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Integration of Technologies – the Ultimate Solution of Defending Israel's Home-Front Against Ballistics Threats

Executive Summary

This broad scope paper aims at proving the following:

1. There is no economic viability of defense against ballistics threats based solely on the concept of multi-tiered missiles systems. The cost of one day's fighting ("pushing the button") may reach up to \$900 million. For 40 days of fighting, the inventory that includes missile rearmament may reach up to \$70 billion. These sums are way beyond any means. Within a few days of belligerence Israel may remain without any protection.
2. Missile defense systems are incapable of protecting communities within the range of approximately 15 km away from the rocket's launching; i.e. the customary mix of Qassam 3; standard or improved Grads. They are also unable to protect against mortars.
3. The only solution to the prevailing concept is combining the prevailing anti-missiles defense systems with high energy laser systems – the ground Skyguard systems that are ready for production (completely designed and planned, based on the Nautilus prototype that was successfully developed – a U.S. and Israel joint-venture) and the airborne Skyguard systems; principally proved their technological capability - to intercept enemy rockets or missiles at distances of hundreds of kilometers away.
4. The cost of a single day of exclusively utilizing laser defense systems (the cost of destroying a single threat is 2,000 to 3,000 dollars) would be approx. \$3 million; 300 times cheaper than the prevailing concept, based solely on missiles defense. The current missiles defense systems will only be deployed in extreme weather condition, whereas laser efficiency decreases.
5. Ground Skyguard systems (with additional capacity – when combined with airborne laser systems) will be capable of dealing with any threat - mortar to long-range missiles, and cruise missiles. Furthermore they are the only systems that can protect communities located close to the launching site of the projectile.
6. There is no truism to the 'legends' slandered about the lasers: it has no size problem (actually smaller than a Patriot launcher), it is not harmful to the environment (required safety margin is about 100 m - smaller than the Patriot). It has a remarkable ability to intercept salvos (i.e. 2 Skyguard systems, protecting Kiryat Shmonah are able to intercept 24 improved Grad rockets launched simultaneously). The defending area of one Skyguard system with adaptive optics (effective range of about 15 km) is approx. 700 sq. km.
7. "Solid State Lasers" (SSL) lauded as the future laser technology to replace the chemical lasers technology (Nautilus, Skyguard), is technologically unsubstantiated. It seems unlikely to be able to produce SSLs megawatt class powers – that is required to protect cities and strategic sites at ranges of 10 km and above, in the foreseeable future.

8. Combining missile and laser technologies will formulate a comprehensive defense system against any threat, at any weather condition, for an unlimited combat period, all at low operating costs, which economically is realistic, contrary to the concept based solely on missiles defense which economically is prohibitive. 48 ground based Skyguard systems, that protects against all mortars, rockets and missiles fired from the Gaza Strip, and from the northern region down to the Haifa - Afula – Beit She'an axis, including the protection of 14 additional strategic sites in center and southern Israel, will cost approximately \$2 billion, projected to spread over several years. Additional 32 ground laser systems may be required in the future if the political situation in the region deteriorates, as well as 5 airborne laser systems protecting against long range rockets and missiles. This is applicable, and not exorbitantly expensive.

Faced with approx. 200,000 rockets and missiles deployed against Israel, it appears that the circumstances are appropriate for a formal application to the U.S. authorities on this issue. Northrop - Grumman in early 2007 wrote a letter of commitment to numerous Israeli Defense officials, which can serve as a basis for renewed negotiations. In this letter, the Company pledges to fully cooperate with the Israeli industries.

Ignoring the concept of integrating these two technologies will eventually leave the State of Israel without any viable protection against rockets and missiles attacks, within several days after the initiation of renewed hostilities.

Background

The major factor is the predicted prognosis of a possible comprehensive warfare against the "axis of evil", as publicly defined by former Defense Minister, Mr. Ehud Barak, and former Minister for Home Front Defense, Mr. Matan Vilnai. According to this concept, the State of Israel could face an assault on its entire home front, including the Dan Agglomeration, of more than 1,000 missiles and rockets per day, during 30 days of combat. The Northern Command recently estimated that the attack on the home front may even reach 1,500 missiles and rockets per day.

Formulating this scenario is reasonable. During the Second Lebanese War which lasted 34 days, Hezbollah launched (despite the consistent efforts of repression by the Israeli Air Force {IAF}) approximately 200 to 250 missiles and rockets per day. Even during Operation "Pillar of Cloud" Hamas launched 1,500 rockets in 8 days (that averages nearly 200 a day). Thus, the assumption that during a future conflict that might include Syria, Hezbollah, Hamas and perhaps even Iran, launching about 1,000 rockets per day, is indeed plausible.

This became the most significant military threat to Israel. During the warfare's and conflicts between 1965 and 1982 radical Arab states and terrorist organizations realize that they cannot defeat Israel by conventional means of infantry, armor and air force. Thus since the 80's of the previous century they mainly focused and allocated resources on ballistic armaments. This threat has already granted them a most significant quantitative advantage (currently there are about 200,000 ballistic warheads of various types directed against Israel) and actually in many instances it has given them a qualitative advantage.

This threat will most likely endure during the next few decades, and it will only increase in amounts, type of warheads and targeting accuracy.

Current distinctive model are represented by the following types of threats:

- Short range threats, up to 40 km - various Qassam rockets, Grads and improved Grads (Katyusha). Quantities wise, this is the biggest threat.
- Ranges up to about 100 km - Fajr- 3 and 5 and Zalzal rockets.
- Launching ranges of 100 to 300 km - Scud B, F110 and M600 – the last two have an accuracy of few tens of meters, while carrying warheads weighing 200 – 300 of kilograms.
- Threats launched from greater ranges - 300 kilometers and up - Scud C and D, Shahab 3 and 4 launched from Iran, all carrying warheads weighing up to one ton.
- Cruise missiles such as the Russian P- 800 (Yakhont) having supreme operational capabilities (cruising speed in excess of Mach 2; at an altitude of about 15 meters; warheads of hundreds kilograms with GPS accuracy), which is a very substantial threat to all strategic installations within the country and offshore.

Against those threats, Israel decided to deploy a mix of missiles-anti-missiles defense systems - Iron Dome, David Sling, Patriot, Arrow 2 and Arrow 3. Even the American Aegis Ballistic Missile Defense System was mentioned in this context.

Having taken this decision, the Israeli Defense Ministry has abandoned the High Energy Laser project – the Nautilus prototype, and its derivative, the Skyguard system. This, despite the remarkable success the Nautilus has achieved in 46 interceptions tests of variety of ballistic and artillery threats – successfully intercepting all of them, achieving a 100% success rate.

The current anti-missiles defense systems suffer from several significant drawbacks:

- Prohibitive price, as will be shown below, that is exorbitant. Israel will be unable to financially sustain the expenses of missiles defense, essentially required during an extensive onslaught, meaning that it will eventually be left with no defense.
- Limited in their ability to protect communities near the border and up to 15 km from it.
- Is incapable of intercepting mortar shells (a significant threat on communities near the border).
- A limited ability (if any) against cruise missiles, like Yakhont.

Unlike it, the ground Skyguard system, with adaptive optics, has an effective range of about 15 km, (10 kilometers without adaptive optics). This reflects a protected area of about 700 sq. km. The system's average rate of destruction of a single threat is every 3 seconds, including the transition to the next one. In fact, any threat that penetrates a hemisphere radius of 15 km from the main system - will be destroyed within 2 to 4 seconds after its detection, regardless of its nature - a mortar or a Scud Missile. Hence, the laser system has no difficulty of dealing with short range threats fired at Sderot and the communities surrounding the Gaza Strip, or Tel Aviv for that matter.

The "killing price" using the Skyguard system averages \$2,000 for a single shot, in comparison to about \$100,000 for a single "Iron Dome" missile, (which however usually requires 2 missiles to eliminate a single threat, meaning that it doubles the prices); or approx. \$3 million when shooting one "Arrow" or one "Patriot" defense missiles.

The only drawback of the ground Skyguard system is degradation in performance in thick and very low clouds (actually cloudiness of less than 5/8 will not interfere, because the laser beam is capable of following the target through that). During heavier clouds (which are very rare in southern Israel) the current missiles defense systems will have to be used.

Nonetheless, the laser system can intercept threats during assaults that are below the base of those clouds – which are typical in an average Israeli winter surrounding Gaza Strip.

The existing theorem of the airborne Skyguard system has been proven by the ABL (Airborne Laser) system. However the airborne Skyguard - ARIEL Air Defense Weapon System (Agile Robust Intercept and Engagement Laser) is much simpler than the ABL, and has an invaluable defensive potential. It can intercept ballistic threats at ranges of hundreds of kilometers from the laser plane. It can intercept any threat launched from a range of 30 kilometers and up (from improved Grads to Shahab) with no weather limitations. These long-range interceptions will allow operations against salvos and split war heads. It is also able to separately intercept any "split".

A Proposed Guiding Principle to Decision-Makers:

1. As mentioned - it will never be economically viable to protect the entire country by implementing a multi-tiered system based solely on missiles, during an ongoing engagement as detailed above. The cost of one day's defense against the 1,000 (or possibly 1,500) rockets and missiles can theoretically reach up to \$900 million a day as detailed below:
-500 Iron Dome missiles for intercepting Kassam and Katyusha rockets = \$50 million per day, since usually two interceptors are launched against each threat.

- 200 David Sling missiles to intercept medium-range rockets like Fajr 5, M600 or F110 = \$250 million per day.
- 200 Patriot, Arrow 2 and Arrow 3 missiles to intercept Scud B, C, D and Shahab 3 and 4 missiles = \$ 600 million per day.

This brings the total sum of \$900 million for one day of warding off offensive ballistic attacks.

The price for just “pushing the button” can come up to \$27 billion for one month of hostile ballistic assaults against Israel.

Added to this, is the cost of re-armament after the confrontation, which must be included (is within the range of \$36 billion in preparation for 40 additional days of onslaught) and the price for the batteries, radar systems, telecommunications and other necessary infrastructure, which may easily reach \$70 billion.

Even if our estimates exceeds several tens percent's, and are halved - these incredible sums can never be allocated, even with the generosity of the U.S government. This is the inevitable breaking point of the multi - tiered concept, based solely on missiles defense.

2. Evidently the result will be that Israel will remain unprotected after several days of assault. The defense missiles inventory will run out early in the conflict, or using them will be limited, thus real protection may be implausible. This is exactly what happened during operation "Pillar of Cloud", as the renowned journalist Amnon Abramovich revealed in a recent interview, claiming that it ceased because Israel ran out of Iron Dome missiles. Uncharacteristically neither the IDF nor the MoD spokespersons confirmed or refuted those assertions.

3. Additionally, there is a technological problem: Iron Dome cannot protect Sderot and the communities surrounding the Gaza Strip, since the range of the rockets launched against them is below its minimal effective range. Therefore, the Government has decided to fortify all residential building at a distance of 7 km from the border. Actually former Minister Matan Vilnai officially declared the necessity of fortifying all residential building up to 15 km from the border.

4. Iron Dome suffer from further limitations: It cannot protect Tel Aviv and the Dan Agglomeration from incoming ballistic threats from the north, since it cannot handle threats launched from distances longer than about 70 Km. and neither can the I.D intercept mortar shells or cruise missiles.

Furthermore, for logistical reasons, the Iron Dome intercepts rockets that are estimated to hit only "urbanized areas", as though the others who fall in “open spaces” do not cause damages or raise anxiety amongst the inhabitants of the attacked areas. What will happen in the future when rockets become more accurate, necessitating the interception more of them?

5. "A Laser Shell" travels at the speed of light. Therefore it is effective against any threat – from a mortar shell to Shahab, up to cruise missiles. It reaches its target in a fraction of a second. There is no need for an assessments and calculation of the attacking rockets or missile course. There is no need to reinvent a new system whenever a new threat appears on the scene. Thus the problem of minimum range at which the threat is launched ‘evaporates’, as is the maximum range impediment.

6. Former Minister Vilnai, correctly contemplated the implications of bringing into the area missiles such as the F 110 or M 600, capable of accurately attacking gas facilities, electric and fuel infrastructure, petro-chemical industries and other strategic sites, while also intentionally aiming at Tel Aviv. These missiles will also disrupt the IAF activity which will find it difficult to function under a barrage of missiles and rockets attacking its airfields. There will never be sufficient amount of missiles to protect all these vulnerable targets at once.

7. We are not aware of any missiles defense system capable of thwarting the low-flying cruise missiles, like the Russian Yakhont, currently in Syria that are fast and accurate: (cruising altitude: 10 to 15 m; speed: 2.5 Mach; range: about 300 kilometers; warhead: 300 kg, with GPS accuracy), they can within minutes paralyze the IAF bases, or destroy power stations and other infrastructures, also destroying the gas facilities in the Mediterranean Sea.

8. However the Skyguard system can correspondingly deal with this threat as well. It can provide the most effective defense of strategic sites across the country. There will be no need to develop other systems to safeguard against an introduction of new ballistic threats. The State of Israel in conjunction with the U.S has developed the operational prototype - the Nautilus. Rendering the Skyguard systems operational may be implemented within approximately two years after arriving at that resolution. This solution is the only viable one to confront the prevailing ballistic threats against The State of Israel!

9. The only effective solution which is both operationally and financially sustainable in protecting the entire country from the diverse assortment of ballistic threats, in all weather conditions and for an unlimited belligerent period, is a combination of high energy laser systems, the Skyguard - ground and airborne, in conjunction with the missile defense systems. This is the only conceivable defense, closest to hermetic protection of the country, including all its strategic sites, as indicated above.

10. The cost of this combination is financially viable, and can be implemented in phases, which may extent over an 8 years' period:

- Approx. half a billion dollars (including transforming of the Nautilus prototype to the Skyguard configuration) will be required for eight systems, to be stationed around the Gaza Strip, preventing virtually all shelling from it.
- Approximately one billion dollars for 26 Skyguard systems to protect northern Israel down to Haifa - Afula - Beit She'an axis.
- About half a billion dollars for local protection of 14 strategic sites within center and southern Israel.

Total sum of about \$2 billion will be required for 48 Skyguard systems. This amount includes the entire essential administrative and logistical infrastructure required.

- In the eventually of an eastern front evolving, it may require an additional 32 Skyguard system, at the cost of about \$1.1 billion, to protect central and southern Israel.
 - Investment in five airborne Skyguard type systems, ARIEL, costs about \$1.4 billion, which will allow long-range protection from any ballistic threats fired from hundreds or even
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thousands of kilometers away. The interception will occur about 400 km away from Israel's territory.

For the combined "Laser and Missiles" defense system - the estimated expenditure of equipping the "missiles part of it" would not exceed 10% of the total amount that would have been required if only a "multi-tiered missiles system" would have been implemented, thus saving enormous amount of financial resources. The "missiles-parts" will be designated as a backup to the ground laser systems in the event of severe weather conditions (yet as mentioned, the airborne laser systems do not suffer from any weather limitations). The laser systems will deal with about 90% of the anticipated interceptions. Economically, the laser is the only sustainable solution

11. The Gaza Strip is a singular case. 8 ground Skyguard systems deployed near its border will serve as a "protective shield". Most of the threats will be destroyed while still over Gaza, disregarding their destination – whether Sderot, Ashkelon, Be'er Sheva or Tel Aviv, for that matter. Furthermore, in most cases, none of the residents of these cities will have to scuttle to take cover. Actually they may not even know that their city has been under ballistic attack.

12. These 8 laser systems are also efficient against ultra-dense salvos. Every launching area in the Gaza Strip will be covered by 2 to 3 Skyguard systems. Salvo of 16 rockets, as launched at Be'er Sheva during operation "Pillar of Cloud", will be intercepted immediately after launch (each laser unit can destroy about 7 to 8 rockets launched simultaneously, before they reach out of its cover range). To execute this 8 systems are required, so that they appropriately overlap.

13. Due to the amount of ballistic threats confronting Israel, the anti-missile defense systems will run out of ammunition during confrontation ("will shot itself to death"), due to their prohibitive costs they have relatively small inventory. Long before the end of the conflict, defensive missiles supplies will run out, leaving Israel exposed, lacking protection. On the other hand, the laser systems after the initial investment, as specified above, can be operated continuously, without any limitation, and at a negligible cost.

14. The Laser system is fed by 5 different types of gases combined with jet fuel that are all easily accessible on the open market, and are inexpensive. Therefore using the laser systems eliminates the vulnerability of defense capabilities related to the extent of a war. The fuel and gas supply that produces the laser beam is continuous and smooth, with no limitation, similar to air craft refueling or supplying cooking gas to kitchens.

It allows constant defense with little economic constraints. Cheap gas and fuels will consistently be available to operate the laser systems, confronting the incoming enemy projectiles. Thus the economic erosion will hinder the enemy and not Israel.

15. In early 2007 Northrop - Grumman pledged a commitment in a formal letters to key Israeli defense officials, pending an order from the Israeli government, to begin supplying 3 operational Skyguard systems within 18 months from placing it. This was at a firm and fixed price of \$310 million, with underwriting an assurance of bearing penalties on falling behind schedule, while endorsing full cooperation with Israel's defense industries. Possibly due to time lag there may be changes in the pre-proposed schedule and price. However to re-initiate the project (as we have recently assessed) a formal appeal from the State of Israel to the U.S. authorities is obligatory.

16. During the last decade, however, alleged reports denouncing the laser option were regularly published by the media, initiated by the defense establishment, spreading misleading and false accusations. This included claims of toxicity, sensitivity to weather (giving the impression that the prevailing weather condition in southern Israel is either cloudy or dusty most of the year, which actually is about 10% of the year) enormous consumption of electricity, lack of mobility, risk to the operators, personal vested interests, etc. These false claims were "well known" to the defense officials who initiated the laser project some 18 years ago, prompted by then P.M and Minister of Defense Mr. Shimon Peres, and yet "despite" it, development of the Nautilus commenced.

We explicitly assert that all the above are utter nonsense, and are able to counter and disprove each and every one of these false accusations, and others that have been contrived.

Ignoring the high energy laser system option, (originally initiated by the Israeli defense establishment), is one of the most severe defense negligence in the history of the State of Israel, bringing it to the brink of the abyss, in every conceivable way, pertaining to its defense requirements.

Lasers based on the solid-state technology (SSL):

Officials within the Israeli defense establishment are fully aware of indispensable advantages of the laser technology, yet focus on developing a "future laser", "solid state" based. The solid state lasers (SSL) technology is sixty years old and yet its progress has been excruciatingly slow, with no significant breakthrough in the foreseeable future.

Due to significant physical / technological / material barriers, the highest laser power reached utilizing this technology is about 100 kW (Northrop – Grumman, February 2009). Within this power, the interception range of ballistic threats can reach 1 to 2 km only, compared to the chemical lasers, of megawatt powers class, that was attained more than thirty years ago, allowing interception of rockets or missiles at ranges exceeding 10 km (ground lasers - Skyguard) to several hundred kilometers (airborne lasers - ABL, ARIEL).

Additionally, due to the shorter wavelength of the SSL (by a factor of 4) it has greater sensitivity to weather conditions (atmospheric degradation is significantly higher). It also suffers from a serious safety problem - the danger of blindness by the reflected light. It will be improbable to apply SSL to protect Israel's home front from ballistic threats in the foreseeable future.

In this context it is imperative to read the following from an eminence expert:

D. L Carroll - President, CU Aerospace, 301 N. Neil St. – Suite 400, Champaign, IL 61820, Fellow AIAA.

... "It is my opinion that in 20 years, the chemical and gas lasers will remain the only Megawatt-class systems that retain excellent beam quality for long distance strategic military applications (I acknowledge my personal bias in this area as it has been my area of expertise)..."

... In my estimation, and trying to factor in my own complete underestimation of where SSL technology is today, I believe that we will have SSL, fiber laser, and FEL systems of around

100 kW with excellent beam quality in 20 years; these will be perfect for tactical military situations, and fiber laser systems will almost certainly be the first fielded tactical high energy laser systems on a large scale (in terms of number of systems)"...

D.L. Carroll, "Overview of High Energy Lasers: Past, Present, and Future" 2011, AIAA Paper 2011-3101, (2011), http://cuaerospace.com/pdfs/AIAA_Carroll_2011-3101.pdf

The U.S. Army's requirements are primarily to protect mobile field forces. This task can be executed with the range limitations of the SSL. However this is not viable to Israel's requirements.

Recommendations:

To reinitiate the high energy laser project, by initially producing eight Skyguard systems to be stationed around the Gaza Strip, as there are no other means of protecting this area. It will allow a comprehensive verification on the capabilities of these systems. Estimated investment, as aforementioned, is around \$500 million, including deliveries which will commence around two years after placing the order.

To perform a comprehensive feasibility study on the implementation of the airborne Skyguard system, an application which should be simpler than the ABL system, which proved the existing theorem of the efficiency of airborne high energy chemical laser system.

In light of the ballistic threats aimed at Israel, and talks currently taking place with the U.S. government examining Israel's future defense needs, it is imperative to re-examine the option of restarting the process of equipping Israel with high energy laser systems, as a complementary and critical element in the overall protection of the Israel's home front.

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