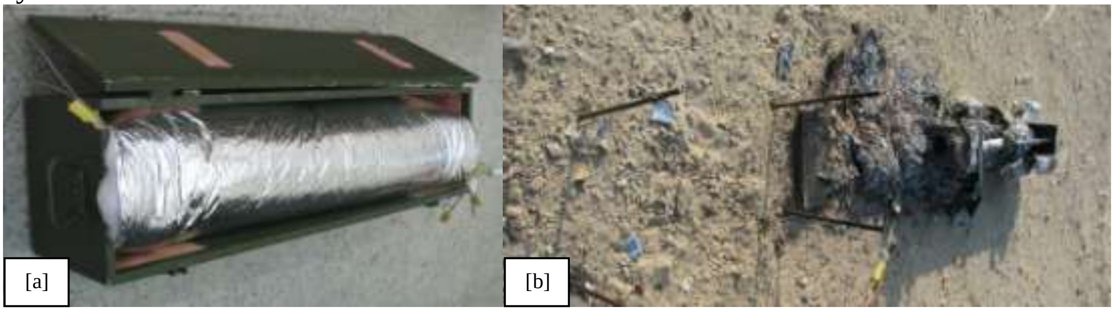

Figure 8 – Propulsion system preliminary slow heating test setup [a] and results [b]

Fuel Fire

The test was conducted on the propulsion system in a similar manner to the slow heating. Again, the liquid countermass dissipated before the propellants reacted so the reaction did not launch the projectile.

In this test the mechanical failure of the composite launch tube also contributed to the success of the test.

AUR Testing

The next and final stage in the IM program was All-Up Round (AUR) testing as part of the full system qualification. The results of the preliminary tests as well as results from similar munitions were evaluated to finalize the test setups – mainly to determine fragment aim point and the sympathetic reaction donor design.

The following tests were conducted:

Fragment Attack

The test was conducted on unpackaged and packaged systems. The point of aim was considered the highest risk as identified from tests in the preliminary stage i.e. the BICs booster.

In the tests the fragment was accelerated in a powder gun and had the shape and material in conformance with the STANAG requirements. The fragment hit velocity was 2500m/sec.

Four tests were conducted (2 unpackaged and 2 packaged). In one of the unpackaged system tests detonation of the BIC occurred. This result was anticipated from the preliminary stage where an 1830 m/sec fragment had caused a detonation of an unpackaged warhead. In previous work [3] and in the preliminary tests we demonstrated the contribution of the composite launcher to mitigate the fragment energy, but even when this is taken into account, sufficient deceleration has not occurred to reach a safe level.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

When the packaged system was subjected to the same test the reaction was declared as type V. This improvement in results is most probably due to the additional contribution of the packaging in mitigating further fragment energy.
The reaction was graded as type-I for the unpackaged round and type-V for the packaged round.

Slow Heating

The Slow Heating Test was conducted with a packed AS in accordance with STANAG 4382 using a 3.3°C per hour temperature rise until a reaction occurred. For this test the packed AS was placed in an oven (rather than the just the launcher as was done in the preliminary test).
The reaction started at an oven temperature of approximately 145ºC. The results indicated that no significant detonation occurred, a fact confirmed by the lack of a trigger function from the piezo blast pressure sensors and the photographic evidence that showed the weapon was consumed in place by fire.

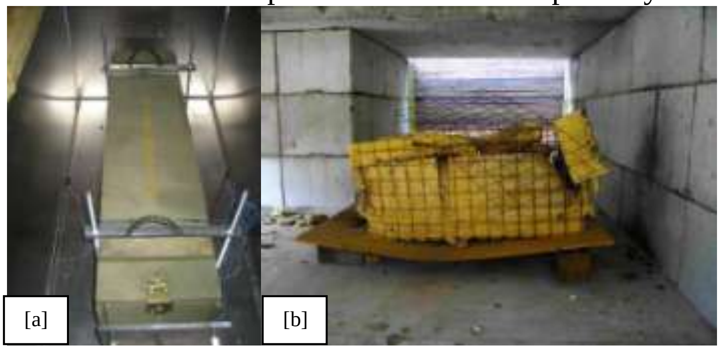

Figure 9 – AUR Slow heating test setup [a] and results [b]

An important insight in this test is again the significance of the packaging mitigation: the reaction temperature as measured on the side of the launcher was approximately 130ºC (similar to the preliminary test) however the oven temperature was 15ºC higher. This temperature difference, caused by the insulation properties of the packaging, is equivalent to an extra 4.5 hours in the time to reaction. This means an extra 4.5 hours for firefighters to overcome the fire which has caused the slow heating scenario in the first place.
The reaction was graded as type-V.

Fast Heating

Two Fast Heating Tests were carried out in accordance with STANAG 4240 – one was conducted on an unpackaged AS and another on a packaged AS.

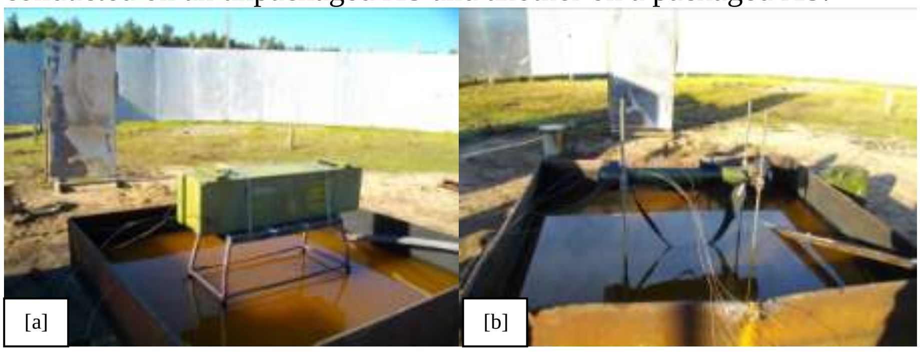

Figure 10 – AUR Fast heating test setup for packaged [a] and unpackaged [b] configurations

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

In both tests the first reaction that occurred was a burn reaction in the BIC. The burn caused a pressure buildup in the BIC structure and led to the expulsion of the BIC out of the hearth where it completed its burn. The propellant reaction, which occurred later, did not result in the launch of the projectile.
Again, no overpressure was recorded and the photographic evidence which showed that other then the BIC, the AS stayed in place.
The reaction was graded as type-IV.

Sympathetic Reaction

The final test was a Sympathetic Reaction (SR) Test following the guidelines in STANAG 4396 with the purpose of categorizing the type of reaction the AS acceptor weapons may have suffered. Four Acceptor weapons were used. Each one was painted in a different color for recognition purposes. The Donor weapon was painted red and was modified to allow the FTB to be triggered directly via an electric detonator. The pallet was assembled with a 2mm Aluminum Witness sheet placed between the bottom and second row.

Figure 11 – AUR sympathetic reaction test setup

The donor weapon detonated successfully and the pallet was destroyed in the blast. The acceptor and ballast weapons were thrown to distances of up to 70 meters from the blast point. However none of the acceptor weapons reacted in any way. The reaction was graded as type-V.

Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il

Summary and Conclusions

The following table summarizes the AUR test result or IM signature of the AS:

	FI	BI	SCO	FCO	SR
Unpackaged	I	V	V	IV	NA
Packaged	V	V	V	IV	V

Table 2 – AS IM signature

As can be seen in Table 2 above, most of the test results were type IV/V reaction. The only type I reaction appeared in a 2500 m/sec fragment attack aimed at the BIC's booster in an unpacked configuration.

IM issues were taken into account at the very beginning of the design which led to the implementation of key features in the design such as advanced cure-cast explosives and a liquid countermass.

The early attention to the IM issues helped achieve a roadmap for IM compliance.
Looking at all the results gathered in a "full body of evidence" approach gives us a better understanding and greater confidence in estimates of the systems insensitivity.

The contribution of packaging to the success in meeting the IM requirements is meaningful both as a fragment blast shield as well as an insulator. Packaged / unpackaged configurations for each scenario must be considered at the THA stage.
The AS is now a qualified weapon system in active service.

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Tal Eliash
RAFAEL-MANOR-Advanced Defense Technologies
talel@rafael.co.il