Christopher Harmer

BACKGROUNDER

August 16, 2012

THREAT AND RESPONSE: ISRAELI MISSILE DEFENSE

Today the state of Israel contends with the threat posed by state and non-state actors who possess short and medium range surface-to-surface strike capabilities. Hezbollah and Hamas persistently launch mortar and rocket strikes from southern Lebanon and Gaza. Simultaneously, Iran has significantly increased the quantity and quality of its medium range surface-to-surface missile inventory. These two threat streams have encouraged a fundamental shift in Israel's defense strategy. This backgrounder will review how Israel has responded to these two threats with what has become a core component of Israeli defense strategy, the world's first battle-tested, integrated missile defense shield.

MORTAR AND ROCKET FIRE FROM SOUTHERN LEBANON

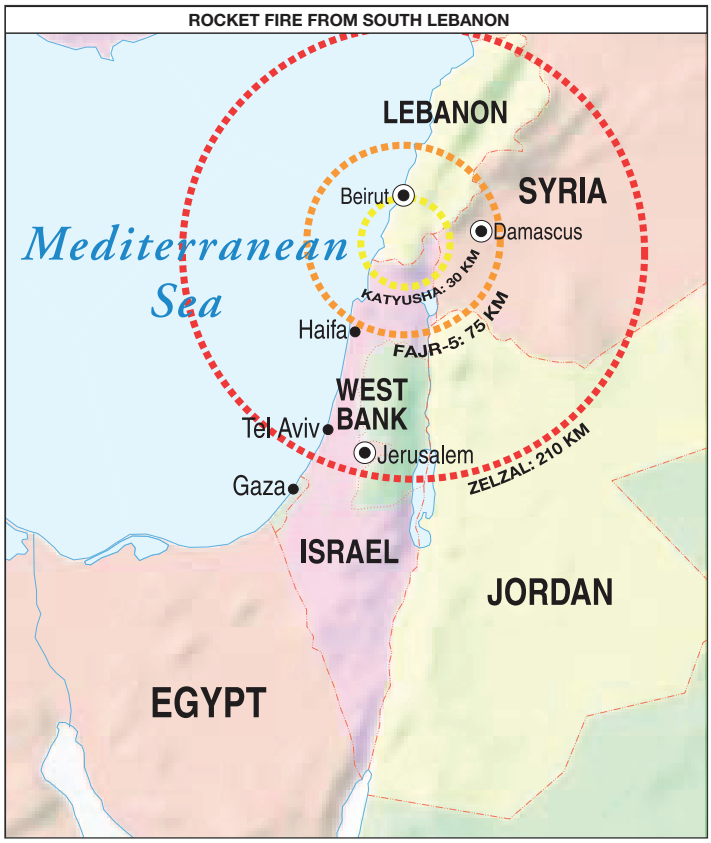
For over thirty years, Israel has endured mortar and rocket attacks from southern Lebanon and responded with overwhelming force. The first large scale attacks were initiated by the Palestinian Liberation Organization (PLO) in July of 1981, with a barrage of rockets targeting Galilee.[1] In response to this attack, the IDF retaliated with air strikes and ground operations that forced the PLO to suspend the strikes. Immediately following the Israeli invasion of Lebanon on June 6, 1982, the PLO again targeted Israeli villages in Galilee with mortar and rocket fire.[2] Along with counterbattery fire by artillery and airstrikes against the PLO firing locations, the IDF responded by occupying territory in southern Lebanon to suppress the attacks. As the PLO declined in political relevance and military capability in Lebanon, the terrorist organization Hezbollah emerged and initiated a new wave attacks. By April 1996, Hezbollah attacks from southern Lebanon evolved from intermittent, disjointed, and poorly targeted strikes to a sustained and coordinated offensive. At that time, Lebanese Hezbollah fired more than 600 Katyusha rockets into Israel over a two-week period.[3]

HEZBOLLAH KATYUSHA ROCKETS IN SOUTH LEBANON WITH CONCEALED LAUNCHER. SOURCE: WIKIMEDIA COMMONS.

In response to this attack, IDF initiated Operation Grapes of Wrath to find and destroy rocket supply depots, rocket launchers, and individual Hezbollah terrorists. IDF attacked several hundred Hezbollah safe houses and rocket storage facilities in southern Lebanon with artillery, air strikes, and infantry units.[4] While Operation Grapes of Wrath led to a temporary decrease in the mortar and rocket attacks, it did not eliminate them. Throughout the late 1990's, Hezbollah continued to strike at Israel with mortar fire and rockets from southern Lebanon.[5] The IDF responded to these attacks also with counterbattery artillery fire, air strikes, and ground operations.

IDF CLEARS UNDERGROUND HEZBOLLAH BUNKER IN SOUTHERN LEBANON. SOURCE: WIKIMEDIA COMMONS.

Following the withdrawal of IDF from southern Lebanon, Hezbollah grew in strength and capability. By 2006, Hezbollah developed freedom to maneuver around Lebanon, establish supply depots and other improved positions, and conduct operations at will. This freedom of movement allowed Hezbollah to develop three critical components of their rocket strategy to launch strikes against Israel. First, Hezbollah recruited and trained a large force of dedicated, technologically capable operators who could rapidly set up and fire mortars and rockets. Second,



Hezbollah established a number of safe havens from which they could launch mortars and rockets. Third, Hezbollah acquired a substantial supply of mortars and rockets from Iran and smuggled them through Syria, which enabled them to carry out an extended attack against Israel.[6] These developments allowed Hezbollah to conduct a coordinated, sustained, tactically effective campaign against Israel from across the border.

In July 2006 Hezbollah launched a rocket attack against Israel that lasted one month. At least 4,300 rockets and several hundred mortal shells were fired at northern Israel.[7] This attack was twice as long and deployed seven times as many rockets as the previous large-scale attack in 1996. During the April 1996 attacks, Hezbollah fired approximately 600 Katyusha rockets over a two-week period, averaging 40 rockets per day.[8] During the July 2006 attacks, this number increased to 155 rockets per day.[9] Not only was Hezbollah able to fire four times the rate of rockets in 2006 as compared to 1996, but also the size of the rockets fired was greater and their targeting was more accurate.

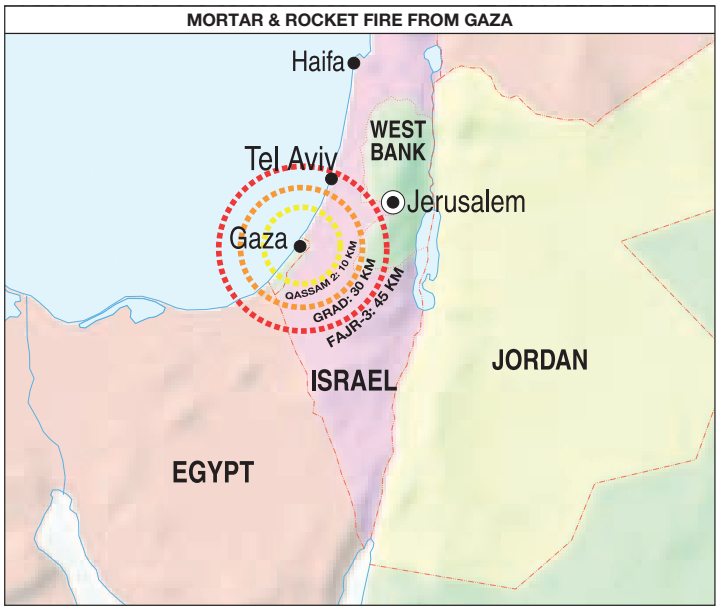
The damage sustained by the Israeli population and economy during the 2006 attacks was significant. 53 Israelis were killed, 250 were severely wounded, and over 2,000 were lightly wounded. Hundreds of residential dwellings were destroyed, and hundreds of public building and utilities, as well as dozens of industrial and business facilities, incurred considerable damage. 250,000 civilians evacuated northern Israel as a result and temporarily relocated to other areas of the country.[10]

In each of these periods, the IDF responded with air strikes, counterbattery artillery fire, and ground operations. These tactics, while temporarily effective, have not reduced the long term mortar and rocket threat against Israel.

MORTAR AND ROCKET FIRE FROM GAZA

The mortar and rocket threat from Gaza developed later, with the first attack occurring in 2001.[11] As long as Israel occupied Gaza, the danger of mortar and rocket attacks was limited to small, inaccurate mortar rounds and homemade Qassam rockets. Following the withdrawal of Israel from Gaza in 2005, and the election of Hamas in 2006, Iran began smuggling longer range, higher payload mortars and rockets into Gaza, including improved Qassam rockets and Grad and Fajr rockets.[12] By the end of 2006, rocket fire from Gaza threatened all of southern and most of central Israel.

With the electoral victory of Hamas in 2006, Hamas operatives had free reign to use any position in Gaza, including schools and hospitals, to launch mortar and rocket attacks against Israel.[13] While not as numerous or as well trained at that time as Hezbollah operatives in southern Lebanon, Hamas operatives still were able to fire Qassam rockets into Israel. Hamas launched 179 rockets at Israel from Gaza in 2005, and following its parliamentary victory in the January 2006 election, that number multiplied more than five times to 946.[14] As Hamas consolidated political



power, rocket attacks continued to increase. According to the Israeli Ministry of Foreign Affairs, the total number of mortar and rocket rounds fired out of Gaza into Israel grew to a total of approximately 2300 in 2007 and 3200 in 2008.[15]

In response to the ongoing mortar and rocket attacks, the IDF launched Operation Cast Lead in December, 2008.[16] According to the Israeli Ministry of Foreign Affairs, the specific intent of Operation Cast Lead was to "stop the bombardment of Israeli civilians by destroying Hamas' mortar and rocket launching apparatus."[17] Accordingly, over a three week period, IDF conducted air, artillery and naval strikes against Hamas positions in Gaza as well as ground incursions. While Operation Cast Lead did result in a major reduction of rocket attacks, falling to approximately 900 in 2009 and just 200 in 2010, in 2011 rocket attacks increased to 800.[18] Operation Cast Lead, like Operation Grapes of Wrath, did temporarily suppress mortar and rocket attacks, but appeared to have no long term deterrent effect.

SPECIFIC TYPES OF MORTARS AND ROCKETS USED BY HAMAS AND HEZBOLLAH

Mortars

Mortars are used extensively in southern Lebanon and Gaza. They are relatively small, easy to hide, easy to assemble, and can be quickly fired and disassembled in retreat. Given their short range, mortars are used primarily as a harassment tool by Hamas and Hezbollah.

Due to the availability of Soviet-era military equipment throughout Egypt, Libya, and Syria, these low- tech weapons have been readily available in southern Lebanon and Gaza throughout the conflict with Israel. The Iranian Ammunition & Metallurgy Industries Group (AMIG), part of Iran's Defense Industries Organization (DIO), has successfully reverse-engineered and is currently producing a number of Russian and Israeli mortar designs in 60mm, 81mm, and 120mm sizes.[19] Hamas and Hezbollah terrorists often use the AMIG Hadid 120mm HM16 mortar, which is a copy of the Israeli Soltam 120mm K6 design.[20] The maximum range on the 120mm mortar is approximately 7.2 kilometers.[21] This makes the mortar the shortest-range weapon available to Hamas and Hezbollah, aside from the Qassam 1 rocket.

CAPTURED HEZBOLLAH MORTAR AND ROUNDS IN MAHVIV, LEBANON. SOURCE: WIKIMEDIA COMMONS.

Qassam Rockets

QASSAM ROCKETS IN A GARAGE IN TUL KAREM. SOURCE: WIKIMEDIA COMMONS.

The Qassam series of rockets started as low-cost, homemade weapons produced with locally available materials in Gaza, yielding a short-range, inaccurate, small-payload weapon. The first Qassam rockets were fired in 2001. Since then, the series has developed into longer-range, higher-payload rockets. The smallest rocket, the Qassam 1, has a range of approximately four kilometers with a .5 kilogram warhead; the Qassam 2 rocket has a range of approximately ten kilometers with a 5-kilogram warhead; and the Qassam 3 rocket has a range of approximately twelve kilometers with a 15-kilogram warhead.[22] Most of the rocket attacks conducted by Hamas against Israel use Qassam rockets.

Grad Rockets

The Grad rocket system originated in the Soviet Union in the 1960s and was a refined development of the Katyusha rockets used during WWII. The Grad rocket is sometimes referred to as simply a "Grad model Katyusha rocket."[23] It is much larger than the Qassam rocket, with a range of up to thirty kilometers and a warhead of twenty kilograms. Grad rockets are manufactured in a number of countries, including China, Iran, North Korea, and Syria, but most Grad rockets fired into Israel from Gaza are produced in Iran.[24] Though there are fewer Grad rockets than Qassam rockets, they are longer-range, higher-payload, and more accurate. While Hamas operatives fire Qassam rockets into Israel on a regular basis, Grad rocket attacks are less prevalent. The first Grad attacks against Israel occurred in 2006, five years after the first Qassam rocket attacks.[25] In June of 2012, in response to IDF airstrikes in Gaza, Hamas fired 10 Grads into Israel.[26] According to Hamas officials, this was the first time Hamas had used Grad rockets

GRAD ROCKET LAUNCHER AT BATEY HA-OSEF MUSEUM, TEL AVIV. SOURCE: WIKIMEDIA COMMONS.

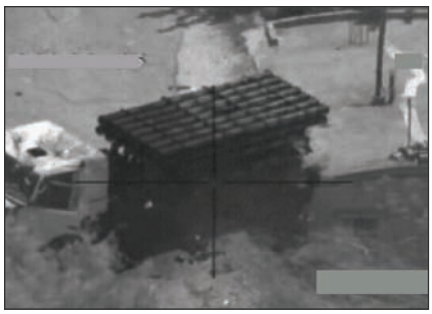
against Israel in over a year.[27] Hamas appears to prioritize Qassam rockets to conduct ongoing, low intensity harassing fire against Israel, thereby saving the limited quantity Grad rockets for specific targets or events, such as responding to IDF airstrikes in Gaza.

Katyusha Rockets

Russians developed the Katyusha series of rockets during World War II. Hezbollah in southern Lebanon has a greater number, variety, and range of Katyusha rockets than the Qassam and Grad rockets available to Hamas in Gaza. The baseline Katyusha rocket fired out of southern Lebanon is roughly equivalent to the Grad rockets fired out of Gaza, with a range of up to thirty kilometers and a warhead of twenty kilograms.[28] The Arash series of rockets are improved Katyusha rockets produced in Iran. They range from the Arash-1 with a 21.5 kilometer range to the Arash -4 with a 40 kilometer range.[29] The Noor and the Haseb variants are also from this series.[30] The Katyusha series of rockets are fired primarily from southern Lebanon into Israel, and Hezbollah operatives have more of them than any other rocket.

Fajr Rockets

Iran produces the Fajr series of rockets based on a North Korean design that evolved from the baseline Katyusha, but have a longer range and payload.



IDF TARGETING RETICLE ON KATYUSHA ROCKET LAUNCHER IN SOUTHERN LEBANON. SOURCE: WIKIMEDIA COMMONS.

The Shahid Bagheri Industrial Group in Teheran, part of the Iranian government's Aerospace Industries Organization, manufactures Fajr rockets.[31] The rockets are subsidized by the Iranian government, smuggled from Iran and into Syria by the Syrian government, and then distributed to Hezbollah agents in Syria who then smuggle them across the border to Hezbollah safe havens in southern Lebanon.[32] Fajr-3 has a range of 45 kilometers with a 45-kilogram warhead, and the Fajr-5 has a range of 75 kilometers with a 90-kilogram warhead.[33] Hezbollah uses these rockets primarily in southern Lebanon, and they represent a significant increase over the Katyusha rockets in both range and payload.

IRANIAN FAJR-5 SOURCE: MEHR NEWS.

Zelzal Rockets

Zelzal rockets are Iranian-produced rockets of a Russian design. With a 210-kilometer range and a 600-kilogram warhead, these rockets represent a substantial increase in range and payload over the Katyusha and Fajr rockets. A Zelzal rocket with a 210-kilometer range fired out of southern Lebanon could target all of the population centers of Israel except for Eilat on the Gulf of Aqaba. Zelzal rockets were reportedly shipped from Iran to the Bekaa Valley in 2002, but IDF officials have never confirmed any attacks in Israel by Zelzal rockets.[34] Given the size of the warhead, it is unlikely that any Zelzal rocket attacks would have gone unreported in the press. Hezbollah has hinted that it has Zelzal rockets in southern Lebanon. In October 2002 Sheikh Mohammed Yazbek, head of the Juristic Council of Hezbollah, said "All sensitive areas of the Zionist entity were within the range of our fire … wherever they exist."[35]

IRANIAN ZELZAL ROCKET. SOURCE: VOICE OF AMERICA NEWS.

TYPES OF MISSILES THAT THREATEN ISRAEL

The threat of missile deployment against Israel garnered worldwide attention during the First Gulf War in 1991 when Iraq fired approximately 42 Scud missiles against Israel.[36] The threat has evolved substantially since then in quality and quantity. Iran and Syria are the two states most likely to threaten Israel with long range missile attacks, but there are other states in possession of ballistic missiles, such as Libya, Egypt, or Pakistan, that could emerge as adversaries.

Three ranges of missiles threaten Israel. The US National Air and Space Intelligence Center defines Short Range Ballistic Missiles (SRBM) as having a range of approximately 150 kilometers to 1,000 kilometers; Medium Range Ballistic Missiles (MRBM) as having a range of 1,000 kilometers to 3,000 kilometers; and Intermediate Range Ballistic Missiles (IRBM) as having a range of 3,000 kilometers to 5,500 kilometers.[37] Intercontinental Range Ballistic Missiles (ICBM) have a range of above 5,500 kilometers, but none of the countries that possess these missiles pose a threat to Israel.

Scud Missiles

Scud missiles are of Russian origin and were the first widespread SRBM Missiles available in significant quantities in the Middle East. The baseline Scud missile has a range of approximately 300 kilometers and a warhead of 500 kilograms.[38] Scud missiles are the most widely proliferated ballistic missile in the world and are found in many countries in the Middle East, including Iran, Syria, Egypt, and Libya.[39] There are at least several hundred Scud missiles or Scud missile derivatives in Iran.[40] Due to the relatively short range of the baseline Scud missile, it cannot reach Israel from Iran. The most likely firing point for a Scud targeted against Israel would be either Syria or southern Lebanon. Because the Scud is transportable by cargo aircraft, Iran could move some of its inventory to Syria on short notice. The majority of the Scud missiles currently in the Syrian inventory were most likely air delivered by transport aircraft.[41] Some reports indicate that Syria transferred control of several Scud missiles to Hezbollah in 2010, although none have been fired at Israel from southern Lebanon.[42]

As a tactical military weapon, the Scud missiles shot into Israel from Iraq in 1991 were ineffective and inaccurate. Scud missiles did not hit any significant military, government, or infrastructure targets, and only two Israelis died from the direct impact of Scuds.[43] As an instrument of terror, however, the Scuds were very effective. Targeting

IRANIAN SHAHAB MISSILES. SOURCE: FARS NEWS.

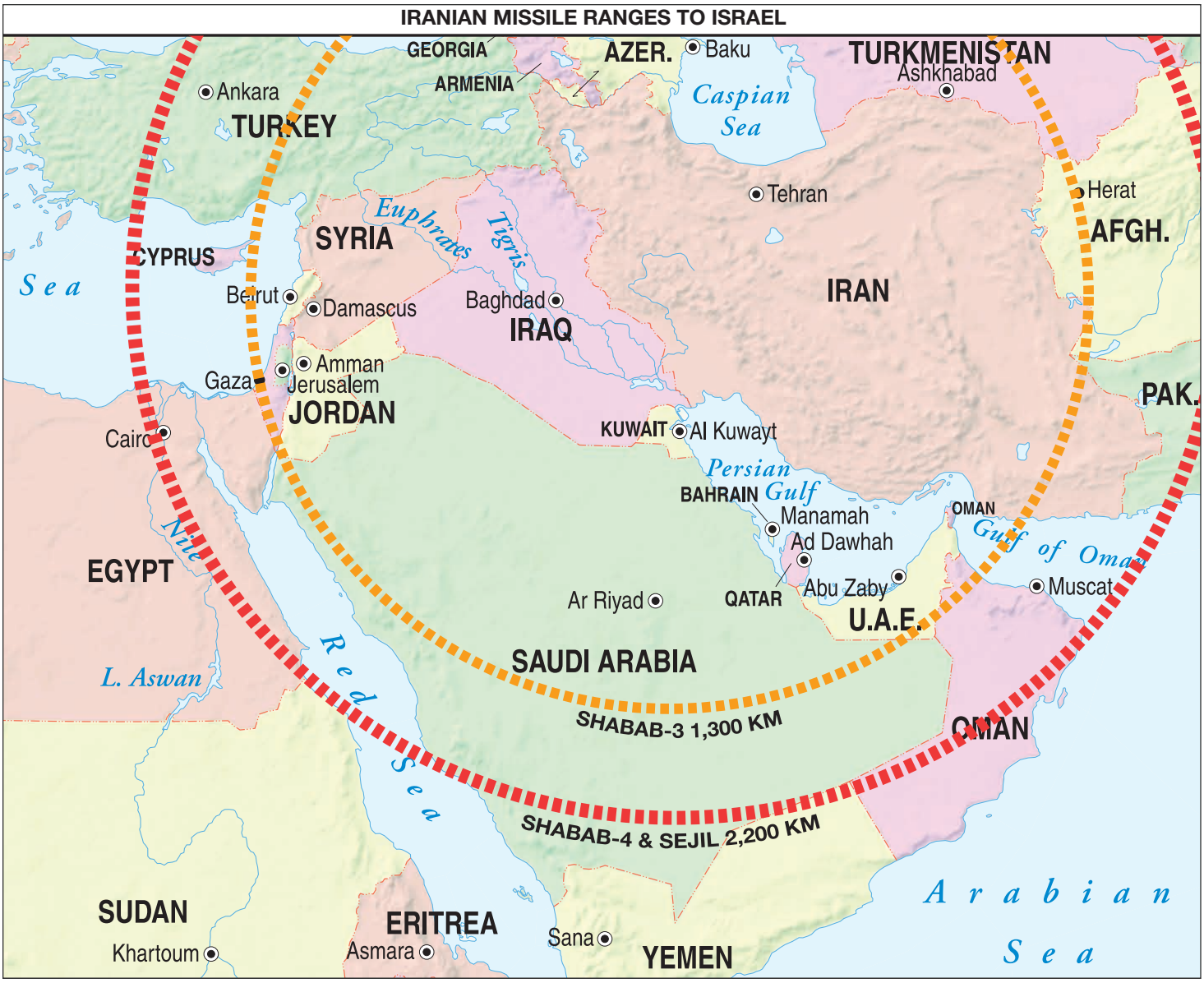
Scuds at urban areas led to widespread terror amongst the Israeli population.[44] Although the IDF missile defense program was in research and development prior to the First Gulf War, the Scud missile attacks galvanized public opinion in favor of increasing funding, and the missile defense program moved into high gear.[45]

Shahab Missiles

The Shahab series of missiles are an Iranian design derived from the basic Scud. Iran is the only country currently operating the Shahab missile. The Shahab series of missiles is accurate enough to hit specific large-area targets such as airports or port facilities and has a big enough payload to cause significant damage. There are a number of derivative designs of the Shahab series, including the Qiam 1 and the Ghadr-110, but for all practical purposes these can be considered part of the Shahab series of missiles. The Shahab-1 and Shahab-2 are essentially updated Scud missiles, and are classified as SRBM Missiles, but the Shahab-3 and Shahab-4 are much more capable versions and represent a significant improvement in range, payload, and accuracy. The Shahab-3 was the first MRBM Missile in the Iranian inventory. With a range of up to 1,300 kilometers, the Shahab-3 can strike Israel from numerous launching points in Iran. The Shahab-4 has an increased range of 2000 kilometers, meaning it can strike Israel from almost any launch point in Iran.[46]

Sejil Missiles

The Sejil series of missiles are a derivative upgrade of the Shahab series of missiles with some important technological improvements. The most consequential feature of the Sejil series of missiles, they are powered with solid fuel, giving them a significant operational advantage over the standard liquid-fueled Shahab. Because solid-fueled missiles are ready-fueled, they do not need a separate liquid fueling



process. Therefore, solid-fueled missiles have a much shorter launch cycle than liquid-fueled missiles.[47] In terms of range, the baseline Sejil is roughly comparable to the Shahab-4 and is classified as a Medium Range Ballistic Missile. In terms of operational effectiveness, it is significantly more lethal, as it has a shorter shoot cycle and is faster, giving missile defenses less time to react.[48] It is also more accurate. It would be best applied against large-area targets, such as airports and ports, or could target specific city areas, such as the Tel Aviv Financial District. Because the Sejil missile uses solid fuel and has multiple stages, meaning that the missile can be increased in range by simply adding another stage to the motor without changing the basic design of the missile warhead or guidance system, the Iranian Aerospace Industries Organization (AIO) will probably develop the Sejil further into an Intermediate Range Ballistic Missile.[49]

Cruise Missiles

Because ballistic missiles have a high trajectory, they are easy to see on radar and fairly easy to target. In contrast, cruise missiles fly low to the earth and are much more difficult to detect by ground-based radar, so they are much more difficult to shoot down. Iran has a number of anti-ship cruise missiles, including the Russian models SS-N-22 Sunburn and SS-N-26 Yakhont, as well as the older Chinese Silkworm missiles and new domestically-produced missiles called the Zafar and the Qader.[50] Iran is working on overland cruise missiles, but it does not yet have a significant operational capability in this regard.[51]

A COMPREHENSIVE ISRAELI DEFENSE

In response to this variety of mortar, rocket, and missile threats, Israel has developed and deployed three primary defensive anti-missile systems: Arrow, Patriot, and Iron Dome. While these systems are separate, in that each can be deployed without being linked to the others, strategically they represent a seamless, integrated defensive missile shield. In terms of policy, the Israeli missile defense shield, particularly the short range Iron Dome system, has given the IDF an option to respond to mortar and rocket attacks with a purely defensive action, i.e., shooting down inbound mortars and rockets instead of responding with overwhelming force, as was the case during Operation Grapes of Wrath and Operation Cast Lead.

Arrow

ARROW MISSILE. SOURCE: WIKIMEDIA COMMONS.

The Arrow missile system defends against medium to long-range ballistic missiles. Arrow can defeat the largest, longest-range, and fastest missile threats. The most likely missiles that Arrow would target would be Shahab-3, Shahab-4, and Sejil missiles. Israel has developed three versions of the Arrow missile: the baseline Arrow-1 technology demonstrator, the Arrow-2 initial operational variant, and the Arrow-2, the most capable version in use today.[52]

System components and capabilities:

- The radar component of Arrow is an advanced phased array radar that transmits on multiple frequencies and wavelengths, making it virtually impervious to radar jamming.
- It is capable of detecting over 200 inbound targets at ranges of up to 500 kilometers.
- The fire control component of Arrow can direct up to fourteen interceptors simultaneously.
- The Arrow missile itself is contained in a mobile launcher holding six individual missiles.
- The Arrow missile is a two-stage, solid-propellant interceptor missile with high explosive warhead that has a top speed of Mach 9.
- The Arrow missile has a range of 100 kilometers, with a maximum altitude of 50 kilometers. This gives the Arrow the ability to intercept inbound missiles at a range far from any possible target. By destroying missiles far from the intended target, the Arrow system minimizes the risk of collateral damage to the intended target.[53]

Patriot


PATRIOT MISSILE. SOURCE: WIKIMEDIA COMMONS.

The United States developed the Patriot missile system, and it entered service in 1984. It was originally intended to defend against aircraft. Shortly after introduction to service, a program was initiated to upgrade the Patriot to protect against ballistic missiles. By the First Gulf War of 1991, it had achieved operational capability in the anti-missile role.[54] The most advanced IDF version of the Patriot, the Patriot Advanced Capability–3 (PAC-3), is intended to defend against short- to medium-range ballistic missiles. The most likely missiles that IDF Patriots would target include older Scud missiles and Scud variants, such as Shahab-1 and Shahab-2.[55]

System components and capabilities:

- The radar component of Patriot is similar to the Arrow radar in that it is a phased array radar that transmits on multiple frequencies and wavelengths, making it virtually impervious to radar jamming.
- It is capable of detecting over 100 inbound targets at ranges of approximately 100 kilometers.
- The fire control component of Patriot can direct up to nine missiles simultaneously.
- The Patriot missile itself is a solid propellant interceptor missile with a high explosive warhead that has a top speed of Mach 5.
- The Patriot missile has a range of over 100 kilometers and a maximum altitude of 25 kilometers. This gives the Patriot the ability to intercept inbound missiles at a range far from any possible target, minimizing the risk of collateral damage.
- The PAC-2 version of the Patriot missile is detonated with a proximity fuse and uses a blast fragmentation

warhead to explode the inbound missile; the PAC-3 version of the Patriot missile is a "hit to kill" missile with no warhead.

- Israel has both PAC-2 and PAC-3 Patriot missiles in its inventory.[56]

IRON DOME

In the aftermath of the 2006 mortar and rocket attacks from southern Lebanon and Gaza, it became clear that there was a critical gap in IDF capabilities. While IDF could provide some defense against ballistic missiles through its Arrow and Patriot missile defense systems, it could not defend against short-range rocket and mortar attacks. The tactic of massive counterstrikes against rocket launching sites was not effective in preventing rocket attacks and caused massive civilian casualties. IDF needed to develop better options to defend and respond to frequently occurring mortar and rocket attacks.

As a result, IDF initiated a high priority research and development program to field a defensive system against short-range mortar and rocket attacks. IDF officials considered a number of concepts and systems to defend against the threat, and in February 2007 they selected the Iron Dome short-range defensive missile system and put it into full-scale research and development.[57] Although Iron Dome is a unique, purpose-built system, with its own dedicated radar, command systems, and interceptors, it is both conceptually and technologically a spiral development of the previously deployed Arrow and Patriot missile defense systems.[58] Because IDF had such a high degree of technical and operational proficiency with Arrow and Patriot, IDF could develop and deploy Iron Dome quickly and effectively.

Iron Dome is a short-range, ground-based missile system optimized to detect, track, and intercept short-range mortars and rockets. It is the newest and most technologically advanced component of the IDF missile defense system, and it is the only missile defense system in routine use. Like the early versions of Patriot, the Iron Dome system shoots a radar-guided missile interceptor with an explosive warhead. After being guided to the inbound rocket or mortar by the radar, the Iron Dome interceptor explodes in close proximity to the rocket or mortar.[59] Because it targets short-range rockets and mortars, it has much less time than either Patriot or Arrow to detect an inbound projectile, track it, and launch an interceptor to hit it. The effects of Iron Dome in tactical terms are clear –an Iron Dome interceptor can shoot down an inbound rocket or mortar round, exploding it in flight, avoiding any serious damage at the intended point of impact. After detonation, debris may hit the ground, but because the warhead detonates or disintegrates in flight, there is little danger of consequential damage from the destroyed rocket or mortar round.

IRON DOME LAUNCHER NEAR SDEROT, ISRAEL. SOURCE: WIKIMEDIA COMMONS.

Iron Dome was deployed in March 2011, and it quickly proved effective, with an initial interception rate of 75 percent.[60] According to IDF Home Command reports, Iron Dome has increased its interception rate to over 90 percent of its targets.[61] Since its deployment last year, Iron Dome batteries have intercepted over 90 Qassam and Grad rockets fired into Israel from the Gaza Strip.[62] Because of the high resolution the Iron Dome radar provides, the command and control module can determine whether an inbound rocket or mortar will impact an inhabited area; as a result, only rockets and mortars that present a danger to inhabited areas are targeted. This provides some protection against a saturation attack by ensuring that the limited number of Iron Dome interceptors are only targeted against inbound rockets or mortars that present a threat to inhabited locations.

System components and capabilities:

- The Iron Dome system is transportable by wheeled vehicles, can be rapidly moved to wherever the system is needed, and can set up on site in twenty minutes.
- The radar component of Iron Dome is similar to Patriot and Arrow in that it is phased array radar that transmits on multiple frequencies and wavelengths, making it virtually impervious to radar jamming.
- It has a minimum detection range of four kilometers and a maximum detection range of up to 350 kilometers.
- The radar can detect mortar and artillery shells, rockets, missiles and aircraft.
- The command and control suite can provide targeting data for up 1,200 targets per minute.
- The Iron Dome fires the Tamir interceptor missile

armed with a proximity-fused blast fragmentation warhead.

- The Tamir interceptor has a minimum range of four kilometers and a maximum range of 70 kilometers.
- Although it is primarily used against mortars and rockets, the Iron Dome system is also capable against artillery shells, and aircraft.[63]

Aside from IDF technical and operational proficiency, the other key component to Iron Dome's rapid deployment was funding and technical and operational cooperation with the U.S. While Israel financed the research and development of Iron Dome, once the system passed its initial operational validation, the US provided funding for procurement and deployment. This assistance is ongoing- as part of the 2013 Defense Authorization Bill, the U.S. House of Representatives Committee on Armed Services approved an additional $680 million dollars for Iron Dome production in April 2012.[64] This financial support from the US appears to have broad bipartisan support, with increasing cooperation in terms of sharing technology, lessons learned, and system production likely in the near future.

Each of the IDF systems, though capable of independent operations, is designed to be part of a fully integrated air defense system. Accordingly, each component of the entire system has an overlapping minimum and maximum weapons engagement range with the other components. Patriot is designed to counter a SRBM missile such as a Scud. Arrow is designed to counter a higher-velocity, higher-trajectory, IRBM missile such as a Shahab-4. The latest versions of the Patriot and Arrow have overlapping minimum and maximum weapons engagement ranges, and thus can be employed against both SRBM and IRBM missiles. The Iron Dome system was designed to hit mortar shells and rockets but has proven capable of shooting down major artillery shells up to 155mm. By continuously expanding the weapon engagement ranges of each of the three systems, IDF ensures that there is an overlapping capability between each component of the overall system.

FUTURE SYSTEMS

While the current IDF anti-missile systems are extremely capable, IDF is engaged in two important research and development efforts to ensure its technological superiority continues.

David's Sling

The David's Sling system, occasionally referred to as "Magic Wand," is intended to replace the Patriot missile system. Because the system is still in development and has not reached operational status, IDF is still determining its specific performance parameters. IDF estimates that David's Sling will have the following technical specifications:

- Its two-stage, solid fuel motor will have a range of up to 300 kilometers.
- High resolution terminal targeting capability will enable David's Sling to engage cruise missiles and ballistic missiles.
- It will be able to engage every target that Patriot can, plus some targets that Iron Dome and Arrow are capable of.
- David's Sling will increase the overlap between Israeli defensive systems, enabling greater flexibility in setting up and employing defensive missile systems.[65]

Various Laser Systems

IDF has worked with the US on multiple laser research and development programs, including the Tactical High Energy Laser System. IDF officials have said that lasers will replace all surface-to-air missiles and other kinetic interceptors, but the unproven technology and high cost of development have hampered efforts to move from research and development to operational deployment.[66]

Future capabilities such as David's Sling and various laser systems will have even greater overlap in the fields of fire of the integrated components of Iron Dome, making the entire defensive shield more difficult to penetrate.

POSSIBLE REACTIONS TO IRON DOME DEPLOYMENT FROM HAMAS AND HEZBOLLAH

The IDF defensive capability of Iron Dome has significantly reduced the tactical advantage that Hamas and Hezbollah enjoyed from 2006 to 2011. Two tactics Hamas and Hezbollah employed in 2011 indicate they are aware of the capabilities and limitations of Iron Dome.

Finding Gaps in the Defensive Shield

Due to the publicity surrounding Iron Dome, the locations of Iron Dome systems are widely known. Those

locations that are not yet covered by Iron Dome are also sometimes inadvertently highlighted by Israelis. Mayors of Israeli cities and towns have advocated for the limited systems available to be in their cities and towns. As a result, Hamas and Hezbollah have been targeting Israeli towns that Iron Dome does not cover. In August 2011, when Iron Dome was deployed to protect the Israeli towns of Ashkelon and Be'er Sheva, Gaza rocket teams shifted their fire to Ashdod and Ofakim, which did not yet have Iron Dome coverage.[67] By shifting fire to the unprotected towns of Ashdod and Ofakim, Hamas terrorists were able to fire approximately 80 Qassam and Grad rockets into the area in one weekend.[68] Because Hamas had identified a gap in Iron Dome coverage, IDF could not target the inbound rockets, and all 80 rockets hit Ashdod and Ofakim. Prompt Israeli civil defense measures limited the casualties to several wounded, but the tactic of attacking towns that did not have adequate Iron Dome coverage proved valid.

Saturation Fire

Even where Iron Dome protects specific locations, Hamas has been able to attack using saturation fire tactics. In August 2011, Hamas launched a coordinated, simultaneous attack of at least seven rockets fired from separate locations at one target, Be'er Sheva, which an Iron Dome system protected. Of the seven rockets fired, five were successfully intercepted, but two got through, causing civilian casualties including one death.[69] IDF is continuously upgrading Iron Dome radar and command and control to increase the number of rockets that can be simultaneously intercepted, but in this case, Hamas was able to overwhelm an individual Iron Dome system.

These two tactical adaptations, probing and exploiting gaps or engaging in simultaneous saturation fire, could serve as the foundation for future Hamas and Hezbollah tactics. The ability to sustain a saturation fire attack depends on the size of the rocket arsenal available to Hamas and Hezbollah as well as the availability of relatively secure firing positions. While the exact size of Hezbollah's rocket arsenal is unclear, what is certain is that during the thirty years that IDF has been battling the mortar and rocket threat from south Lebanon, Hezbollah has amassed a massive stockpile of rockets. In 2007, Hezbollah leader Sheik Hassan Nasrallah said in a speech that the supply was 33,000 rockets.[70] In 2010, US Secretary of Defense Bill Gates said that, "Syria and Iran are providing Hezbollah with so many rockets that they are at a point where they have more missiles than most governments in the world."[71] In 2012, estimates of the Hezbollah rocket supply range as high as 50,000.[72] Hamas has fewer rockets, perhaps as many as 10,000, situated in Gaza.[73] Even if those estimates are higher than the actual numbers of rockets Hezbollah and Hamas have available to them, it is possible that there are sufficient supplies of rockets to initiate a saturation attack.

The IDF missile defense shield is qualitatively capable of handling every known threat. There is no individual mortar, rocket, or missile that Hamas, Hezbollah, Syria, or Iran can shoot at Israel against which IDF is not prepared to defend. The IDF missile defense system cannot defend successfully against a saturation attack if the number of mortars, rockets, and missiles shot at Israel is greater than the number of Iron Dome, Patriot, and Arrow interceptors IDF has available to defend against the attack. In such a saturation attack scenario, IDF would certainly be targeting mortar, rocket, and missile firing sites with artillery, rocket, and air attacks of its own, but even with air superiority, IDF would be fighting against a coordinated attack of significant numerical superiority.

The IDF does not disclose exactly how many Iron Dome, Patriot, and Arrow interceptors it has available and deployed, ready for action. Without that information, it is impossible to analyze how many mortars, rockets, and missiles IDF can defend against. It is reasonable to assume that a saturation attack would severely strain the IDF missile defense system and the Israeli civil defense system; it is also possible that a saturation attack could overwhelm IDF missile defense and Israeli civil defense and cause massive civilian casualties and consequential damage to Israeli infrastructure.

This inherent limitation of the current defensive system has been a motivating factor behind the IDF's decision to pursue ground-based laser systems as the future of IDF missile defense. IDF's move into laser systems provides not only a qualitative upgrade over the current missile defenses, it also removes the number of interceptors as a limiting factor. No matter how many inbound mortars, rockets, and missiles there are, a ground-based laser with adequate energy and cooling systems in place could theoretically shoot them all down.

CONCLUSION

Israel exists under a threat of mortar, rocket, and missile attack that has grown from intermittent harassment to a constant and existential strategic threat. At the tactical level, the Iron Dome component of the IDF missile shield has proven effective at intercepting inbound mortars and

rockets from both Gaza and southern Lebanon. From a strategic perspective, it has changed the risk / reward ratio for Hamas and Hezbollah operatives. Prior to Iron Dome deployment, Hamas and Hezbollah operatives knew that by setting up and firing mortars and rockets, they would expose themselves to retaliatory fire. That risk was balanced against the reward of knowing that every mortar and rocket fired at Israel would impact in Israel. Now that Iron Dome limits this reward, Hamas and Hezbollah must re-evaluate the cost. In this sense, Iron Dome doubles as a deterrent. Iron Dome again establishes Israeli technical superiority, and it is significant in a broader context as the world's first operational, integrated missile defense system.

NOTES

[1] Ze'ev Schiff and Ehud Ya'ari, "Israel's Lebanon War," Simon and Schuster, New York, June 3, 1985.

[2] Avi Shlaim, "The Iron Wall: Israel and the Arab World," Norton Publishing, New York, 2001.

[3] Patrick Devenny, "Hizballah's Strategic Threat to Israel," The Middle East Quarterly, winter 2006.

[4] "IDF Operation in Lebanon–Grapes of Wrath," Israel Ministry of Foreign Affairs, December 20, 2003, accessed August 04, 2012, http://www.mfa.gov.il/MFA/MFAArchive/2000_2009/2003/12/IDF+Operation+in+Lebanon+-+Grapes+of+Wrath.htm..

[5] CNN World, "Rockets hit Israel, escalating border clash," August 08, 1997, accessed August 14, 2012, http://articles.cnn.com/1997-08-08/world/9708_08_mideast_1_hezbollah-guerrillas-israel-warplanes-lebanese-civilians?_s=PM:WORLD.

[6] Amos Harel and Avi Issacharoff, 'Iran pays, Syria smuggles, and Hizballah receives weapons," *Haaretz*, October 14.

[7] Chris Lawrence and Jim Clancy, "Lebanon Truce Holds despite Clashes," CNN, August 15, 2006, accessed August 03, 2012, http://www.cnn.com/2006/WORLD/meast/08/14/mideast.main/.

[8] Ibid.

[9] Uzi Rubin, "Hizballah's Rocket Campaign Against Northern Israel: A Preliminary Report," Jerusalem Center for Public Affairs, August 31, 2006.

[10] Ibid.

[11] "First rocket fired from Gaza at Israel exactly 11 years ago," Israel Defense Forces, April 16, 2012, accessed May 22, 2012, http://www.idf.il/1283-15636-en/Dover.aspx.

[12] Dore Gold, "Israel's War to Halt Palestinian Rocket Attacks," Jerusalem Center for Public Affairs, March 03, 2008.

[13] Israeli Ministry of Foreign Affairs, "The Hamas Terror War Against Israel," accessed August 14, 2012, http://www.mfa.gov.il/MFA/Terrorism-+Obstacle+to+Peace/Palestinian+terror+since+2000/Missile+fire+from+Gaza+on+Israeli+civilian+targets+Aug+2007.htm.

[14] Dore Gold, "Israel's War to Halt Palestinian Rocket Attacks," Jerusalem Center for Public Affairs, March 03, 2008.

[15] Israel Ministry of Foreign Affairs, "Palestinian ceasefire violations since the end of Operation Cast Lead," August 08, 2012, accessed August 14, 2012, http://www.mfa.gov.il/MFA/Terrorism-+Obstacle+to+Peace/Hamas+war+against+Israel/Palestinian_ceasefire_violations_since_end_Operation_Cast_Lead.htm.

[16] Bethany Bell, "Counting casualties of Gaza's war," January 28, 2009, BBC, http://news.bbc.co.uk/2/hi/middle_east/7855070.stm.

[17] Israel Ministry of Foreign Affairs, "Gaza… Hamas… Conflict… Facts!" accessed August 14, 2012, http://www.mfa.gov.il/gazafacts.

[18] Israel Ministry of Foreign Affairs, "Palestinian ceasefire violations since the end of Operation Cast Lead," August 08, 2012, accessed August 14, 2012, http://www.mfa.gov.il/MFA/Terrorism-+Obstacle+to+Peace/Hamas+war+against+Israel/Palestinian_ceasefire_violations_since_end_Operation_Cast_Lead.htm.

[19] "Ammunition Industries Group - AMIG (Iran), Contractors," Jane's, July 17, 2009, accessed July 15, 2012, http://articles.janes.com/articles/Janes-Ammunition-Handbook/Ammunition-Industries-Group--AMIG-Iran.html,.

[20] "AMIG Hadid HM16 120 mm mortar (Iran) Mortars," Jane's, July 31, 2011, accessed August 07, 2012, http://articles.janes.com/articles/Janes-Infantry-Weapons/AMIG-Hadid-HM16-120-mm-mortar-Iran.html.

[21] "Soltam K5 and K6 120 mm light mortars (Israel), Mortars," Jane's, July 31, 2011, accessed May 22, 2012, http://articles.janes.com/articles/Janes-Infantry-Weapons/Soltam-K5-and-K6-120-mm-light-mortars-Israel.html.

[22] "Hamas Rockets", GlobalSecurity.org, accessed May 22, 2012, http://www.globalsecurity.org/military/world/para/hamas-qassam.htm.

[23] Yaakov Katz, "Iron Dome works in combat, intercepts Katyusha rocket," April 07, 2011, Jerusalem Post, accessed August 08, 2012, http://www.jpost.com/Defense/Article.aspx?id=215635.

24 Calev Ben David "Iranian-Made Rockets Put 500,000 Israelis in Range of Hamas," Bloomberg News, January 13, 2009, accessed July 29, 2012, http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aXEMtG7Ys8tk&refer=mideast.

[25] Congressional Research Service Report, "Israel and Hamas, Conflict in Gaza 2008 - 2009," February 19, 2009.

[26] Gili Cohen and Yanir Yagna, "Grad rocket lands near Be'er Sheva; IAF strikes targets in northern Gaza," *Haaretz*, June 20, 2012.

[27] Press TV, "Hamas fires 10 Grad rockets at Israel," June 19, 2012, accessed August 08, 2012, http://www.presstv.ir/detail/2012/06/19/246969/hamas-fires-rockets-at-israel/

[28] "Hizballah Rockets," GlobalSecurity.org, http://www.globalsecurity.org/military/world/para/hizballah-rockets.htm, accessed May 22, 2012.

[29] Iranian Ministry of Defense Legion Export, Rocket and Missile Division, ARASH 1-4: http://www.modlex.ir/cgi-bin/store.pl/page=product.html/pid=MXF05-000180, accessed May 22, 2012.

[30] Anthony Cordesman, "Iran's Support of the Hizballah in Lebanon," Center for Strategic and International Studies, July 15, 2006.

[31] "Shahid Bakeri Industrial Group," Nuclear Threat Initiative, http://www.nti.org/facilities/286/, accessed May 22, 2012.

[32] Patrick Devenny, "Hezbollah's Strategic Threat to Israel," Middle East Quarterly, Winter 2006.

[33] "Hizballah Rockets," GlobalSecurity.org, http://www.globalsecurity.org/military/world/para/hizballah-rockets.htm, accessed May 22, 2012.

[34] Anthony H. Cordesman, George Sullivan, William Sullivan, "Lessons of the 2006 Israeli-Hezbollah War," Center for Strategic & International Studies, November 30, 2007.

[35] "Zelzal 2," GlobalSecurity.org, http://www.globalsecurity.org/wmd/world/iran/zelzal-2.htm, accessed May 22, 2012.

[36] Mark Thompson "Iraq, The Great Scud Hunt," *Time*, December 23, 2002.

[37] U.S. National Air and Space Intelligence Center, "Ballistic and Cruise Missile Threat," March 2006.

[38] "Missiles of the World–Scud B," The Claremont Institute, http://www.missilethreat.com/missilesoftheworld/id.182/missile_detail.asp, accessed May 22, 2012.

[39] "Ballistic Missiles of the World," The Claremont Institute, http://www.missilethreat.com/missilesoftheworld/, accessed May 22, 2012.

[40] Steven Hildreth, "Iran's Ballistic Missile Programs: An Overview," Congressional Research Service, February 04, 2009.

[41] Anthony Cordesman, "Syrian Weapons of Mass Destruction," Center for Strategic and International Studies, June 02, 2008.

[42] Charles Levinson and Jay Solomon, "Syria Gave Scuds to Hizballah, U.S. Says," *Wall Street Journal*, April 14, 2010.

[43] Clyde Haberman, "Israeli Study Sees Higher Death Rate From '91 Scud Attacks," *The New York Times*, April 21, 1995.

[44] Eric Schmitt, "War in the Gulf: The Weapons; Scud Missiles: An Arsenal of Terror," *The New York Times*, January 20, 1991.

[45] Michael R. Gordon, "Threats and Responses: Preparedness; Israel Set to Use New Missile Shield to Counter Scuds," *The New York Times*, October 06, 2002.

[46] Ladane Nasseri and Ali Sheikholeslami "Iran Tests Shahab-3 Missile Ahead of Nuclear Talks," Bloomberg News, September 28, 2009.

[47] "Solid Rocket Propellant," Florida Space Research Institute, 2002, http://www.jht.com/icuf/Space-Science/SolidRockets/PT-03-027.htm, accessed May 22, 2012.

[48] David Sanger and Nazilah Fathi, "Iran Test-Fires Missile With 1,200-Mile Range," *The New York Times*, May 20, 2009.

[49] Lauren Gelfand and Alon Ben-David, "New Missile Marks Significant Leap for Iran Capabilities," Jane's Defense & Security Intelligence & Analysis, November 14, 2008.

[50] "Iran starts mass production of new naval cruise missiles, IRGC gets first batch," *Tehran Times*, February 04, 2012.

[51] Dennis Gormley, "Cruise Missiles and NATO Missile Defense: Under the Radar?" IFRI Security Studies Center, spring 2012.

[52] "Arrow," Israel Aircraft Industries, http://www.iaf.org.il/907-18137-EN/IAF.aspx, accessed May 22, 2012.

[53] Ibid.

[54] Rebecca Leung, "The Patriot Flawed?" CBS News, December 5, 2007,

[55] "Patriot TMD," GlobalSecurity.org, http://www.globalsecurity.org/space/systems/patriot-specs.htm, accessed May 22, 2012.

[56] Ibid.

[57] Uzi Rubin, "Iron Dome in Action: A Preliminary Evaluation," *Israel Defense*, October 24, 2011.

[58] Tamir Eshel, "Israel Tests Arrow 2 Block 4 ATBM with Super Green Pine Radar," *Defense Update*, February 10, 2012.

[59] Alon Ben David, "Iron Dome Advances to Meet Qassam Threat," *Jane's Defense*, March 18, 2008.

[60] "75% of Gaza Rockets blocked by Israel's Iron Dome Air-Defence System," *AFP*, March 12, 2012, accessed August 14, 2012, http://news.nationalpost.com/2012/03/12/75-of-gaza-rockets-blocked-by-israels-iron-dome-air-defence-system.

[61] Yaakov Katz, Yaakov Lippin, "Iron Dome Ups Its Interception Rate To 90%," *Jerusalem Post*, March 10, 2012.

[62] Yaakov Katz, "IDF working to upgrade range of Iron Dome system," *Jerusalem Post*, May 25,2012

[63] Alon Ben David, "Iron Dome Advances to Meet Qassam Threat," *Jane's Defense*, March 18, 2008.

[64] Barbara Opall-Rome, "U.S. Attaches Strings to Israeli Iron Dome Funds," *Defense News*, April 30, 2012.

[65] "Israel gets ready to unveil David's Sling," *Space Daily*, October 31, 2011.

[66] "Israel plans shift to laser interceptors for air and missile defense," *Geostrategic Direct*, April 10, 2010.

[67] Anshel Pfeffer, "Israeli defense sources: Gaza terror groups changing tactics to avoid Iron Dome system," *Haaretz*, August 22, 2011.

[68] Yaakov Lappin, "Southern Israel hit by 80 Gazan rockets," *Jerusalem Post*, August 21, 2011.

[69] Ibid.

[70] Zeina Karam, "Hezbollah: Rockets can reach all Israel," *USA TODAY*, July 24, 2007.

[71] Natasha Mozgovaya, "Gates: Hezbollah has more rockets than most governments in the world," *Haaretz*, April 27, 2010, accessed August 09, 2012, http://www.haaretz.com/news/diplomacy-defense/gates-hezbollah-has-more-rockets-than-most-governments-in-the-world-1.285021.

[72] Adrian Blomfield, "Israel warns Hizbollah over Iran," *The Telegraph*, May 06, 2012, accessed

[73] Yaakov Katz, "IDF doesn't view rocket attacks as real escalation," *Jerusalem Post*, July 18, 2011, accessed August 13, 2012, http://www.jpost.com/Defense/Article.aspx?id=229797.