New/Old Trends Affecting the Defense Industries

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This article analyzes a number of the trends currently affecting the defense innovation system (DIS) in Israel, especially the defense industry. Among these trends are: the change in the character of warfare, the variety of threats and new domains; the modern weapons systems necessary to deal with the change; the digital transformation, information technologies (IT) revolution and emergence of the cyber domain; the transfer of technology (TOT) revolution and the use of commercial off-the-shelf (COTS) products and technologies in weapons systems; the relative decline in defense R&D investments (in comparison with commercial R&D); and the anticipated decline in the volume of orders for local industry, resulting from the most recent changes in the security MOU between Israel and the US.

The Israeli DIS includes the Ministry of Defense and IDF agencies' directorates and technological units, national laboratories and centers, and the defense industries. This group has operated for many years as a balanced system that develops unique and advanced innovative solutions for the evolving IDF needs, relying on short time-to-market cycles and high-frequency operational feedback from users, ultimately becoming a leading innovator with a large ratio[1] of exports relative to domestic orders. Taken as a whole, the trends described in this article point to a significant accumulative change in the current market balance.

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The Change in the Nature of Warfare and the Armaments Needed

First, let's look at the bottom line: what the IDF demands today are new technological, innovative, more lethal and more accurate systematic solutions, far more than "industrial-more-of-the-same" solutions. Over the years, the enemy has responded to the IDF's methods of operation with "disappearing" and hiding techniques, starting in open areas and moving to urban environments and underground, while firing high-trajectory weapons at the Israeli home front. The defense establishment responded by developing unique technological capabilities for defensive purposes: air defense systems against high-trajectory weapons, on one hand, and the Trophy system against the threat of anti-tank missiles and rockets, on the other. While the enemy was operating from within densely populated civilian centers, the IDF and the defense establishment aimed to develop intelligence capabilities extending from cyberspace to outer space. The asymmetry of the conflict is evident in all aspects: the enemy's small NGO terror activities from busy urban centers versus the IDF's spending on all resources needed to detect, isolate (from civilians) and attack specific targets; the enemy's low-cost statistically weak trajectories versus the IDF's endless and costly efforts to defend its citizens; or the enemy's easy-to-achieve "victory image" – by not differentiating between Israeli civilians and IDF soldiers – versus the IDF troops' impossible mission of acting in an urban terrain, risking their lives to achieve precision, while the Israeli public reflects a low tolerance to each casualty in a non-existential conflict. This situation highlights the complex question of what the "right" military achievement is, and how it can be demonstrated.

An example of the IDF's technologically based efforts in this regard is the development of expensive defense systems with expensive interceptors to counter inexpensive threats. The effect of this trend on the Israeli DIS is clear, and is accelerating in several respects: the volume of large-scale "industrial" production of less sophisticated or less accurate weapons for a conflict is declining every year, superseded by new types of weaponry that are more complex, more "intelligence based," and more expensive (computer and software based, automatic/semi-automatic, digital); the nature of the leading industries and professions needed is changing from production based to development based; and the budget for force build-up is being allocated to the large industries for development of complex solutions rather than to small- and medium-sized ones.

In other words, the weapons needed today are no longer simple arms; they are complex combat systems (and even systems of systems). This is all for the purpose of finding technological solutions against an enemy with supposedly asymmetric inferior self-development capabilities. The other side's ability to accelerate development using commercial technologies as a means of warfare will be described below, and it may well eliminate the asymmetry between the competent high-budgeted Israeli DIS and the supposedly low-budgeted terror organizations. Examples include the use of drones, sensors, and various other COTS elements for the purpose of focused attacks, surveillance, disruption, etc.

The Information Revolution and the Emergence of the Cyber Dimension

The cyber dimension in the realm of warfare grew in recent decades in parallel with the exponential growth of IT such as WAN communication (wide area networks, such as the Internet), computerization (Moore's Law[2]), cellular communications, and the exponential use of these technologies for people's private use such as their offices, cars, personal telephones, and home (the Internet of Things). With the (terror) enemy blending into the civilian and urban environment, this non-military domain has become of increasing interest to the defense establishments, in Israel as well as elsewhere. The use of COTS technologies (on both sides) has become inevitable, given the huge investments in the global high-tech industry. The innovation created by this industry, which has both military and commercial applications, is developing at a much more rapid pace than purely military innovation, in which the investments are relatively far smaller. Most of the innovation in cyber technologies originates in the civilian world, while the defense industry, which initially was the main developer of all IT for its own use (that were spun-off for civilian and commercial use), are now demanding "spin-on" of COTS technologies that were developed in the global innovation system.

The Technology Transfer Revolution and the Use of COTS Technologies in Weapons Systems

In today's reality, many elements of military weapons systems rely on COTS technologies, such as processing and computers, communications and networks, man-machine interface (MMI) elements and even COTS products as drones. This fact seems trivial, but some of the more elderly system engineers remember that only two decades ago, the situation was completely different. Who would have believed 20 years ago that unmanned aerial vehicles (UAVs) for military use or systems for night vision, encryption, outer space, radar, advanced calculation and MMI (LEDs, joysticks, voice and text processors, etc.) would be developed by commercial industries for private use and entertainment purposes, instead of by industries directed by government (and federal) investment? Most information and cyber technologies are examples of this phenomenon, which encompasses all technological sectors.

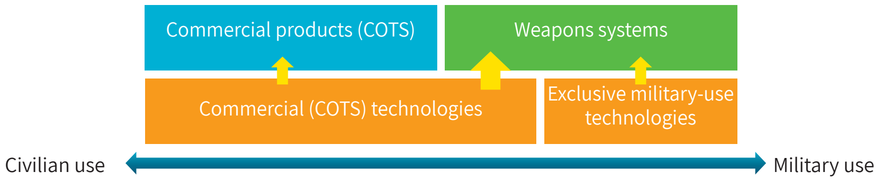

Figure 1: Commercial and civilian arms

A glance at the more distant history of the relations between science and technology and military applications shows that there was once low correlation between these two worlds (see Figure 2), for many different reasons.[3] In recent generations, however, they have become closer. This process peaked in World War II (WWII), when the industrial and technological world was recruited to participate in the war. The first congruence between the two main poles – defense needs and commercial needs – emerged immediately after the war. Some 20 years ago, the phenomenon of spin-offs occurred, in which defense technology developed with state funding trickled into the commercial market for civilian uses. In the past decade, by contrast, there have been more and more cases of technology transfer (TOT) in the opposite direction, with civilian commercial technology being used to develop weapons. From different uncorrelated worlds, the two became close, then co-shared and then became mostly-mutual.

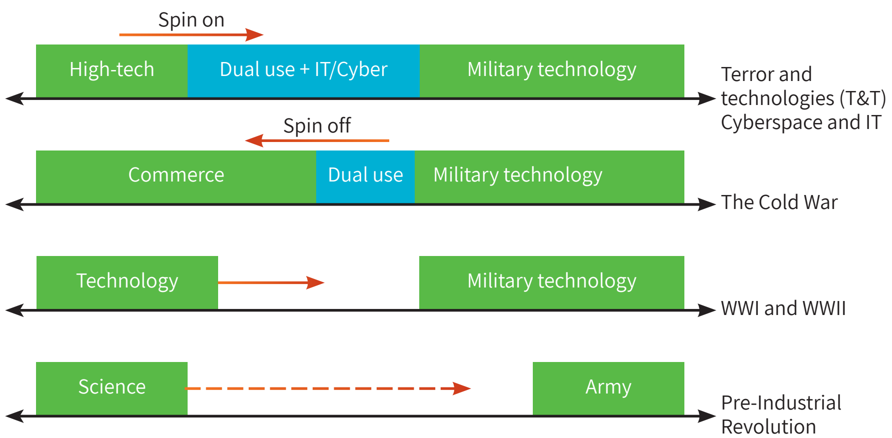

Figure 2: Military and civilian innovative relations and TOT in four generations – from the Industrial Revolution until today

Today, the availability of most of these technologies for private use, whether in a car, mobile telephone, home, or any public service whatsoever, is taken for granted. It should, however, be kept in mind that the vast majority of them were originally developed for military use through the defense establishment and government funding, for example, the Israeli application of an electro-optic tracker for tanks or American technologies such as the first computer, Ethernet, etc. It is interesting to note that in the US, as of now, all of the relevant technologies for operating advanced weaponry – communications, processors and computer miniaturization, computerized photography and MMI, image processing, LCD screens, and even audio signal processing to commands (SIRI) – were developed with US federal funding. Within 20 years, these technologies became the base on which the mobile phones that are privately distributed all over the world were developed, generation by generation.[4]

Figure 3: Typical process in the reversal of the direction and transferral of the technology lead

An in-depth analysis of all the relevant technologies in the past 20-30 years[5] shows a recurring pattern that took place separately and at a different point in time in each family of technology. It began with spin-offs (civilian commercial use of military technology), continued with the development of an advanced generation for commercial/civil users on a large scale (private car, home, office, leisure, etc.), and ended with the commercial sector taking the technological innovative lead. Another observable phenomenon is that this trend began decades ago at the components level, advanced to the sub-systems level, and today already encompasses the ability to adapt existing products and systems to military use. It can also be seen that the IT sector was the first to undergo this revolution, from computers, processors, communications, and eventually even encryptions. Next was the sensor technology sector: computer vision, night vision, audio and radar. Table 1 maps the technological uses of each family and the shift in the lead from military use only (green) to dual-use (blue). Figure 5 shows the trend towards increased use of COTS as a function of the high level of complexity of the weaponry or system.

Table 1 displays the transition of selected technologies from military use only (green) to dual use of military and commercial (blue), according to technological groups and decades.

Table 1: Mapping of technologies for defense and dual-use purposes over time

Technology Group	Uses in 1980-1990	Uses in 1990-2000	Uses in 2000-2010	Uses up to 2010	Uses up to 2020
High-resolution day cameras	Outer space	Observation and intelligence	HD video broadcasts	Professional cameras	Cellular, car industry
Image processing	Outer space observation, target trackers	Air missiles target trackers	Automation, computer MMI	Facial and vehicle license plate recognition (LPR)	AI
Optical networks	Outer space and aerial communication	Strategic uses	Intercontinental communications infrastructure	Individual infrastructure	Brain-machine communication
Thermal imaging	Outer space and aerial observation	Observation and intelligence	Driving, tactical systems	Civil engineering, aviation, plumbing	Autonomous vehicles
Satellites	Strategic uses	Outer space research and communication	Civilian communication	Civilian navigation	Commercial and government outer space research
Inertial navigation	Outer space and aerial systems and applications	Fire control	Tactical navigation systems	Driving	Cellular, autonomous vehicles and drones control
Robotics	Defense use – combat engineers	Defense use – combat engineers and outer space	Police use (sappers)	Industrial robotics	Home robotics
Marine robotics	NOAA marine research	Marine research – military mapping	Military marine mapping	Robotics for the oil industry	Robotics for the oil industry and research
Air robotics	Observation, marking and designation, intelligence missions	Air force intelligence and the beginning of Cruise missiles	Tactical air force applications	Tactical ground forces applications	Drones for agriculture and entertainment
Radar	Targets search and track applications	Field control and surveillance		Detection of invaders	Driving and autonomous vehicles

The Reasons for the Change in the Direction of TOT and the Acceleration of Civilian Innovation

A number of factors, both global and local, some interdependent and others independent, may explain the 180-degree change in the TOT direction:

- A shift in trend in the volume of technological investments in R&D in the world in general and in Israel in particular, from national or federal investments in defense innovative systems to investments (primarily private) in civilian innovative systems. This change attracted most essential assets needed for innovation, such as technological human resources and capital, and was followed by the acceleration of technological development in the civilian sector. In Israel, for example, investment in military R&D is on a lower scale than private investments (mostly from overseas) in the high-tech innovation industry, from start-ups to large companies.
- The worldwide globalization trend in general and the specific trend towards cooperative technological development processes, such as open code, shared databases, cloud services and cloud resources. Those encourage streamlining and professional specialization, on the one hand, and collaborative ventures, on the other, for the purpose of increasing innovation efficiency, research and even industrial efficiency. This global mega-trend further enhances worldwide accelerated development of the civilian industry over the anti-global conservative defense industry.
- The private consumer creates enormous (scalable) economic potential attributed to the private market, especially in the house, office, and car. Therefore, one of the most important motivating forces for investments in technology is the potential to reach millions of users in the private market.
- A growing defense need for and interest in technologies from the civilian commercial sector.

In Figure 4, the left side shows private vs. government R&D investments and the turnover point in the US; the right side shows exponential growth in the infrared camera business following possible private use penetration in the cellular market.

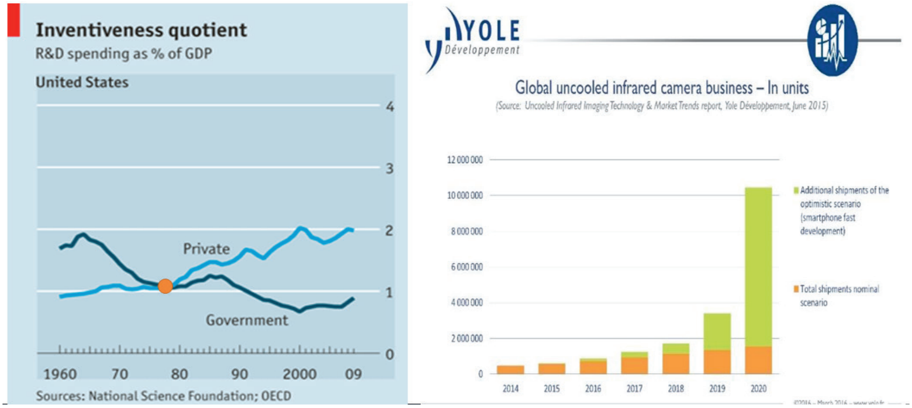

Figure 4: Reasons for acceleration – Private investment and private uses in comparison with government investment

The Dilemma of Using COTS Products and Technologies versus Defense R&D Investment

In some cases, weapons and weapons system development processes begin with an operational demand or gap, while in other cases, a technological opportunity emerges that can be tapped as an out-of-the-ordinary response to an operational gap that is not in the conventional "toolbox." Responses of this type are usually unique, and to a large extent constitute technological-operational breakthroughs or force multipliers. The way to develop such unique capabilities is through "innovation," i.e., by encouraging creative thinking.

When a need is based on technology that does not yet exist, or whose viability has not yet been demonstrated, it is necessary to wait for the technology to emerge or reach a suitably mature readiness-level. This means developing the technology and testing its feasibility and relevance through a technological demonstration. At the same time, when the need is based on the integrative use of existing technologies (of the kind likely to be encountered in the military or civilian environment) or a shelf product (from the level of an electronic component to an entire product), a much shorter process can be adapted to achieve the system's requirements or a more complex system.

Thus arises the procurement dilemma of COTS items or technologies versus self-development. The main considerations are as follows:

- The expected end result from the converted product differs from a product developed specifically for the purpose;
- The economic consequences of adapting a product;
- The time required to get the product to market;
- Technical considerations and standards (environmental, safety, survivability, and durability);
- The required life-cycle cost, including technical and maintenance support;
- The available upgrade ability and dependence;
- The required level of connectivity;
- The security risk in using the shelf product; and
- The ability to confront barriers in the defense establishment in cases in which it is feasible to use a shelf product.

The advantages of using a shelf product or item are clear: the lower cost of a mass-produced item; quality and reliability guaranteed by large-scale or mass use of the product (electronic components and processors, for example) and a high degree of replaceability, resulting from the larger demand of the product; saving the cost of establishing production lines; and saving time and expenses for development and trials. At the level of a single item or system component (e.g., an electronic card, power supply, electric engine for the system, a wheel for a vehicle), the benefit from using a shelf product outweighs the benefit from self-development.

On the other hand, when the item or component involved is controlled (a dual-use item subject to supervision, for example), incurs a sensitive information security risk or requires adaptation for military use, the dilemma between self-development and procurement is heightened. The wish to maintain independent production and flexibility for changes, reduce dependence, and lower the security risks is balanced with the economic benefits.

The impact of this phenomenon on the defense industry in Israel lies in the emerging change in the profile of products developed by it. On the one hand, there is a need to focus on exclusively military technological capabilities (explosives, armor, special weapons, etc.) that have no commercial use (to date) at the expense of products for which there is no longer a need for independent development (computerization, MMI, etc.). On the other hand, there is an accelerated development of capabilities and a need to present more complex solutions, such as mega-systems and connectivity of existing systems to a "system of systems" architecture, formerly for command and control needs and today for integrated multi-domain warfare, starting as an industry developing and manufacturing weapons based on hardware and technology. The defense industry today consumes more and more commercial hardware and services and even processes in order to adapt them to its needs. The globalization effect on development processes, together with the science of systems engineering and the system of systems idea, led to an increasing level of capability to design complex mega-systems. Of late, much larger budget allocations have been made in these areas, requiring more manpower at a relatively high cost, resulting in an exponential increase in defense investment in weapons systems, in comparison with less complex weapons manufactured in large numbers. This phenomenon has positive aspects, because Israel's defense exports rely mostly on innovative and unique systems that are usually based on IDF's operational lessons.

The effect of this has been greater in Israel than in other countries, for the following reasons:

- Israel is, relative to its size, one of the world's innovative high-tech centers;
- Israel is in constant high-intensity friction with its enemies, which requires the development of unique defense solutions even before the rest of the world requires them;
- The opportunity given by the IDF to try out innovative solutions in action as part of the development process; and
- The uniqueness of the Israeli defense industry's strong orientation towards exports.

The following diagram illustrates the trend over time towards the general use of commercial components in weaponry. Over the years, the use of available technologies and products, together with the development of systems engineering science, has led to the design of more complex systems increasingly relying on developed modules and elements (software and hardware).

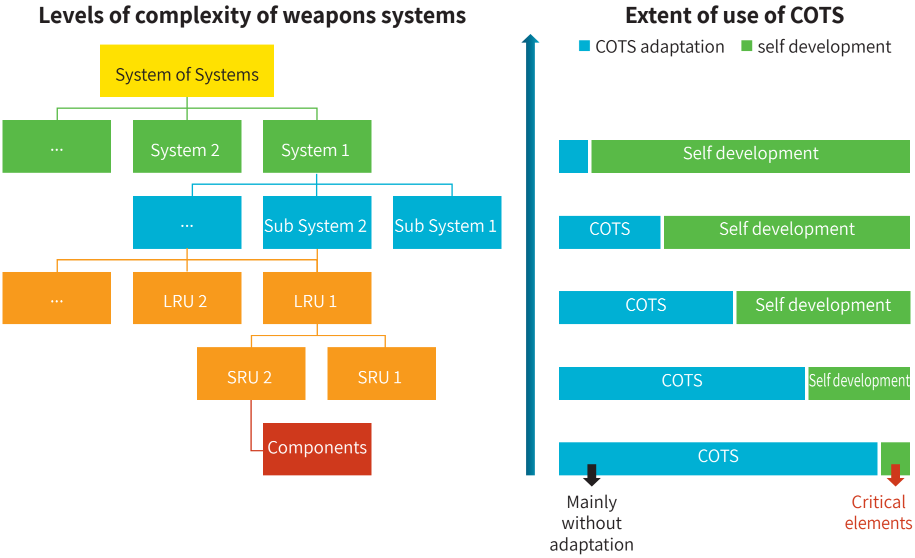

Figure 5: The growing use of existing elements at "higher" system levels

Inherent Barriers in the Defense Innovation System

All of the trends described hitherto are challenging the DIS, including the defense industries, the defense establishment, and the IDF. Until recently, it appeared that the system had reached a productive equilibrium point and was gaining an advantage over both collapsing enemy states and proliferating terror non-government organizations. In practice, the character of the opponent and its behavior has changed, both in operational and innovative aspects. In recent years, the enemy has employed, in parallel, two different innovation systems: first, empowering itself to be used as a proxy for a powerful highly budgeted national weapon industry and, second, the effective use of COTS and the adaptation of them for its needs. These two trends threaten to erode the IDF's relative edge, in the long run, creating an urgent need for a new National Defense Innovation strategy. While the IDF needs to develop more agile and more complex capabilities in a shorter time, including augmented use of COTS technologies and products and their adaptation, the Ministry of Defense and related industries are still limited in their ability to embrace this change. To do so, the system has to overcome the many inherent obstacles and barriers in its institutional structure and processes that prevent it from effectively realizing its potential. For example, the lack of defense innovation mechanisms integrated into the civil high-tech industry; the limitations of contractual mechanisms, mainly for the ownership of knowhow and intellectual property; development regulations that are still adapted to lengthy self-development processes, rather than to rapid use and adaptation of commercial technologies; and mechanisms for focusing R&D and dynamic investment on national infrastructure and even the balance between mechanical, electrical, system, and software engineers.

The New MOU

In October 1976, American Deputy Secretary of Defense William Clements visited Israel and met with Israeli Minister of Defense Shimon Peres, senior Ministry of Defense staff, and members of the IDF General Staff. Clements made a very aggressive speech at the time, saying that Israel "would not receive one cent of American aid money for spending or investing in Israel." He added, "There is a shortage of employment in the United States, 8 percent unemployment, and the United States will not allow money paid by the American taxpayer to fund employment in Israel."

That same day, Assistant Minister of Defense Gen. (ret.) Israel Tal hosted Clements at a banquet with US Ambassador to Israel Malcolm Toon, who told the deputy secretary, "Our host, General Tal, is anti-American." Tal immediately explained: "Unfortunately, the United States has applied two aid norms in international relations. One was the Marshall Plan, designed to help countries that underwent suffering and destruction to rebuild themselves after WWII. Using American aid money, they rebuilt their industry and economy. Such countries should be grateful to the United States. But the United States practices a second method in Israel that differs from the Marshall Plan: we receive substantial and generous aid from the United States government, but we cannot use this aid to develop our own industry and rebuild our economy. On the contrary; we order everything from the United States and neglect our industry. In this way, the generous American aid is increasing our dependence in the long term, and reduces the chances of establishing our industry and economy."

Twenty-four hours later, Clements visited the Merkava production line, and several months later, President Jimmy Carter gave approval for the conversion of US$107 million of the American aid to Israeli currency for the manufacturing of the first Merkava tanks in Israel industries.[6]

It appears that a banquet of this type is more necessary today than ever before. Israel has a stable economy and a highly developed defense industry with an impressive and globally unique export coefficient, but its defense budget, especially its force build-up budgets, still rely on American aid to a significant extent. While US policy still encourages local production. President Donald Trump's administration recently endorsed the new aid agreement signed under his predecessor, Barack Obama, which changed the longstanding rules of the game by eliminating the option of converting dollars (to shekels) for local use, while at the same time imposing further restrictions on the use of dollar aid. The Trump administration is putting special emphasis on the traditional industries in the industrialized countries, and is supporting those industries with large-scale orders. Within a short time, the volume of activity has risen steeply, resulting in a price rise that is eroding the purchasing power of the US aid dollar.

In order to analyze the effect of this change on the Israeli defense industry, a number of teams have been formed, and are acting simultaneously, in the Ministry of Defense and the Manufacturers Association of Israel, and there is also an inter-ministerial team from the Ministries of Finance, Economy and Industry, and Defense. These teams all concluded that the change would affect many defense industries, initially the smaller ones, and cause an "export of labor" from Israel to the United States. The disparities in the teams' conclusions refer to the extent of the damage and the macro effect on the economics, if any. What is agreed, is that the damage is expected to be cumulative, occurring first in the small industries that are already affected by all the trends described above, and whose ability to recover is lower than that of the large industries, which in any case have production bases in the US.

The Merkava as a Test Case

The Merkava industry, headed by the Merkava and Armored Vehicles Directorate in the Ministry of Defense (MANTAK),[7] founded by General Tal in 1970, has also undergone fundamental change in the past two decades with respect to the above-mentioned trends. The initial threat for which these vehicles were designed has changed from massive tank brigades in the 1960s to camouflaged ATGM squads in open territory in the '70s and in the 2000s to an enemy concealed in an urban environment. The proportion of "smart" systems and the number of computers in a Merkava tank has increased exponentially from Merkava Mk1 to the fifth generation of Merkava Mk4 that is being developed today: the Barak tank. From the steel and metal industry, with no competition at all, the armored vehicles industry has become a "high-tank" industry based more than 50 percent on high-tech solutions and systems and 50 percent on the traditional industries. In parallel, production rates have plummeted to a minimum, but the effectiveness and capabilities of the vehicles have doubled. In the last 20 years, many products based on the Merkava were developed and produced, such as the Namer family of vehicles for infantry, engineering, rescue, command, and special vehicles; active protection systems, such as the Trophy and Iron Fist active protection systems (APS), were developed and integrated into the vehicles; and the Eitan wheeled FV. International interest in the Israeli AFV solutions has grown, and defense exports based on the Merkava products have grown significantly. The gradual introduction of COTS products and technologies has risen rapidly as part of the systems engineering in order to shorten development processes and lower costs, and larger portions of production are being made in the US based on the MOU.

One thing, however, has not changed: the seminal drive by General Tal towards independence and self-reliance in everything pertaining to the capabilities of the manufacturing and development of advanced AFVs in Israel by preserving the Merkava industries in Israel, about half of which are currently located in outlying areas. MANTAK is thankful for the US support that enables the IDF to produce country-unique protected vehicles for its soldiers, and therefore it is using the dollar aid differentially, focusing mainly on items and kits that either have no alternative in Israel or for which the cost-effectiveness of producing in the US is attractive and/or has the potential to be collaborative (Israeli-American).

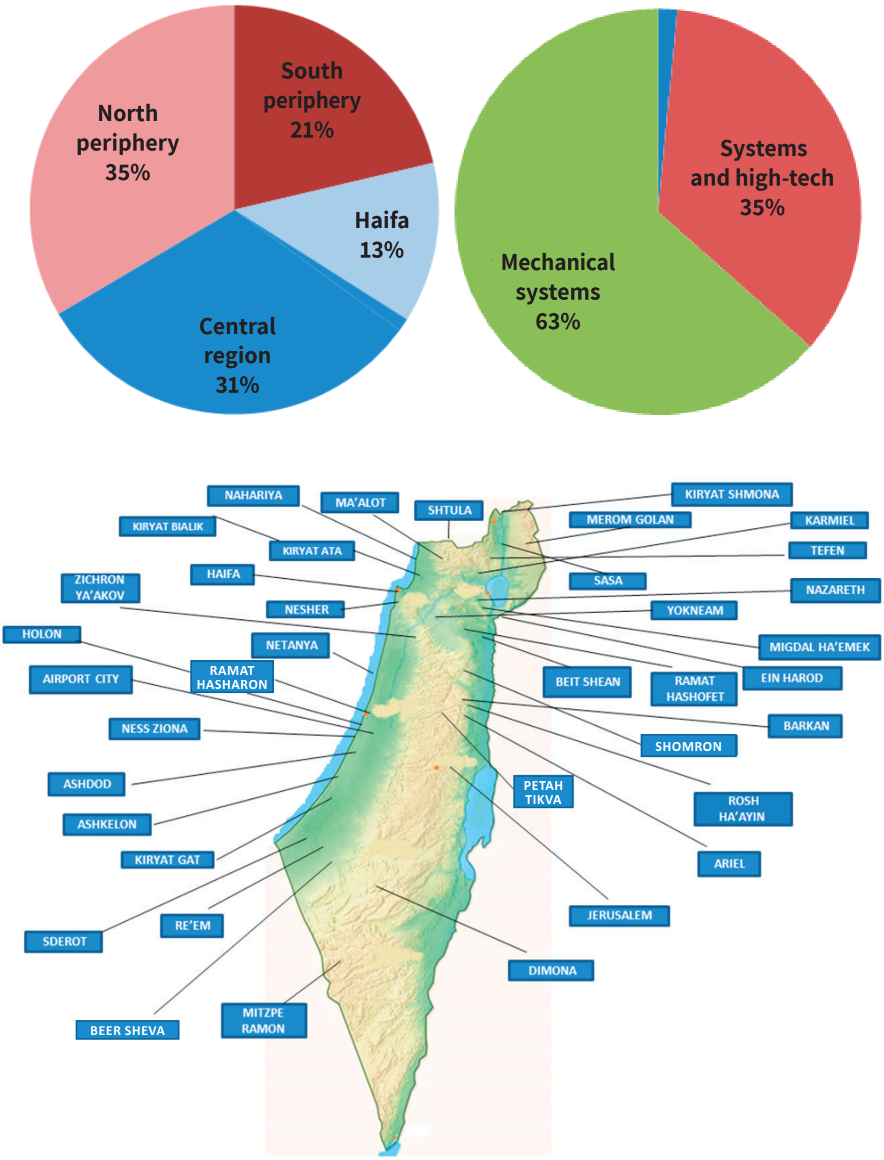

Figure 6: Merkava industries profile: A growing number of high-tech systems, on one hand (35%), and a unique base of more than 100 metal, electrical, and chemical industries manufacturing in the periphery and outlying areas, on the other

Summary

The range of trends described in this article is very challenging to the defense industry in Israel, in that they represent harmonized engines of change, from the required change in weaponry and the need for complex systems with highly developed capabilities to the transition from large-scale industrial production to production of smaller quantities of complex systems and platforms, the change in the occupations needed for development and production, and the need to transfer production work to the US in order to use the aid money.

Israel is unique in comparison with other countries in the following ways:

- Israel rates highly by international standards as a center of high-tech development and investment;
- Israel is in a state of constant high-intensity engagement with enemies of various types having a wide range of technological capabilities, from the use of shelf products to weapons developed by powerful countries;
- Israel has a defense innovation apparatus that operates as one system encompassing the army, the Ministry of Defense, the defense industries, and research and development institutes; and
- Israel faces a significant threat from terrorism and high-trajectory projectiles fired from an urban civil environment replete with commercial equipment.

An analysis of the various defense industry sectors shows a two-pronged challenge. The first is competition for labor and production, involving mainly industries located in outlying areas and small- and medium-sized businesses producing for the large industries and major contractors. These businesses are highly dependent on the defense establishment, and have little independent export capability. Second, the large enterprises, which develop complex systems, face a challenge in recruiting expensive and top-quality personnel in competition with the high-tech market, and in competing with new small players successfully developing capabilities by adopting systems based on shelf products.

Contending with these challenges requires assistance from government ministries, for the following purposes:

- Maintaining the R&D investments, while also preserving the manufacturing element;

- Dealing with the inherent barriers to the usage of COTS technologies – a process that has already begun in the Ministry of Defense; and
- Preserving the small- and medium-sized businesses, with an emphasis on the outlying areas, in order to maintain social, defense, and economic resilience, while preventing the “export of labor.”

All of these measures will make it possible to maintain both the IDF’s advantage through the Israeli defense industry and the attractiveness of exports as part of the equation.

Notes

1 The Israeli defense industries’ ratio of production is approximately 1:3 domestic:export.
2 Moore’s Law – the observation that the number of transistors in a dense integrated circuit doubles every two years.
3 For more on this subject, see Guy Paglin, “The Innovation Race,” Chaikin Chair in Geostrategy, University of Haifa, January 2018.
4 Mariana Mazzucato, *The Entrepreneurial State* (London: Anthem Press, 2013).
5 Paglin, “The Innovation Race,” Chaikin Chair in Geostrategy, University of Haifa, January 2018.
6 Source: An unpublished paper on American aid by Zeev Klein.
7 MANTAK is responsible for the design, development, integration, system engineering, manufacturing, and assembly of the Merkava MBT and the armored fighting vehicles (tracked and wheeled).