Appendix 2

Observations on Hizbollah Weaponry

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The Second Lebanon War aroused much discussion as to the weapons harbored and employed by Hizbollah. The following essay offers some observations on the technical aspects of the weapons used by Hizbollah during the war and their ramifications.

Rockets

Hizbollah's use of rockets against Israeli civilian targets was the organization's most consistent and blatant aggressive measure during the hostilities, and in general, rockets took on new strategic importance during the Second Lebanon War. According to figures supplied by the Israeli police, 3,970 rocket landings in Israel were recorded, with an average of over 120 rockets each day during the thirty-three days of hostilities (table 1). Hamas also uses a similar weapon, although far more primitive, and fires it from Gaza into nearby Israeli towns.

Table 1. Rocket Landing and Casualty Data (according to Israeli Police)

Galilee (Acre to Kiryat Shmona)	3,530 launches
Coastal region - (Acre to Hadera, including Haifa)	221 launches
Valley region (Tiberias, Bet She'an, Afula)	217 launches
Samaria region	2 launches
Total	3,970 launches
Launches into populated areas	901 launches
Home front casualties	2,412
Deaths (of the total number of casualties)	52
Shock (of the total number of casualties)	1,318

Rockets are used by regular armed forces for special purposes only, and do not appear in any military as the backbone of artillery support. Militaries continue to rely on towed or self-propelled artillery. Hizbollah, however, prefers rockets for several reasons. First, rocket launchers are simple to produce and operate. A rocket is launched from a thin barrel or rail that is not heavy or rifled like a cannon barrel. Unlike an artillery shell, there is no recoil, and therefore it does not require the complicated recoil absorption mechanism of cannons. Many launching barrels can be mounted on a light truck or jeep, and a single launching barrel can be placed on the back of an animal or even a soldier. Second, artillery rockets provide firepower coverage for greater ranges than standard artillery: unguided rockets are generally effective up to 100 km. Warsaw Pact armed forces used FROG-7 rockets for ranges of up to 70 km. Even today weapon systems such as the Russian Smerch system (for ranges up to 70 km) or the Chinese WS-1B system (which boasts a range of up to 180 km) are manufactured. Third, artillery rockets provide rapid and dense cover: a Russian BM-21 launcher, for example, is capable of firing forty 122 mm rockets in less than a minute.

At the same time, artillery rockets have an inherent set of disadvantages. Rocket weapons are far from accurate: a reasonable level of accuracy is a range dispersal of between 1-1.5 percent. For relatively short ranges they can be used against defined field targets, but for long ranges there is no point aiming them at specific targets. As a result, during the war the rockets were launched against population centers. Although Hizbollah leader Nasrallah tried to claim that he intentionally did not aim the rockets at the chemical plants in the Haifa Bay in order to avoid mass killings, it is clear that Hizbollah's rocket attacks were aimed at centers of population. In the south, the Qassam rockets are aimed by Hamas at populated areas, for similar reasons. This usage of rockets has made it a serious strategic threat.

Special expertise is required for the manufacture of rockets that have a reasonable degree of accuracy, and for longer range rockets the manufacturing process is highly complex. In addition, and this is probably the greatest disadvantage, rocket fire produces large volumes of fire and smoke, which immediately exposes the launch location to the enemy. Therefore, rocket launchers must withdraw from their firing positions as soon as they finish shooting, although their high mobility level greatly facilitates this rapid exit. In the case of guerilla forces operating a single barrel, several launchers can be placed in the field, aimed at the target, and operated by remote control or by a delayed-action fuse, thereby preventing exposure of the operators to counter-fire. This enables the attacking force to move quickly, hide, fire, and flee to other hiding places. This is an advantage not enjoyed by regular artillery batteries, which are not as mobile and are more difficult to conceal.

Hizbollah's rocket system (table 2) was arranged in a number of formations according to rocket range. The main formation included several thousand short range 107 mm. and 122 mm. caliber launchers. Some were fired from multi-barrel launchers that were moved around on small vehicles. Portable barrels were occasionally transported on donkeys or motorcycles. Others were made of static launching barrels installed in small bunkers (2 meters by 3 meters) positioned in well camouflaged areas with dense vegetation, sometimes in orchards. Missiles were stored in nearby houses. While these rockets have a range of no more than 20 km, this formation managed to fire throughout the north of Israel. The launchers were elusive and the IDF had difficulty attacking them.

The second formation included medium range rockets, with ranges of between 35 and 70 km. These included Iranian-made Fadjr rockets and Syrian-made 220 mm. rockets, which were launched from mobile launchers on heavy custom-made trucks. This formation was operated from extended ranges deep in Hizbollah territory. It is more complicated to use than the first formation, and while the launchers were operated from concealed positions, the IDF succeeded in identifying them immediately after the rockets were launched and destroyed them. The third formation included long range rockets – the Zelzal rocket with a range of up to 200 km (which extends to the center of Israel). This unit was at least partly destroyed and was not used in the war.

In recent years attention has been given to the possibility of intercepting rockets, mainly the byproduct of the idea of intercepting intercontinental ballistic missiles, from the American Sprint system of the 1960s to the Israeli Arrow system and anti-ballistic missile systems currently being developed in the United States.

Table 2. Rocket Weaponry in the Battle Zone: Main Characteristics

Rocket	Caliber	Length	Weight	Warhead Weight	Range Min. - Max.	Warhead Type	Notes
Chinese Rockets 12-barrel launcher, towed, mounted on jeep or single launcher, portable							
Type 63 (Fadjr-1)	107 mm	0.84-0.92 m	18.8 kg	Approx 5 kg (estimated.)	8,500 m	Explosive, fragmentation	Chinese rocket
The Grad Series BM-21 launcher with 40 barrels, and launchers with 12 or 36 barrels, and even portable single-barrel launchers							
9M22U	122 mm	3.226 m	66.2 kg	19.4 kg	1,500 m. - 20,389 m	Fragmentation, smoke, ignition	This is the original basic rocket
9M22M	122 mm	2.870 m	66.0 kg	18.4 kg	1,500 m. - 20,000 m		
9M2B	122 mm	1.905 m	45.8 kg	19.4 kg	2,500 m. - 10,800m		Used by special forces
9M217	122 mm		70 kg	25 kg	30,000 m		New models
9M218	122 mm		70 kg	25 kg	40,000 m		
9M521	122 mm		70 kg	21 kg	37,500 m		
Syrian Launchers							
220 mm.	220 mm					Seems to be a Syrian version of the Uragan	
302 mm.	302 mm					Possibly a Syrian version of the Chinese WS-1	
Various Iranian Launchers							
Fadjr-3	240 mm	5.2 m	407 kg	90 kg	17,000 m. - 43,000 m		12 barrels on a truck
Fadjr-5	333 mm	6.485 m	915 kg	175 kg	75,000 m		4 barrels on a truck
Falaq-1	240 mm		111 kg	50 kg	10,000 m		4 barrels on a jeep
Falaq-2	333 mm		255 kg	120 kg	10,800 m		1 barrel on a jeep
Zelzal-2	610 mm	8.46 m	3400 kg	600 kg	210,000 m		Track on a truck
Possible weapons in the arena							
Uragan BM 9P 140 Rocket: 9M27F	220 mm	4.8 m. - 5.1 m., according to type	280 kg	100 kg	10,000 m. - 35,000 m	Explosive, fragmentation, various cluster munitions	Launcher - Zil 135 vehicle carrying 16 barrels with various types of rockets; apparently sold to Syria, and a Syrian-made rocket may be based on this design
WS-1	302 mm	4.737 m	524 kg	150 kg	40,000 m. - 100,000 m		Made in China, possibly sold to Iran, and the Syrian rocket may be based on it
WS-1B	302 mm	6.375 m	725 kg	150 kg	60,000 m. - 180,000 m		Made in China
BM 9A52 Smerch	300 mm	7.6 m	800 kg	120-130 kg	20,000 m. - 70,000 m (some reach 90,000 m)	Explosive, fuel-air, various cluster munitions	12-barrel launcher – used in the arena by Kuwait and the United Arab Emirates

The Nautilus project (also known as Tactical High Energy Laser – THEL) was established in the 1990s to advance rocket interception. The Nautilus system uses directed energy, in the form of a laser beam, directly against rockets in flight. The laser beam is designed to generate heat that causes the rocket to explode in mid-air. The system used chemical lasers and was tried out at missile ranges in the US. Following the success of the technology demonstration phase – in which the technology was operated from a heavy apparatus transported on a number of trucks – development work was started on the mobile model (MTHEL), the first model designed for operational use. However, development of MTHEL did not progress beyond the heavy experimental system and the work was shelved on financial grounds, after the US military lost interest in the system.

Despite the attractiveness of the idea, intercepting artillery rockets is a very complex matter. First, the flight duration of the rockets is relatively short – about one to two minutes, for ranges of 20-40 km. Second, they are low signature. In terms of a radar cross-section, they constitute extremely small targets. True, the propellant has a significant signature (in the infra-red wavelength) while burning, but it operates for a few seconds only, and for most of the flight duration the rockets fly in a ballistic trajectory, without propulsion. Third, they are normally launched in large salvos. A successful interception would be one that hits a very high percentage of the salvo, but the attacker will always be able to saturate the defender's defense systems with more rockets.

The Nautilus system had a relatively short range, and thus defense of the north of the country would have required deployment of dozens of systems for localized protection of strategic targets and populated areas. Moreover, interception was expensive: each laser "launch," at least in the experimental system, cost several thousands of dollars.

Here the economic factor comes into play. A careful financial analysis shows that rockets do not cause a great deal of damage. Their wide dispersal around targets on the one hand, and the dispersal of elements liable to be hit in the target area on the other hand, means that the vast majority of the rockets land in open areas without causing any damage, while only a small fraction actually hit targets and cause death and injury. However, cold calculation is of no value when the country's leadership faces a situation in which its citizens are attacked in their homes by enemy weapons.

Nonetheless, a calculation of this sort must be made when considering the cost of developing a rocket interception system, which in turn will furnish the cost of intercepting a single rocket. It is precisely such calculations that have thus far overridden the idea of developing an artillery shell interception system, for example. No one thinks it worthwhile to invest hundreds of millions of dollars in developing such a system. However, when rockets are fired at cities and political pressure is exerted on the country's leadership, this consideration assumes a different shape. From the perspective of the political leadership, the very existence of a technological option – as limited as it may be – to intercept rockets constitutes a crucial factor, as the leadership feels it is unable to withstand the inevitable argument, "You could have done something, and you didn't."

Thus, once again, rocket fire impacts on weighty and costly political and military decisions, since it was precisely these considerations that led Israel to begin developing a system similar to the Nautilus. It is likely that in the wake of the war in the north, there is a greater chance that Israel will invest more to develop this or other systems designed to achieve the same result.

The main method of the IDF, and particularly the air force, to deal with the problem of rocket launches was the attempt to hit the launchers themselves. The ideal situation is, of course, to hit the launcher prior to the launch. However, chances of success are slim, due to the launchers' low signature in the field and the difficulty of tracking them. The problem is less acute with regard to heavy rockets transported on heavy vehicles, which are easier to trace when they leave their hiding place. The problem is more serious when the launcher is a single barrel, transported on a motorcycle or a donkey, or concealed in a small bunker in an area covered with thick vegetation.

On the other hand, as soon as the launch has occurred it is easier to identify the launcher and pinpoint its precise location. The difficulty lies in completing the process of pinpointing and directing a jet to strike the launcher. This difficulty is illustrated by the attempt of the Americans to hit Iraq's Scud launchers during the Gulf War. Despite the launches being observed from distances of hundreds of kilometers the American war planes did not manage to hit a single launcher.

In a small area such as southern Lebanon, distances do not pose such a serious problem, although a mobile launcher can still disappear from the field within a few seconds, particularly in a built-up or forested area. Thus at least with regard to medium and heavy launchers, Israel's air force achieved highly impressive successes. These results were only achieved by virtue of the ability to complete the pinpointing process, connecting the attacker with the target so that the attacker reached the target before the launcher could vanish. This is naturally more difficult when dealing with a very large number of light launchers, as used by Hizbollah from the border area.

Anti-Tank Missiles

Hizbollah fighters used anti-tank missiles during the Second Lebanon War (table 3). Before the war the organization was known to have At-3 Sagger missiles or its Iranian version, i.e., Raad and even enhanced Raad missiles, but essentially these were the same missiles used in the Yom Kippur War. In the summer of 2006 it became apparent that Hizbollah had more advanced Konkurs anti-tank (known in the West as the AT-5B Spandrel) and Fagot missiles (known in the West as the AT-4 Spigot). However, the biggest surprise to the IDF were the Metis-M and Kornet-E missiles, which are a newer generation of Russian anti-tank missiles. These missiles were sold by Russia to Syria in 2000. The great advantage of the new missiles lies in their enhanced accuracy, and the fact that they carry a "tandem" warhead. This head was designed to overcome the reactive armor used by the IDF (armor enhancement that was developed by Israel following the lessons learned from the Yom Kippur War). These anti-tank missiles were used in large numbers and against infantry forces hiding in buildings.

The endless race of new attack measures and countermeasures has reached a new turning point. In 1973 the Egyptian army surprised the IDF with its use of Sagger missiles. Since then, many defense means have been developed, the most prominent of which is reactive armor. This is an Israeli development used today by many armies around the world. Another phenomenon is the gradual increase in the weight of armored vehicles. The M-47 vehicle used in the sixties weighed 46 tons, while the M1A1 Abrams and Merkava weigh in excess of 60 tons.

Table 3. Anti-Tank Missiles in the Arena: Technical Data

Russian Name	Western Name	Introduced	Missile Weight	Range	Warhead Type	Armor Penetration	Guidance Type	Speed	Notes
Malyutka	AT-3 Sagger	3691	10.9 kg	500 m. -3,000 m.	Designed load (heat)	480 mm	Manual Command to Line of Sight (MCLOS)	115 ms., 26 seconds to maximum range	Track launched; weight of "suitcase" launcher - approx. 30 kg; used in large quantities in the Yom Kippur War
Malyutka-P	AT-3c		11.4 kg	500 m. -3,000 m.	Designed load (heat)	520 mm	Manual Command to Line of Sight (MCLOS)		
Fagot	AT-4 Spigot	3791	13.0 kg incl. launcher	70 m. -2,000 m.	Designed load (heat)	480 mm	Semi-Automatic Command to Line of Sight (SACLOS)	186 ms., 11 seconds to maximum range	Barrel-launched missile, portable; replaced the Sagger used by the Russian army
Konkurs	AT-5 Spandrel	3791	25.2 kg incl. launcher	75 m. -4,000 m.	Heat	650 mm	SACLOS	200 ms., 20 seconds to maximum range	Barrel-launched missile, prototype of the Fagot, with very similar features. Normally transported by vehicle, such as the BMP armored personnel carrier
Metis-M	AT-13	2991	13.8 kg in launcher	80 m. -1,500 m.	Tandem double load	900-1,000 mm	SACLOS (beam-riding?)	287 ms., 8 seconds to maximum range	The new generation of anti-tank missiles – replaces the Fagot used by the Russian army. Portable missile
Kornet-E	AT-14	2991	27 kg	80 m. -4,400 m.	Tandem double load	1,100-1,200 mm	SACLOS (laser-beam?)		Prototype of the Metis-M; transported on armored vehicles; replaces the Konkurs

The next phase in the race is already imminent: active protection systems (known as DAS – defensive aids suite, or APS – active protection systems). These systems are based on principles similar to those of intercepting ballistic missiles. Combat vehicles will be fitted with various detector systems that identify the combat threats – tank shells or anti-tank missiles – and will operate systems that intercept and neutralize the threat at a safe distance from the defending vehicle. Detector systems can be radar-based, or based on optical identification in the fields of the visible, IR or UV, and laser detectors (for laser range detection or beam-riding missile guidance systems). Interception can be implemented by a missile, but this is generally achieved by firing a spray load meant to hit and set off the approaching missile.

Such systems will offer a significant advantage when they reach technological maturity and can be relied on. Then it will be possible to reduce the weight of the combat vehicles considerably and defend against light arms only (up to 14.5 mm), for which such protection systems are not efficient. A vehicle with this kind of protection can protect not only itself but a nearby vehicle as well.

There are serious problems with developing such systems, due to the need to identify targets quickly, to assess if they present a direct threat to the defending vehicle (and are not aimed at another target, outside the range of self-protection), and to decide how to act and activate the countermeasures. In addition, the countermeasures must be designed so as not to endanger friendly forces near the defending vehicle.

Such systems are currently at various stages of development around the world, and some are already operational. In Israel, the Trophy system was unveiled in early 2005 (known in the IDF as Raincoat, made by Rafael); Israel Aerospace Industries has unveiled the Iron Fist system. No details of these systems are yet available. However, even if a decision was made to purchase them, it would be a long process of several years to attain full equipping, and it is questionable whether they would have impacted on the patterns of the last war. Indeed, the Trophy system was tested by the US army and was found to be unsuitable for its needs.

As with any other technological innovation, it is easy to argue with hindsight that an error was made by not investing in equipping the IDF with maximum protection. Such an argument is always problematic in that it does not look back at the investment alternatives and the information in the hands of the decision makers in relation to each of the available alternatives. Based on the Second Lebanon War, however, it is reasonable to assume that a significant effort will be made to acquire such protection systems.