PROGRESS ON INSENSITIVE MUNITIONS TECHNOLOGY APPLICATION IN THE WEAPON SYSTEMS ENVIRONMENT IN SOUTH AFRICA

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South Africa has over the past decade and half, provided insight into the Insensitive Munitions (IM) Philosophy, then Policy development and finally Implementation to the IM community. The inferred increasing tempo of operations in Africa, required in part by the recently approved South African Defense Review necessitates that the South African National Defence Force (SANDF) be equipped with effective weapons that provide minimal collateral damage. Due to the relative small defence spending, coupled to tight schedules of the acquisition programs, and rapid procurement, the IM application of technology in Weapons programs has faced challenges. Despite this, the progress South Africa has made in the medium caliber weapons, infantry systems and missile development area ranges from incremental to exceptional. The paper will discuss, on a technology readiness level, the progress made to identify the maturity of the IM technology. Insight will also be given in terms of the energetic material and the various critical sub-assemblies. The overall IM system performance will be highlighted on a selective basis. The intention of the paper is to provide a broad overview only.

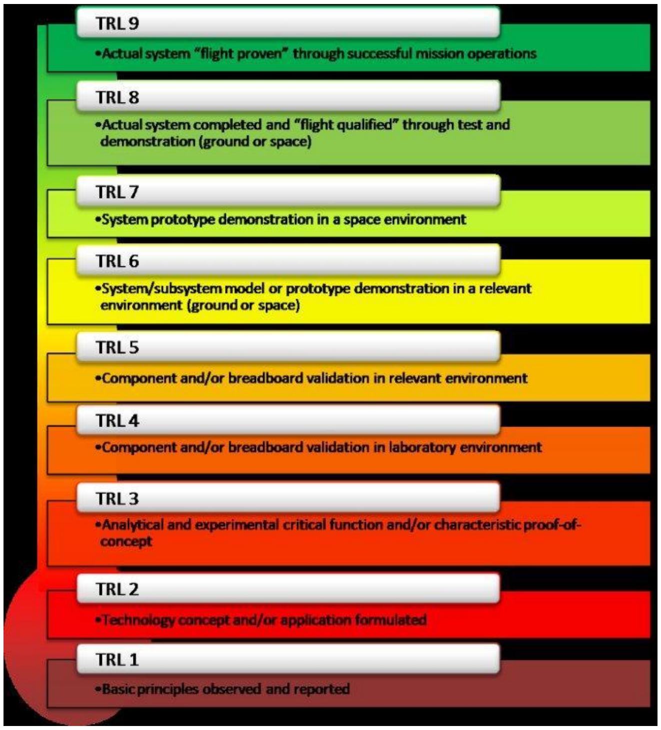
INTRODUCTION

Weapon Systems Project Managers are continually faced with the challenge of delivering high quality, operationally effective and suitable product systems within a tight schedule. At times, the client's budget priorities does not allow for "disruptive technologies"[1]. This is very typical of the defence sector in general with a constrained budget in the tough economic conditions and long term acquisition processes, where operational requirements are given priority. Consequently, there is a considerable "pull" towards sustainment of current technologies. Given this context it is important to look at the progress on IM that may be regarded as "disruptive technology" by some circles.

[1] Clayton M Christensen. "*The Innovator's Dilemma*", Harvard Business School, 1997

In order to set the tone, the technology readiness level (TRL) will be briefly introduced thereafter the discussion commences with an arbitrary selection of weapon systems employed in South Africa across all arms of service, to show progress in terms of IM technology application.

Figure 1: Technology Readiness Level[2]



Progress can be somewhat subjective, so in order to be objective, the NASA TRL is utilized as the scale for evaluation of progress. To be relevant to the defence acquisition environment, the word "flight" can be replaced by the word "operationally" in the adjacent figure.

DISCUSSION

<u>Umkhonto Surface to Air Missile System</u>[3]

Umkhonto is a Denel Dynamics vertically launched Imaging Infrared missile system from either a naval platform (deck penetrating) or a Ground Based Launcher (GBL) which is based on a 20ft ISO container footprint for logistic agility. This missile is capable of engaging air targets within a 20km radius.[3] A recent GBL firing successfully demonstrated the above capability to an international audience at Overberg Test Range (close to the Southernmost tip of Africa) during 2013.

[2] http://www.nasa.gov/content/technology-readiness-level/, March 2015
[3] http://www.deneldynamics.co.za/, March 2015

Umkhonto Warhead

The Umkhonto program was one of the leading programs to look into IM warhead demonstrators. The conventional warhead is RDX based pressed PBX, whereas the IM High Energy (HE) demonstrator is a new generation RDX based pressed PBX with an alternative binder that is STANAG 4170 qualified and fully industrialized[4].

The IM HE demonstrator is a replacement for the current warhead and the performance results are consistent with the current conventional fragmentation warhead. The retrofitting of warheads is possible with sub-system level detonic chain modifications should it be required by the customer. This is regarded as exceptional progress and on a TRL level of 6.

Umkhonto Rocket Motor

The rocket motor is low smoke for reduced IR signature based on the traditional "workhorse" which is HTPB (hydroxy-terminated polybutadiene) that may be susceptible to thermal threats due to its inherent characteristics. However due to the system level comprising of a composite filament wound casing that "melts" below the rocket ignition temperature - allowing for a burning reaction; this slow heating vulnerability is effectively mitigated. Current alternate propellant formulations locally produced that show reduced vulnerability on an energetic material level are either hydroxy-terminated polyether (HTPE) or hydroxy-terminated polycaprolactone (HTCE) based[5]. These formulations can be applied in replacement of the conventional rocket motor should it be required by the customer and is on a TRL level of 6. The latter two technologies may be regarded as disruptive; however the sustainment of the existing HTPB technology does not pose any additional threats on a system level.

Vertical Launch Canister (VLC)

The Umkhonto missile system is traditionally utilized in deck penetrating naval platforms. However the VLC is made up of Stainless Steel or Composite Material as the Umkhonto can be utilized in smaller size naval or coastal patrol vessels as well as for land based launch applications. This offers protection against mechanical threats, typically small arms fire or fragment impact.

[4] Christo du Toit, "*IM Technology options for Umkhonto PBX",* Presentation - Rheinmetall Denel Munition (RDM), July 2007

[5] Deon Van Zyl et al, "*IM Technologies and Ammunition in RDM",* Poster - Land Warfare Conference - Australia, Oct 2012

A-Darter[3]

A-Darter is a Denel Dynamics fifth generation imaging infra-red (IIR) short range air-to-air missile (SRAAM) system integrated on the wing tip of the JAS-39 Gripen Type C and D fighter through a bi-lateral venture with Brazil. Work is already on way for integration onto the HAWK Mk 120 Lead in Fighter Trainer (LIFT) following on the success of the Gripen integration.

A parallel technology program during the A-Darter development some years ago was enhanced to look into inter alia IM for air-to-air missile and steel casing technology applications to ensure that future upgrades, where necessary, shall ensure fully IM compliant solutions. In the meantime the A-Darter is fully characterized (in other words the IM signature was determined) on system level.

As a "disruptive IM solution" a Thermally Initiated Active Mitigation System Device (TIAMS) was developed to combat slow heating tests for the A-Darter steel casing, which is initiated at 140˚C and shows a Type V burning reaction as an option[3]. This is a "strap on" solution that can be employed as effectively an aftermarket device to reduce the vulnerability of existing rocket motors of customers. This is especially important as many nations are considering re-visiting their existing inventory and prioritizing IM solutions based on their conducted Threat Hazard Assessments (THA). To this regard, the TIAMS can be applied during long term and forward storage and be removed just before flight, which is a cost effective solution to mitigating the IM threat of slow heating during storage; where the threat is most prominent during its life cycle.

The current fragmentation conventional pressed PBX with maximum HE performance is highly effective and has been optimized for the threat and target scenarios. The IM variants evaluated are several reduced sensitivity PBXs which have improved vulnerability[6]. This is regarded as exceptional progress and on a TRL 6. This is especially so as the missile is extremely agile coupled with the relative extreme environmental requirements that needs to be met.

[3] http://www.deneldynamics.co.za/, March 2015
[5] Deon Van Zyl et al, "*IM Technologies and Ammunition in RDM",* Poster - Land Warfare Conference - Australia, Oct 2012
[6] Christo du Toit, "*IM Technology options to Armscor for A-Darter PBX",* Presentation - Rheinmetall Denel Munition (RDM), July 2007

Ingwe Anti-Tank Missile System[3]

The Denel Dynamics Ingwe Anti-Tank missile is a highly agile laser beam riding missile (non-jammable) and is capable of penetration of 1 000mm of RHA after one ERA due to its creative tandem warhead design[3]. It is employed on land vehicles like the Ratel and the new Infantry Fighting Vehicle variant and on helicopters. Depending on the application, an advanced stabilized optical (thermal imaging) and auto tracking system is available which is currently employed on higher valued assets. Alternatively a cost effective robust tripod application is also available.

Ingwe Warhead

IM shape charge concepts were explored aggressively from early 2007 for the Ingwe application. Based on this intervention, the project plans to industrialize the IM shape charge variant by end 2017 where there is technology insertion. The promising PBX IM candidate is a reduced sensitivity PBX formulation[7]. This is exceptional progress and is on a TRL 7.

76/62 mm SA Navy Compact Gun[8]

The SA Navy employs the 76/62mm as the Main Gun Weapon on its Frigate Small Guided platforms. This is a highly capable Oto Melara gun, and from a suitability point of view, the gun is reliable and supportable. A wide range of ammunition types is locally produced with quick turnaround time to support the various threat and target scenarios.

[3] http://www.deneldynamics.co.za/, March 2015

[7] Ben Smit, *"Ingwe presentation to Armscor"*, Rheinmetall Denel Munition, Feb 2007

[8] Sarel Janse Van Rensburg, "*76/62mm IM packaging*", RDM, Feb 2014

Figure 2: 76/62mm ammunition types [9]

- PRAC & TP
- PRAC AA FLASH
- TP/T
- HE (PLGD, FZD PD, FZD PROX)
- HE PFF (PLGD, FZD PD, FZD PROX)

76/62mm Packaging

The packaging plays an important role in mitigating sympathetic detonation. The SA Navy employs the mono-pack which is an aluminum container. During sympathetic detonation tests a "*type V (no reaction) was obtained and this is because the transfer of the detonation from the donor to the acceptor was mitigated by the aluminium wall of the mono-container that deformed and absorbed some of the energy. This prevented the violent reaction. It is evident that just by changing the packaging that IM can be achieved on a system level*" [10]

Figure 3: Sympathetic denotation results in packaged configuration (mono pack) for 76/62mm [10]

76/62mm Propellant

The current propellant for the 76mm ammunition types is the S760 which is a very suitable propellant in terms of mechanical and chemical properties. In fact, finding an IM alternative with such superb properties was a significant challenge for the local ammunition manufacturer as any compromise on especially the mechanical properties for these high set-back ammunition is a no-go area for the client. The most stringent of small scale IM tests is the shape charge jet impact test; however the EMTAP tubes shape charge jet impact may be a good start for screening of candidate formulations. During the initial phases of IM formulation options "*only DEGN and TEGN gave reactions better than deflagration and DEGN and TEGN formulations passed all IM tests and were further evaluated as S760 replacements*[11a]"

[9] Derek Pentz, "*Conversion of 76/62mm to STANAG and/or IM STANDARD*", RDM, May 2011

[10] C.M. Brijraj, F.C Fouché, *"South African Navy 76/62mm Ammunition Evolution from Prioritization to THA to Characterization and eventually IM Compliance*", Presentation - IM&EM Technology Symposium –Tucson AZ, May 2009

[11a] Charles Weihahn, "*IM Gun Propellants"*, Presentation - IM Workshop South Africa, RDM, May 2011

Figure 4: EMTAP tubes shape charge jet impact test results on promising IM 76/62mm gun propellant formulations[11a]

DEGN

TEGN – Solvent Process

The above propellants, although good IM candidates, did not meet all the requirements for a “green” formulation. This is an especially important requirement during inter alia, lot acceptance for the client due to the close proximity of personnel during these tests. Hence subsequently to this a “green” and IM compliant propellant, designated SSE-52 by Rheinmetall Denel Munition has been STANAG 4224 and STANAG 4170 qualified. Full scale IM testing of the propellant in 76mm rounds were performed (with an inert primer and practice shell) and the SSE-52 propellant complies with the IM requirements[11c]. The results are depicted in the Figure 5 below as far as STANAG 4439 requirements are concerned.

Figure 5: Summarised IM Test results[11b]

IM Test Summary[11b]						
	STIMULI					
Propellant	**Fast Cook-off (FCO)**	**Slow Cook-off (SCO)**	**Bullet Impact (BI)**	**Fragment Impact (FI)**	**Sympathetic Detonation (SD)**	**Shape Charged Jet (SCJ)**
STANAG 4439	**V**	**V**	**V**	**V**	**N/A**	**III**
SSE-52	**IV V**	**IV V**	**V / VI**	**IV**	**N/A**	**V**
S760	**III**	**IV**	**V**	**III IV**	**N/A**	**III**

The important requirements for propellant safety under STANAG 4224 include but are not limited to the following on the weapon/ammunition interface level: mean breech pressure, pressure standard deviation, initial negative differential pressure, weapon design pressure, maximum operating pressure and temperature/pressure sensitivity[8]. The IM progress in the 76/62mm propellant formulation is regarded as exceptional and world class as the SSE-52 is now a qualified Naval round as well as in the 76mm HE/T and PRAC/T rounds for the Rooikat Infantry fighting vehicle[11c]. This is exceptional progress and is on a TRL 7.

76/62mm SA Navy Compact Gun Fuze

The traditional fuzes employed are the M8953 proximity fuze and the point detonator (PD) M9030 with an exceptional high reliability. A local "new generation" fuze development was deferred during 2007 as it required combat suite upgrades in order to utilize the additional functionality, which is a costly exercise. In order for an IM fuze to be developed it will need to comply with STANAG 4187, STANAG 4170, STANAG 4363 and STANAG 4157 which is an extensive set of requirements. In doing so, "*the fuze will meet modern standards for safety, environmental resistance and functioning*[9]*."* The initial challenge was that the backward compatibility with existing stocks may not be possible due to the exploder system configuration needing to be changed apart from the explosive type that is used[9]. These are key system considerations that one must take into account when considering the IM option. "*The design of the fuze and the SAD has subsequently been successfully modified to comply with STANAG 4187 regarding arming and safety*[12]." The new explosive composition, used as part of the detonation train within the SAD has also been proven to successfully pass seal testing. The fuze is currently in the last stages of selection for energetic material within the booster assembly with only two candidates remaining and final trials to be conducted to select the optimal candidate to provide an IM fuze capability[12]. Following these final trials and material selection the fuze will be ready for qualification[12]. This is incremental progress on TRL 6.

[8] Sarel Janse Van Rensburg, "*76/62mm IM packaging*", RDM, Feb 2014

[9] Derek Pentz, "*Conversion of 76/62mm to STANAG and/or IM STANDARD*", RDM, May 2011

[11a] Charles Weihahn,"*IM Gun Propellants"*, Presentation - IM Workshop South Africa, RDM, May 2011

[11b] Charles Weihann, "76/62mm propellant IM feedback", Presentation- RDM, May 2014

[11c] Charels Weihann, "76/62mm propellant", email comments, April 2015

[12] Sarel Janse Van Rensburg, "*76/62mm IM fuze*", email comments - RDM, March 2015

AGL GLI-40[13]

The Denel Land Systems AGL GLI-40 is capable of throwing high quality grenades like the 40mm HEDP MO705 A1 HV IM at a rate of 320 grenades per minute over a distance of 2 000m and the High Explosive Dual Purpose (HEDP) round fired from the GLI 40 AGL provides anti-personnel shrapnel as well as a penetration capability of 50mm of armour plate even at a distance of 2 000m [13]

A series of IM tests were conducted by Rheinmetall Denel Munition on their locally produced 40mm HEDP MO705 A1 HV IM and following is an extract of the results obtained for the slow heating test.

STANAG 4382: Slow Heating, Munition Test Procedures for 40mm HEDP MO705 A1 HV IM[14]

Results[14]
Fair amount of pressure build up because of trapped air expansion.
No blast over pressure recorded.
Nothing thrown out of box.
Reaction confined to box and thus classified Type V.[14]

Figure 6: PA120 Box with 32 linked cartridges after test, in closed pos and with lid removed

Live round after test

A reduced sensitivity pressed PBX is used in the IM round in place of conventional CH6 main charge explosive. This is exceptional progress and is on TRL 7.

40mm Grenade Fuzes

There are currently two fuzes that can be employed which is the DM441 (locally produced) for the HEDP IM Self Destruct, or the STANAG qualified M0726A1 on Diehl HEDP IM ammunition from Junghans Microtec[15]. These fuzes are excellent to complement the IM rounds.

[13] www.denellandsystems.co.za, March 2015

[14] Paul Van Niekerk, "*IM Feedback on Rounds 40mm HEDP M0705 A1 HV IM*", IM Workshop South Africa, RDM, May 2011

[15] Gordon Blackbeard, *"Armscor-AMMS Junghans Fuze local production IM update"*, May 2011

CONCLUSION

A wide variety of local weapon systems are illustrated and it can be seen that IM technology application is present in all of them, from the superb 5th generation air-to-air missile with helmet mount interface, to the automatic grenade launcher for the infantry soldier on the ground. This has been achieved by a collaborative conscientious effort, and co-funding between the Department of Defence, foreign and local stakeholders. It is envisaged over the medium term that all the technologies mentioned will be up to a TRL 9, and when this is achieved the question will be again, should we sustain or disrupt?

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REFERENCES

[1] Clayton M Christensen. "*The Innovator's Dilemma*", Harvard Business School, 1997
[2] http://www.nasa.gov/content/technology-readiness-level/, March 2015
[3] http://www.deneldynamics.co.za/, March 2015
[4] Christo du Toit, "*IM Technology options for Umkhonto PBX*", Presentation - Rheinmetall Denel Munition (RDM), July 2007
[5] Deon Van Zyl et al, "*IM Technologies and Ammunition in RDM*", Poster - Land Warfare Conference - Australia, Oct 2012
[6] Christo du Toit, "*IM Technology options to Armscor for A-Darter PBX*", Presentation - Rheinmetall Denel Munition (RDM), July 2007
[7] Ben Smit, "*Ingwe presentation to Armscor*", Rheinmetall Denel Munition (RDM), Feb 2007
[8] Sarel Janse Van Rensburg, "*76/62mm IM packaging*", RDM, Feb 2014
[9] Derek Pentz, "*Conversion of 76/62mm to STANAG and/or IM STANDARD*", RDM, May 2011
[10] Cedric Brijraj, F.C Fouché, "*South African Navy 76/62mm Ammunition Evolution from Prioritization to THA to Characterization and eventually IM Compliance*", Presentation - IM&EM Technology Symposium –Tucson AZ, May 2009
[11a] Charles Weihahn,"*IM Gun Propellants*", Presentation - IM Workshop South Africa, RDM, May 2011
[11b] Charles Weihann, "*76/62mm propellant IM feedback*", Presentation- RDM, May 2014
[11c] Charels Weihann, "*76/62mm propellant*", email comments, April 2015
[12] Sarel Janse Van Rensburg, "*76/62mm IM fuze*", email comments - RDM, March 2015
[13] www.denellandsystems.co.za, March 2015
[14] Paul Van Niekerk, "*IM Feedback on Rounds 40mm HEDP M0705 A1 HV IM*", IM Workshop South Africa, RDM, May 2011
[15] Gordon Blackbeard, "*Armscor-AMMS Junghans Fuze local production IM update*", May 2011