TITLE: UK Soft Vertical Launch - A Flexible Solution to an Integral Concept for Ground & Naval Air Defence

UK Soft Vertical Launch - A Flexible Solution to an Integral Concept for Ground & Naval Air Defence

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Summary

The paper describes the need for versatile and flexible systems in supporting Crisis Reaction Forces, and the role that soft vertical launch can play in meeting that need. The concept of operation is described together with the configuration and results of a demonstration programme of live firings. Plans for continued development are outlined as is the vision for future operation.

Introduction

Current UK Air Defence (AD) systems were specified and designed during the cold war era. During this period the nature of any anticipated conflict was well defined and well understood. UK forces would be part of a NATO alliance defending Western Europe from advancing Warsaw Pact Forces. This then was a quasi-static battlefield situation with the enemy Concept of Operations (Conops) well understood. This in turn led to a well defined situation for air defence where the location of sites could be planned and, if necessary, surveyed.

In contrast, the situation now is completely different. The location of any conflict is unknown, the enemy and associated Conops is undefined. The level of intensity of combat is also unknown and therefore the requirement for AD is very difficult to quantify. What is known is that the sophistication of threat weapons, and the proliferation of such weapons, is increasing. Ownership of low level cruise missiles (LLCMs) and tactical air to surface munitions (TASMs) is becoming more widespread as is the military use of unmanned air vehicles (UAVs) for attack as well as surveillance. An increasing emphasis on making aircraft more stealthy will complicate the threat diversity.

Countering this range of air threats makes the task of the air defender complex. Add to this the requirements to reduce defence spending and the system designer is faced with a dilemma – more performance is needed against a wider threat spectrum for lower cost.

Joint Operations of a Crisis Reaction Force

The evolving geopolitical and economic climate is making less probable the likelihood that any future conflict or dispute will escalate into major war. European forces are now more likely to become drawn into peace keeping operations and/or operations to defend a small friendly nation against a larger aggressor. The cost of such operations is however significant both in political and financial terms.

To meet this situation the concept of the Crisis Reaction Force (CRF) has been introduced. These CRFs may have to deploy at short notice, and at great speed to any location. This may be done under the control of NATO or an individual country. Especially for NATO operations the benefits of equipment inter-operability would be considerable in terms of cost and logistic re-supply.

For CRF operations, a joint operating area (JOA) is set up defining the battle space within which the Naval, Army and Air forces will operate. This necessitates control of information for situation awareness that, in turn, requires a pan NATO integrated communication system. Casualties in such operations are inevitable but must be minimised to make operations acceptable to the general public (voters) of the nations supplying the

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forces. The deployment of such a force therefore necessitates the appropriate layered defence system comprising surveillance sensors, fighters, surface to air missiles (SAMs) and passive defence measures to protect the joint assets. *Unless total Air dominance can be guaranteed absolutely then not to deploy such measures is politically unacceptable.*

Clearly, for weapon systems to be cost effective for occasional joint operations they need to be developed with extended Service Life and associated minimum Life Cycle Costs as primary design drivers; to do this the following criteria are considered as key:

- Commonality - weapons capable of being deployed by different service platforms.
- Inter-operability - joint services capable of deploying variants of common weaponry.
- Flexibility - meeting the increasing diversity of missions within the future operating environment.
- Modularity - to allow flexibility of capability within tightly constrained military budgets.
- Versatility - being able to deploy a weapon mix to meet the warfare requirements.

UK Approach

In 1993 the UK began to address the problem of what type of ground based air defence (GBAD) system would be needed in the future to protect battlefield assets against attack from this wide threat spectrum.

From the start it was considered unlikely that there would be any major advances in GW technology and that improvements in weapon performance are more likely to accrue through miniaturisation or better integration of proven technologies. Thus, if conventional weapons are to form the backbone of the next generation of AD weapons then it is essential that more cost efficient missiles and associated systems such as launchers are procured.

The UK research work evaluated, through a combination of system studies, mathematical simulation and bench testing, the key technologies needed for cost effective air defence. From the onset of this work the method of launch was identified as a key enabling technology. In particular, containerisation was seen as a key to creating a stable environment and thereby offering the potential of extended shelf life.

Via an iterative process, see Figure 1, the UK MoD research programme has now identified the key technologies for GBAD and has now embarked on a series of demonstrator programmes to prove these technologies and thereby reduce the risk of subsequent development.

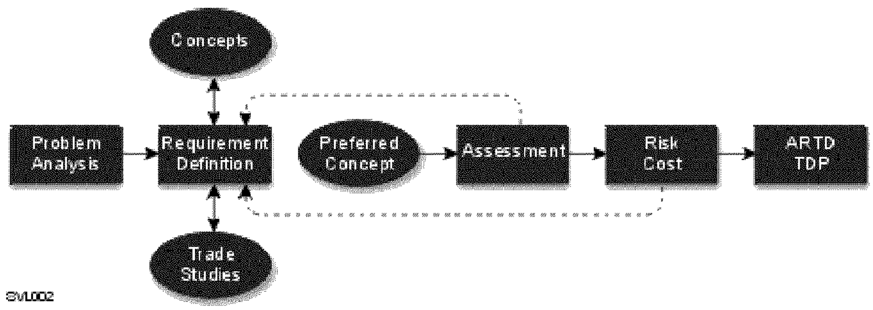


Figure 1 : Systems Approach

One of these technologies, soft vertical launch (SVL^{TM}), was seen as fundamental; the rest of this paper describes the UK implementation of this technology.

From the onset of this technology development, the SVL^{TM} programme has been a partnership between government and industry and thus is very much aligned to the new UK Smart Procurement Initiative.

Vertical Launch for AD

To counter the perceived future threat, ground based air defence (GBAD) missile systems will not only need a high single shot kill probability (SSKP) but also the ability to cope with saturation raids and provide a rapid re-engagement facility. High rates of fire and a large number of 'ready to fire' missiles are the consequence of this requirement. The requirement to deploy and re-deploy rapidly in a range of scenarios immediately pointed to vertical launch (VL) as an option to be considered rather than the more conventional trainable launch currently employed by UK ground forces.

The launch method and how it can impact on the cost effectiveness of the overall weapon system is described in Figure 2. This highlights the relationship between design and effectiveness showing how the launch method can influence the system architecture of the weapon, its flexibility, its performance, availability and cost. This in turn can impact on the system effectiveness, force mix and therefore cost effectiveness.

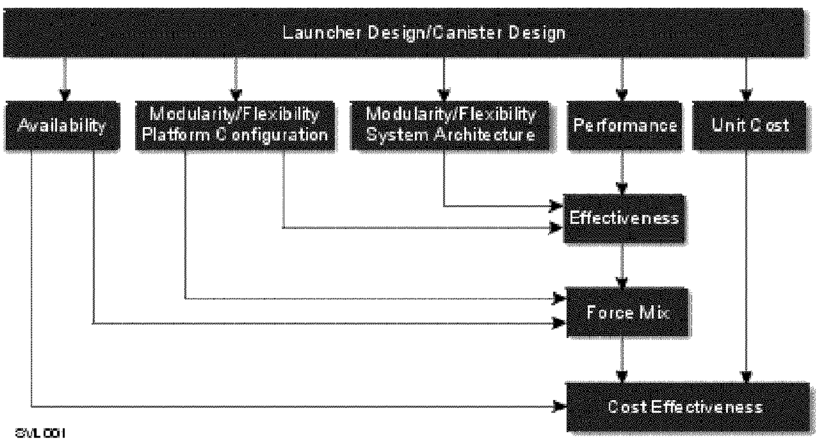


Figure 2 : Impact of Launch Method

A programme of work began several years ago where MBD carried out a combined system and operational assessment study for DERA into the application of VL to Army air defence. Vertical and trainable launch systems were compared. The work demonstrated that significant advantages can be forthcoming with the adoption of VL for the next generation GBAD systems –

- all-round, simultaneous, multiple engagement coverage,
- greater firepower for the same mass,
- lower overall mass, costs and improved A, R & M,
- deployment flexibility - no free line-of-fire required in front of the launcher,
- faster reaction times in the presence of all-round threats and rapid into action benefits,
- scope for commonality with Naval systems,
- more scope for planned product improvements,
- logical solution for large missiles.

The advantages offered by VL over traditional naval deck-mounted launchers were also applicable: VL enables more missiles to be embarked, provides an increased rate of fire and reduces 'topside' signatures.

However, there remained several disadvantages of VL for GBAD not least of which was the problem of efflux management. Alternative VL techniques were developed and evaluated by MBD in conjunction with DERA from which emerged the concept soft vertical launch. A follow-on study set out to investigate SVL™, comparing it with other VL technologies. The categories of VL are described below:

(a) Hard launch. For example, Vertical Launch Seawolf (VLSW), where the missile motor is ignited while the missile is in the launch canister. This approach requires efflux management. The missile accelerates rapidly and conducts turnover with a high vertical velocity component.

(b) Cold launch. In contrast to all other Western launchers, the missile rocket motor is ignited only after it has been “pushed” out of its canister and turned over. An example is the SA-N-6 that entered the Russian navy in the late 80’s on board Kirkov-class and Slava-class cruisers.

(c) Soft launch. SVL™ is akin to cold launch in that the missile rocket motor is ignited after it exits the canister, however missile ejection is more precisely controlled such that the missile is subjected to much lower launch loads and requires less energy to complete the launch and turnover sequence. The technique also offers the prospect of programmability of missile ejection characteristics. The technique has been developed by MBD in conjunction with DERA.

The systems approach to select a preferred VL method covered:

- operational requirements,
- missile system and kinematics,
- ground launcher system and platform interfacing,
- missile turnover system and capability,
- system effectiveness, and minimum range.

From the study a preferred option emerged. This is a canistered round from which the missile is soft vertically launched. This choice was shown to provide the most flexible, versatile, modular and operationally effective solution for a future, mobile GBAD system.

SVL™ Merits

Figure 3 illustrates the likely impact of SVL™ on a conventional vertically launched missile.

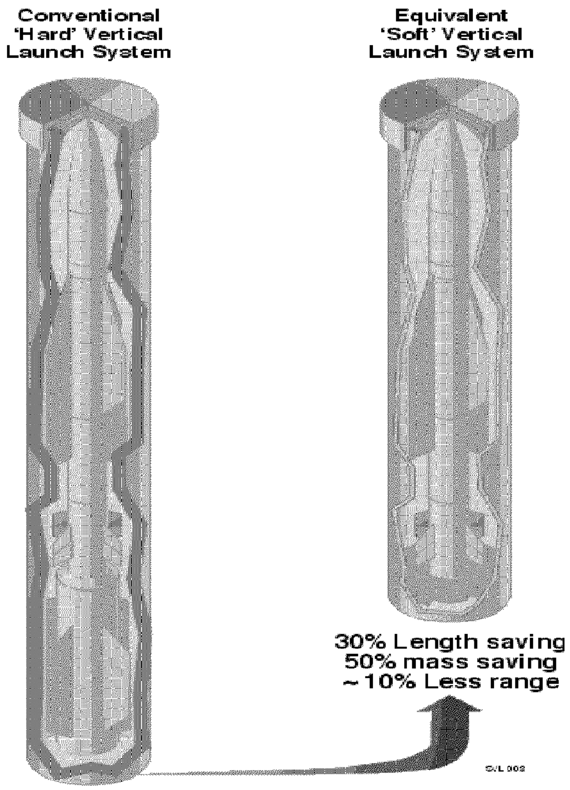


Figure 3 : Relative Comparison of SVL™ & HVL Missiles

The following is a brief benefits summary that SVL™ offers over conventional VL methods:

- Potential for reduced acquisition and through life costs.
- Longer maximum range (for a given mass when compared with hard VL).
- Army/Navy commonality.
- No efflux management requirements thereby improving the modularity and evolution potential.
- Can be a simple, lightweight construction and be placed in restricted spaces.
- No unwanted launch debris.
- Capable of reduced launch ejection loads.
- Improved minimum range capability due to a more direct turnover trajectory that can enable earlier target acquisition by the missile seeker.
- Reduced probability of disclosure of launch position due to reduced smoke trails and launcher heating.
- More benign environment for other platform mounted subsystems.
- Can be used to launch a variety of missile types and countermeasures.
- Capable of adaptation to horizontal launch of existing equipment

SVL™ - Concept Description

Soft vertical launch, in contrast to more conventional VL systems, ignites the rocket motor after the missile has been launched and directed towards the target. The GBAD concept is illustrated in Figure 4. The missile is ejected from the launch tube by a piston driven by means of hot or cold gas, similar to an ejection seat. MBD are developing a powered piston approach that allows the missile ejection to be more precisely controlled such that the missile is subjected to much lower launch loads and requires less energy to complete the launch event. The piston is caught and retarded before it leaves the canister.

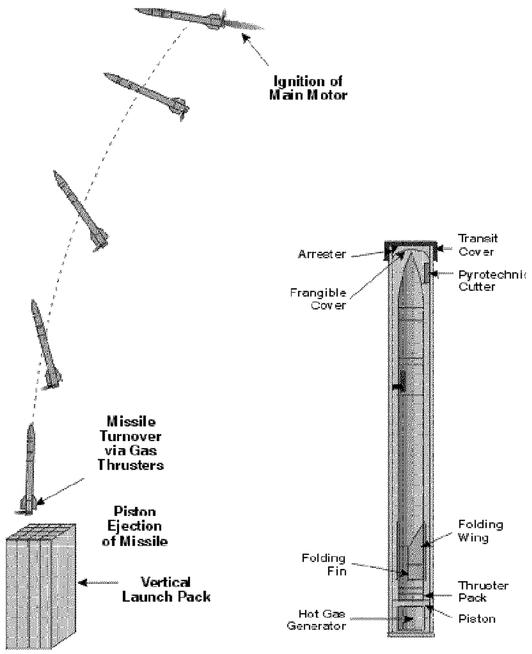


Figure 4 : SVL™ Concept

The ejection system imparts the missile with an exit velocity allowing it to achieve the optimum turnover altitude within the required time. All ejection effects are contained in the canister. All ejection loads are transferred through the canister down to the surface.

For GBAD, the missile is turned over towards the target predicted intercept point by means of a solid propellant, rocket powered, thruster providing lateral control in pitch, yaw and roll. Once turned over, the missile boost motor is then ignited. A smoother and more direct missile turnover is possible enabling rapid target acquisition, by the seeker, for minimum range engagements.

This approach eliminates the need for a complex efflux management system and a simpler, lightweight launcher can be used. This in turn means that there is no restriction to launch site or its proximity to ground troops. Deployment in urban areas is only limited by the requirements of surveillance and alerting devices.

The SVL™ launcher would consist of the tube with electrical interfaces for operation and test together with the ejector mechanism. This would be a unified design made in selected dimensions that could be configured to provide multiple launch containers. Once loaded with the missile the tubes would be hermetically sealed.

SVL™ - Concept of Use

For GBAD operations the launch containers can be deployed on a variety of standard UK Army vehicles, either tracked or wheeled. At the launch site these containers can remain located with the vehicle or be deployed remotely.

Alternatively, containers deploying canistered SVL™ missiles could be temporary structures on board ships. These containers could be transported with an amphibious force, or helicopter, for use on land. The container could therefore be deployed as a multi-role and multi-service launcher (see Figure 5).

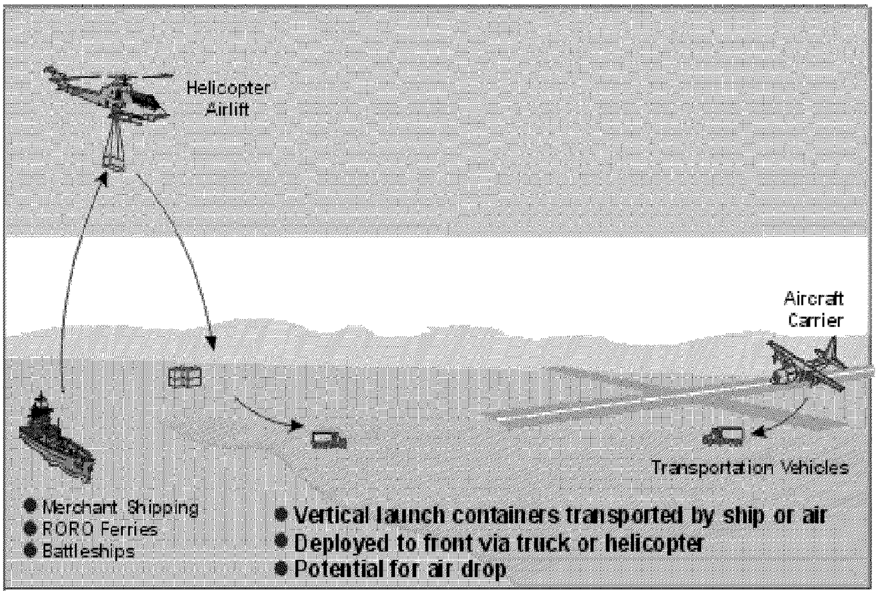
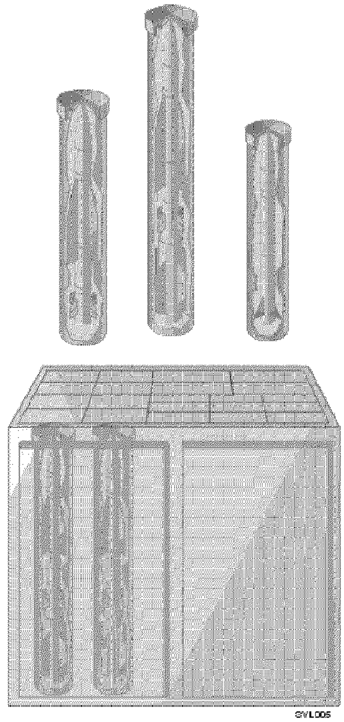


Figure 5 : Joint Service Use

SVL™ is a technique that can be used to launch short or longer range missiles of differing types, thus providing the potential for different threats to be engaged using the same launcher. It also has the potential to be used for horizontal launch of missiles from platforms that cannot accept a severe launch environment (blast, noise or heat) such as small craft and helicopters.

Thus SVL™ facilitates a more flexible response to target variety and offers the potential to change the weapons mix without affecting the overall configuration of the carrier platform. Figure 6 illustrates the concept for a SVL™ launcher that has been configured to launch a mix of weapons - short and medium range missiles, countermeasures, and potentially micro-UAV's.



Container configured to deploy different soft vertically launched missiles and countermeasure types

Figure 6 : Multi-role Launcher

Applied Research Technology Demonstrator

In 1997 the Soft Vertical Launch Applied Research Technology Demonstration (ARTD) programme was initiated by DERA Farnborough and carried out by MBD.

SVL^TM^ ARTD - Phase 1

The aims were to demonstrate the proof of principle of soft vertical launch, and examine the applicability of the approach to larger missiles.

The technical approach to be demonstrated was similar to that described in the previous section. Missile turnover to a near horizontal attitude had to be achieved within a height of 30m, in 1 second.

A low cost, re-usable, cold gas, launcher was developed to soft vertically launch a 60kg SHORAD representative missile from a fixed ground location. Following launch the missile was to be turned over to near horizontal by means of a solid propellant, rocket powered, thruster providing lateral control in pitch and yaw. Once turned over, the missile was to be held at a selected heading and attitude by the thrusters.

The autonomous missile control system used to carry out the turnover sequence included proven, off-the-shelf, ASRAAM technologies - the inertial measurement unit and missile processors. Available hardware provided a low risk, quick and low cost method of demonstrating autonomous missile control. The required heading and attitude were communicated to the missile during the pre-launch sequence.

Pre-trials activities required the use of mathematical models and MBD's Synthetic Environment (SE) tools to predict the behaviour of the missile and its subsystems. A simulation based visualisation of its predicted pre-trial behaviour is shown in Figure 7.

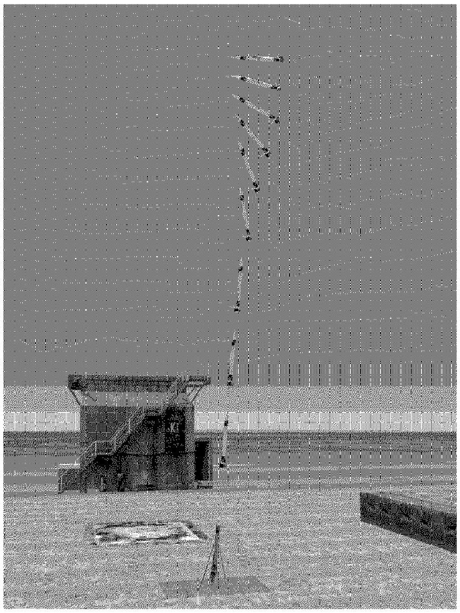


Figure 7 : Synthetic Environment SVL™ Prediction

A photograph of the missile flight from one of the three successful SVL™ firings at a UK trial's site is shown in Figure 8.

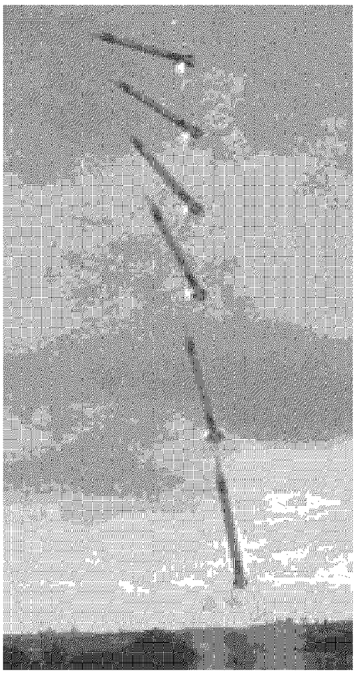


Figure 8 : SVL™ Demonstration Firing

The ARTD demonstrated the vertical launch of a 60 kg missile without the need for efflux management. Soft launch was achieved using a simple and compact launch tube. The ability to control the missile velocity and acceleration during the stroke length was demonstrated and the launch event clearly subjected the missile to relatively reduced launch loads that can benefit both missile and platform (see Figures 9 & 10).

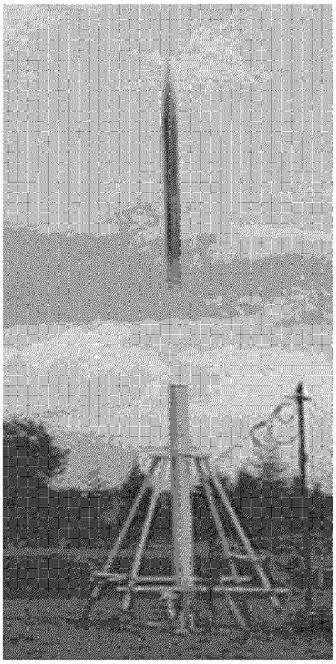


Figure 9 : SVL™ Launch Phase

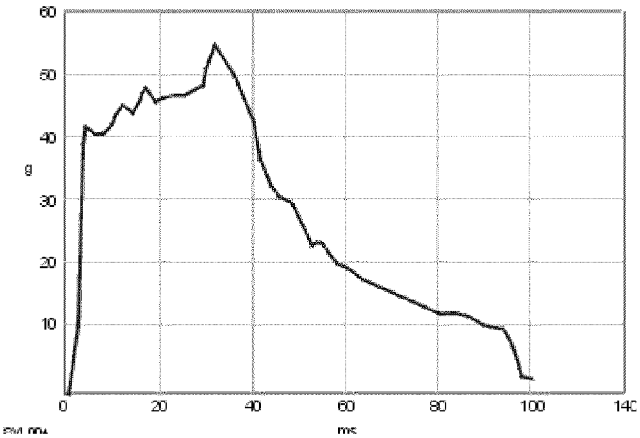


Figure 10 : Launch Accelerations

The successful launch of the missile using the basic piston approach also provided confidence for the future development of enhanced piston concepts. A simple device retained the piston within the tube resulting in no launch debris. The launch event also produced a low acoustic and visual signature.

Turnover was successfully achieved using an existing MBD, 8-nozzle, proportional control, thruster design that was adapted for the SVL™ application. Once ejected each missile was turned over rapidly, and stable attitude control was demonstrated by the use of lateral thrusters only. The thruster design concept is clearly viable for the SVL™ application.

The complex manoeuvres performed by the missile under thruster control would be difficult to achieve using alternative technologies e.g. TVC.

Application of Synthetic Environments (SE)

MBD piloted the use of Synthetic Environment (SE) tools during the SVL™ ARTD to demonstrate its risk reduction potential.

SE was used to visualise the system behaviour early in the programme (see Figure 7). This aided both the customer and subcontractors to understand the concept of operation. It also assisted in resolving problems and reduced the risk in the early design stages, by providing a more visible solution.

SE also assisted in missile integration and test. By combining simulations with hardware-in-the-loop, SE was used to demonstrate 'virtual trials' by exercising the missile electronics and control laws. It was possible to stimulate the system to explore tolerances to external influences (wind and launch angle). The SE tool was used to conduct a virtual trial, twelve months ahead of the real trials.

This approach can potentially reduce the number of (costly) firing trials required.

During each firing the missile behaviour was monitored by means of a recoverable, onboard, flight recorder. This data was processed by the SE to provide a simulation 'replay' of the missile flight. This was compared with the actual trials data to provide a confidence check of system behaviour (see Figure 11).

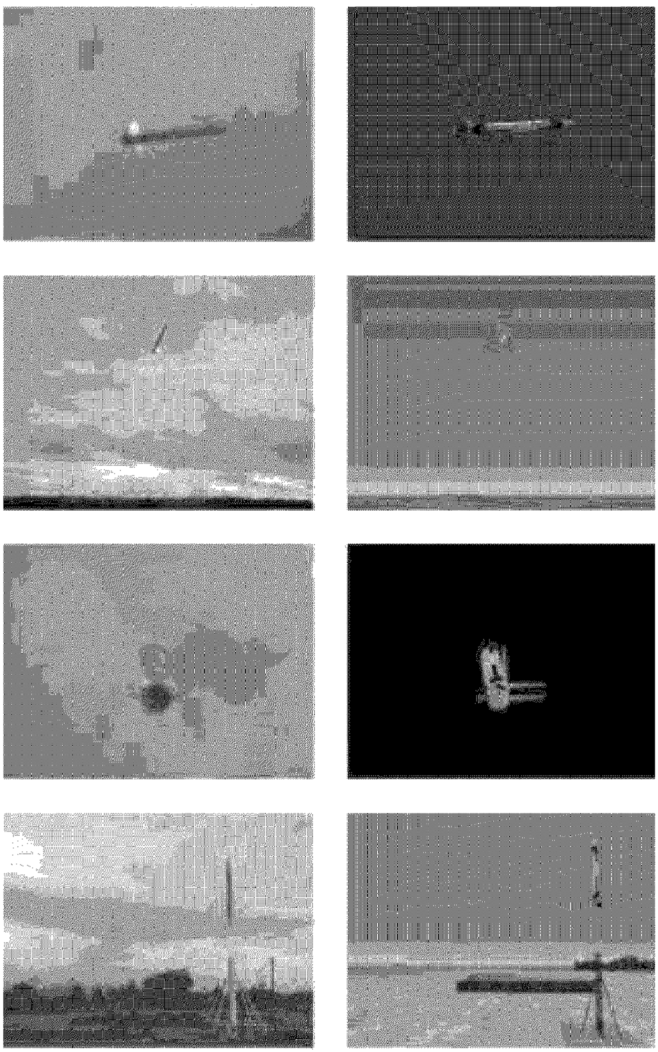


Figure 11 : Actual vs SE SVL™ Replay

Phase 1 Conclusion

The Phase 1 ARTD was a major success and clearly demonstrated the SVL™ principle and the viability of the concept for application to future ground-based and naval air defence.

A detailed system study also showed that SVL™, using the piston technique, is applicable to larger missiles - a 250 kg concept was analysed. Its use would enable such missiles to have a reduced minimum range compared to conventional VL methods, without compromising the maximum range capability. A Phase 2 ARTD then followed.

SVL™ Phase 2 ARTD

The aims of the Phase 2 demonstration are threefold and build on the successful work conducted during the Phase 1 SVL™ ARTD:

- To demonstrate the SVLTM technique using a hot gas powered launcher to eject a SHORAD representative missile.
- To demonstrate stable missile control transition following vertical launch turnover from thruster control at near zero speed to full aerodynamic control at missile speed.
- To demonstrate a flight weight missile turnover mechanism capable of pitch, yaw and roll control, and packaged around the missile blast pipe.
- To demonstrate virtual trials throughout system development using the Synthetic Environment application and measure its ability to reduce risks on programme costs and timescales.

This programme is being carried out by MBD for DERA Farnborough. Phase 2 is a three year programme and began early 99. Four soft vertically launched missile firings are planned during late 2001.

Technical Approach

The MBD SVL™ Phase 2 scheme is illustrated in Figure 12.

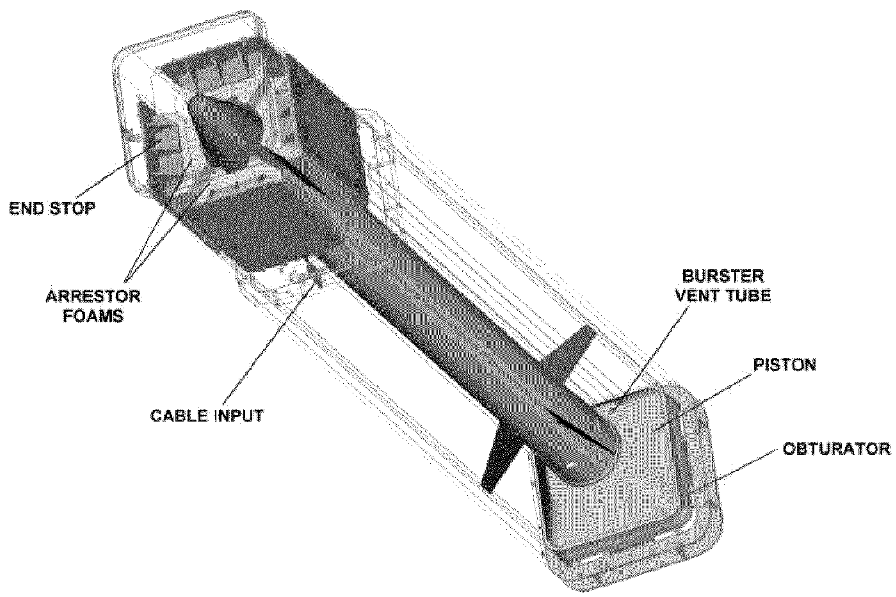


Figure 12 : SVL™ Phase 2 System Configuration

The 65 kg missile will be ejected vertically from a lightweight, tube using a hot gas powered piston technique. A square tube, desirable from both design and logistic standpoints, is made possible due to low launch pressures resulting from the novel SVL™ technique being developed by MBD. Hot-gas is proposed as the energy source where long-term standby is required, and where a one-shot device is more appropriate.

On initiation, the gas pressure, augmented by thrust, forces the piston upwards ejecting the missile. The piston, sliding within the launch tube, is caught and retarded at the end of its stroke. The ejection system imparts an initial velocity (of approximately 30 to 40 m/s) to the missile allowing it to reach the required turnover altitude and velocity within the specified time constraint (approximately 1 second from missile first movement).

The missile will incorporate a lateral thruster system, containing 8 thrusters in linked pairs to provide pitch, yaw and roll control, which will be initiated on exit from the launch tube. The thruster unit will be powered by an independent, annular, on-board gas supply and actuated via linkages to the fin servo system.

When the missile reaches the required height the boost motor will be ignited and during the initial phase of flight a stable handover in missile control from the thruster system to the fin actuation system will be demonstrated.

The missile will contain the ASRAAM missile electronics, inertial measurement unit and fin actuator.
MBD are extending the use of SE to demonstrate both virtual 'static and dynamic hardware-in-the-loop' trials. Its application will be monitored to measure its ability for reducing risks on the programme cost and timescales.

SVL™ Vision

SVL™ is a new and alternative vertical launch approach that has operational and integration advantages that will benefit ground based and naval air defence systems for joint operations.

It provides logistic efficiency through containerisation, can be platform independent and provides for a flexible, lightweight, responsive firepower system.

The technology offers the potential for a new generation of compact, lightweight, vertical launch missile systems that can be used with towed and self propelled vehicles, The launch packs can be integral with the vehicle, located with the vehicle or be deployed remotely (see Figure 13).

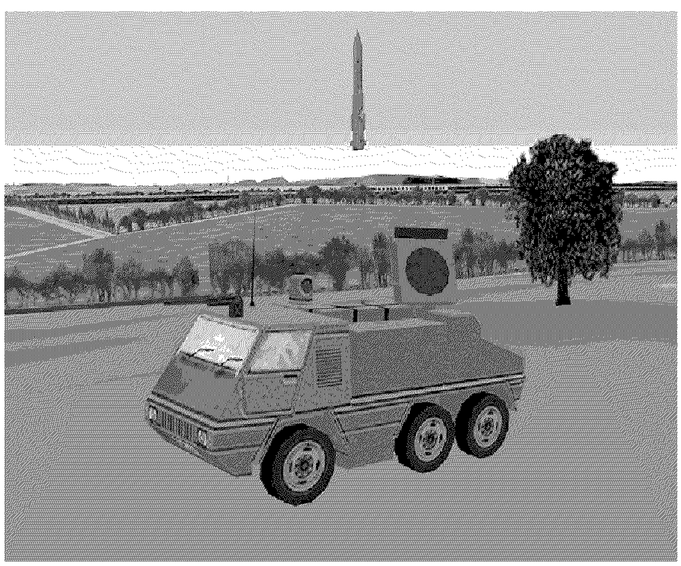


Figure 13 : SVL™ Integral with Vehicle Option

A potentially attractive concept is the possibility of launching SVL™ munitions from within transportable, modular containers that are appropriate to sea and land platforms allowing for commonality.

SVL™ launchers are particularly applicable to ships taken up from trade (STUFT), as well as fighting and support ships, because of the potential SVL™ offers for lightweight and modular structures that can be temporarily fixed and then removed. These structures have the added advantage of being able to be transported with an amphibious force, or helicopter, for use on land.

It is a technique that can be used to launch a mix of weapons using the same launcher. This facilitates a more flexible response to target variety and offers the potential to change the weapons mix without affecting the overall configuration of the carrier platform.

Standard ISO containers could be packaged with a weapon mix of encanistered SVL™ munitions from which the appropriate missile, countermeasure, and possibly micro-UAV, could be launched. The ISO container could include both the missile, and a fire control system with links to the navigational system and communications.

Alternatively, the fire control system could be housed in another ISO container and an interface with the navigation and link data system would be required. For fighting ships an interface to the ship weapon control system would be required.

In summary SVL™ technology offers many benefits compared with the current launcher systems available. The technology provides the opportunity to provide a flexible response system to the commander in terms of positioning of weapons, quickness of response and versatility in weapon load.

Conclusion

In order to meet the increasing requirements for the engagement of modern air-attack assets, the effectiveness of systems deployed by joint forces must be configured to provide a multi-purpose and multi-service capability.

SVL™ has the credentials to be considered as an enabling technology to satisfy this capability. Ground based and naval air defence weapons can potentially reduce their overall weapon life cycle costs by adopting the comparatively lower cost, lightweight and compact launcher configuration. The concept provides for a minimal required force structure, consistent with low manning deployment. By being modular, it can be appropriated for land and sea applications and would require less maintenance costs compared with hard VL systems.

The potential application of SVL™ on various types of ground based and shipping platforms, e.g., towed and self-propelled vehicles, military fighting ships, support and patrol ships and logistical support ships, indicates an initial role of SVL™ for point defence in the context of VSHORAD/SHORAD, ILMS and FILADS and could be expanded if required due to the versatility of the launcher.

Patents are pending to cover the method and technologies employed on SVL™.