



INSTITUTE FOR DEFENSE ANALYSES

**Changing International Arms Market:
Implications for the Department of Defense**

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Executive Summary

This paper identifies trends and radically changing operating principles in the international arms market over the last two decades. It is intended to provide the Department of Defense (DOD) with a better understanding of potentially far-reaching implications of changes for the scope, structure, substance, and field of potential partners for future DOD efforts to establish and carry out international programs.

The starting point and framework of the analysis is based on the experience of the authors studying the dynamics of that market through first-hand field research for the past 25 years. During those years, the Institute for Defense Analyses (IDA) team has attended and reported on 90 international arms shows in 26 countries. This allows the IDA team to see the “big picture” of general trends, as well as changes in particular regions or at individual events over time. IDA’s firsthand experience was supplemented by official statements of foreign government arms trading organizations, discussions with representatives of defense firms, data provided by exhibition organizers, and Internet military forums.

Key findings include:

- The international arms market has undergone revolutionary changes over the past two decades and is still evolving. These changes have profound implications for the way weapons are developed, produced, and operated. For example, crossover and “spin-on” technologies are the norm in some areas such as defense electronics, communications, and cyber. The electronic warfare and cyber markets are converging and their technical capabilities are becoming more technically similar.
- The international arms exhibitions have become increasingly important and competitive over the past two decades. This is partially illustrated by the emergence of many new defense and security exhibitions. Over time, many new shows have been created and existing arms exhibitions have expanded. The size of events (both in terms of numbers of exhibitors and floor space) has also grown substantially.
- The proliferation of exhibitions and cost of attending has caused some vendors to become selective about which shows to attend. Increased regional focus allows vendors to tailor products offered more specifically to interests/requirements of potential regional customers.
- There has been a convergence of defense and security products and services at international arms exhibitions over the past decade. New actors are emerging from traditionally non-defense markets (e.g., police, internal security, and border control). Additionally, adjacent industries offering commercial off the shelf (COTS)/dual-use technologies (e.g., biometrics, information technology, cyber, new materials, big data

analytics, artificial intelligence, 3D printing) are also becoming regular features at international arms shows.

- Traditional arms exporters like Europe, China, Russia, Israel, and the United States remain the mainstays of arms exhibitions. However, a growing number of other countries are expanding their presence, both geographically and in the range of technologies/systems being offered. This trend has economic implications, e.g., these industries will inevitably “squeeze” Western defense manufacturers over the next 10 years. Even if significant penetration of the export market remains limited, emerging exporters (e.g., Turkey and South Korea) do present a challenge to U.S. third-party sales, since domestic orders for military equipment that might otherwise have gone to American firms will go to local ones instead. There are also security implications. Coalition military operations may become more difficult for U.S. military forces if our partners do not have equipment that is interoperable.
- Based on experiences at international arms shows, it appears that the pace of introduction of new platforms/major systems by foreign vendors has accelerated in the last decade in some areas and that the pace of foreign introduction exceeds that of the U.S. in the same areas. Some of these areas are manned aircraft (e.g., trainers, transport aircraft), unmanned systems (especially unmanned ground vehicles), and ground force systems (e.g., armored vehicles, future soldier systems).
- Exports today are the lifeblood of the global defense industry. Arms transfer decisions are increasingly seen in economic rather than national security terms. Arms have come to be seen as just one more commodity in the perpetual struggle to gain a positive balance of trade and keep defense industries open and people employed.
- Since exports are the key to survival for many foreign defense firms, they are predictably sensitive to limits on marketability. Consequently, over the last few years we have witnessed a growing dissatisfaction and restiveness among potential buyers of U.S. military equipment over U.S. export controls. Dissatisfaction is often focused on the provisions of International Traffic in Arms Regulations (ITAR) that limit the resale of items produced in the buyer’s country that have U.S. content. Buyers also object to ITAR restrictions on operational employment of equipment purchased from U.S. vendors or on locally produced military systems with U.S. components. Past purchasers of U.S. defense products are now taking steps to deal with the problem in the future (i.e., developing products with no U.S. content). This process is known as “de-ITARING” in Europe.

- Over the past two decades, supplier restraint has often been replaced by a readiness to sell almost all kinds of conventional weapons systems to anyone. There is an increased number of highly motivated vendors offering arms purchasers a great deal of leverage to drive down prices and have greater access to sophisticated, top-of-the-line systems. It is now a buyer's market and the buyers know it.
- The new buyer's market has forced many companies to move to a market demand-based approach that involves either developing products specifically for the foreign market and/or being willing to modify designs to meet the specific requirements of individual customers.
- As a growing number of countries compete to sell their wares in the international arms market, importing countries are increasingly being offered (or insisting) that products purchased be assembled in whole or in part in their country rather than that of the exporter which was the standard practice in the past.
- Insistence on the transfer of technology and industrial know-how has important consequences. Many emerging defense exporters can trace their heritage to key roles played by technology transfer from American, European, and Russian firms as part of earlier arms sales. Growing capabilities of domestic defense industries are limiting market access of Western and Russian suppliers, particularly with regard to after-market spares, services, and upgrades. Technology transfer and industrial know-how are becoming key determinants of which companies win contracts in the global arms market.
- Increasing capabilities of homegrown defense industries are undermining the West's traditional competitive advantages in the international arms market and are likely to change the landscape of the global defense market in coming years, including making it more difficult to sell U.S. systems and aftermarket spares.
- Strategic decisions by the U.S. Government to limit the sale of some types of defense products for policy reasons have encouraged other nations to enter those market areas. (Representatives of Chinese defense firms for instance say that China decided to market armed UAVs because the U.S. abandoned that market for policy reasons.)
- In some sectors, U.S. defense industry has no products (e.g., medium-size transport aircraft, fighter jet trainer, corvettes, and conventional submarines) to offer in the export market, despite the growing international demand in these market segments.

DOD's organizational response to a more competitive, globalized international arms market should include: assessing the implications of these trends on U.S. national security interests, defining U.S. objectives related to the international arms market, and developing a strategy to achieve those goals. Acquisition, Technology and Logistics (AT&L/International Cooperation)

should play a prominent role in that process. Precursor actions that could be taken to support the development of such a strategy include:

- DOD Organizational Responses
 - Propose a study by the Defense Science Board Summer Study or other independent organization on “Emerging Challenges to International Defense Cooperation and U.S. Defense Trade.” AT&L (International Cooperation) could assist in drafting the terms of reference and participate in that study.
 - Host/sponsor a conference with academia, think tanks and industry focused on developing a national strategy.
 - AT&L (International Cooperation), with assistance from the Directorate of Defense Trade Controls of the Department of State and the International Trade Administration of the Department of Commerce, could lead a DOD team in drafting a DOD-wide defense export strategy: “Defense Trade a Key Element in National Soft Power: DOD’s Defense Export Trade Strategy.”
 - Establish a mechanism for intelligence community liaison whose purpose is to provide insight into emerging foreign weapon system developments and requirements trends on the international arms market.
- Defense Industry Competition
 - Host/sponsor a multi-day regional defense trade symposium on emerging defense trade issues. Host this on an annual basis.
 - Explore the creation of a public-private defense board to examine consequences of alternative U.S. positions in the international arms market in the face of growing competition.
 - Sponsor a study to identify and assess emerging threats and opportunities to the current U.S. position as a major provider of second- and third-tier technology, subcomponents, and software.
- Regulatory and Technology Control Environment
 - DOD, working with appropriate interagency partners, **could** assess the effects of the U.S. arms control regulatory regime against the objectives for that regime, and develop alternative or supplementary courses of action that might better achieve U.S. objectives.

- Host a government-wide conference on how to best regulate defense technology in light of new market realities that are emerging over the next 5 to 10 years.
- Convene a working group in AT&L looking at implications for the U.S.’s position in the international arms market in emerging new markets where the U.S. is not positioned to be competitive or have presence due to the U.S. regulatory environment.
- Market Competition
 - Make consideration of the export potential a strategic element in the acquisition process and urge that design for export be the default whenever possible. (DOD’s Defense Exportability Features initiatives may assist in this effort.) The AT&L (International Cooperation) office role could be to assess all of the acquisitions in the DOD pipeline on a continuing basis to determine if due consideration is being given to defense exportability features. In some cases, it may mean DOD buying a limited number of the export variants (e.g., for aggressor squadrons), the U.S. military is a big consideration for other countries’ purchasing and assures them of a continuing logistics train.
 - Given the importance of defense exports as a component of U.S. national security relationships with foreign partners, AT&L (International Cooperation) could serve as an advocate ensuring that U.S. suppliers provide suitable platforms for export markets.
 - Create and fund an ongoing analytical effort to monitor, assess, and inform DOD of current trends in the international arms market with a focus on identifying emerging opportunities, international cooperation, and defense trade, as well as impediments to those opportunities.
 - Produce an analytical framework and assessment of the size of the U.S. defense technology export markets in design, services, and software.
 - Request appropriate U.S. government agencies provide assessments of likely new weapon systems, technologies, and subcomponents they believe will transform the international arms market in the next 5 to 10 years. The office of AT&L (International Cooperation) could synthesize these viewpoints to develop a strategy or candidate/product list of potential cooperative international programs that addresses advanced technologies and potential buyers’ needs.
- Cost Competition
 - Cost is often a decision driver/barrier for potential buyers. Many U.S. systems are too expensive for the markets. If the objectives are to deter/defeat neighboring states and support internal security missions, then lower quality/less expensive “good enough” systems may suffice. AT&L (International Cooperation) could

participate with other U.S. government agencies in identifying such opportunities where there is a reasonable opportunity for economic return. DOD should then encourage U.S. industry to identify and address opportunities such as the private low-cost SpaceX initiative, which designs, manufactures, and launches advanced rockets and spacecraft.

- Produce a study on U.S. weapon systems cost competitiveness in the international arms market in the next 5 to 10 years when compared to increasing competition among traditional suppliers and numerous off-set providers (e.g., newly emerging defense manufacturing Research, Development and Acquisition Enterprises (RD&A) in countries such as Turkey, South Korea, and United Arab Emirates).

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1. Introduction

A. The Problem

The collapse of the Soviet Union was a seminal event that signaled, among other things, the beginning of revolutionary changes in the structure and operation of the international arms market. The once-static bipolar structure of the international arms market gave way to a market in which the nature, dynamics, and processes changed radically over the past two decades. One of the largest of those changes was the globalization of the market. The international arms market is still evolving today. These modifications have potentially important implications for the competitiveness and market share of American defense and dual-use technology companies in the international marketplace, as well as for Department of Defense (DOD) international programs. These changes can affect the scope, structure, substance, and field of potential partners for future DOD efforts to establish and carry out cooperative international programs.

This paper identifies trends and changing operating principles in the international arms market over the last two decades to provide DOD with a better understanding of potentially far-reaching implications of changes for the scope, structure, substance, and field of potential partners for future DOD efforts to establish and carry out international programs. Areas of focus in the study are:

- Trend analysis of U.S. market share as it pertains to unmanned technologies, electronic warfare, cyber, stealth, and combat platforms and how this affects U.S. foreign defense efforts regionally for Europe, Asia-Pacific, Middle East, and South America.
- How the growing diversification of defense suppliers affects nations' willingness and ability to pursue armaments cooperation with the U.S. and acquire U.S. defense articles.
- Technology and regional security concerns and implications as a result of the proliferation of advanced foreign weapons systems entering the market.
- Levels of nations' participation and representation at international trade shows over the last 10 years and key observations of trends.

B. The Approach

The starting point and framework of this analysis is based on the extensive experience of the authors studying the dynamics of that market through first-hand field research for the past 25 years. Over those years, the Institute for Defense Analyses (IDA) team has attended and reported on 90 international arms shows in 26 countries, including covering multiple events in different parts of the same country (e.g., events in five different cities in Russia, two cities in China, and two cities in Malaysia). IDA attendees have talked with more than 20,000 representatives of non-U.S.

defense firms and maintained enduring professional contact with several hundred of them. IDA has also amassed the largest collection of open-source defense trade literature in the U.S., allowing IDA analysts to detect change states in the types of products offered and the emergence of new players in the market. Note: virtually all of the figures in this report are from either original IDA photos taken at arms shows or from brochures collected by the authors at international arms exhibitions.

This experience allows the IDA team to see the big picture of general trends, as well as changes in particular regions or at individual events over time. IDA analysts routinely cover international arms exhibitions in different areas of the world in the same year, giving them an opportunity to see how the style, substance, and points of emphasis of individual research, development, and acquisition (RD&A) enterprises and defense manufacturers change to accommodate local conditions. For example, the IDA team covered exhibitions in China, Russia, the United Arab Emirates, Jordan, France, Malaysia, and the United Kingdom over the last two years. IDA analysts can provide the “long view” of a specific event as well, by virtue of multiple visits to the same exhibition (e.g., IDA analysts attended the 2016, 2014, 2012, 2010, 2008 and 2004 versions of AirShow China, as well as all but one edition of the Moscow Air Show since 1992). IDA’s understanding of the big picture is also facilitated by attending shows that span a broad range of technologies, including aerospace, ground force, naval, air defense, police equipment, defense electronics, and Special Forces equipment.

The experience of the IDA core international arms market team is supplemented by two of the co-authors who have a long history of studying and forecasting trends in particular technology areas and interacting with the IDA core team. Steven Zaloga is an IDA Adjunct Staff Member and contributor to Teal Group’s *World Military & Civil Aircraft Briefing*. His other responsibilities include developing and maintaining Teal’s *International Defense Briefing* and the unmanned aerial vehicles (UAV) portion of Teal’s annual *World UAV Systems Market Profile and Forecast*. Christopher Foss is an IDA consultant who has been the editor of *Jane’s Armor and Artillery Annual* for 39 years. This experience is supplemented by files covering the period since the collapse of the Soviet Union in their respective specialties.

Before turning to the body of this paper, it is important to note that the following discussion and analysis of issues is based largely on our experience and the primary-source material we have collected. We have done our best to ensure their accuracy. They have not, however, been coordinated with or validated by other entities. The reader might sometimes find small deviations from other sources in data we present from different company brochures, press releases, and company websites regarding the same product. Likewise, organizers of international arms shows often release multiple versions of the official statistics regarding the size and attendance of shows, often with minor variations in the numbers. Also, public statements by senior representatives of defense firms and national marketing organizations are a snapshot of that moment and reflect their personal knowledge and opinions. Therefore, ground truth does not exist (or at least cannot be established) at the micro level. Generally, discrepancies are small and we believe that they do not affect the big picture assessment of long-range overall trends.

We recognized from the outset of the research that official statements of foreign government arms trading organizations, discussions with representatives of defense firms, and marketing literature sometimes had an underlying agenda, or at least an idiosyncratic slant to the information being conveyed. We corrected for this by seeking confirmation/correction of information being presented. This often involved using what can be described as “crowd sourcing” to vet available information. Sometimes the vetting came from commercial rivals. At other times, Internet military forums offered detailed discussions of data provided at specific international arms exhibitions. Internet forums attract many technologically knowledgeable participants from many nations, participants who often have an appreciation for military operational requirements and are willing to offer assessments of what has transpired at arms shows. Claims made at international arms shows are often subjected to rigorous assessment by Internet forum participants with a wide variety of skills, knowledge, and backgrounds, all anxious to debunk perceived misstatements and exaggerated claims. Sometimes the back-and-forth debate among forum participants provided interesting insights in their own right.

Lastly, in the interest of full disclosure, note that the IDA core team’s primary focus (and expertise) is on foreign systems and companies, not American ones. To overcome this, we have relied on the inputs of Steven Zaloga and Christopher Foss, who have far more experience dealing with U.S. technologies and marketing trends.

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2. U.S. Weapon Systems Market Trend Analyses

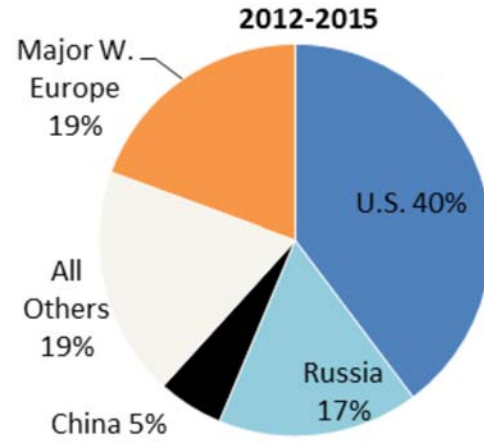
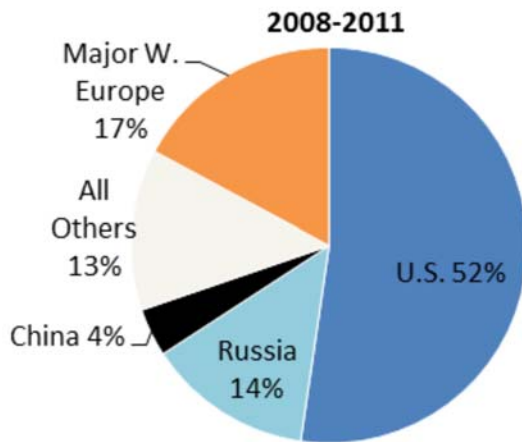
A. Big Picture Trends (2008 to 2015)

This section focuses on a number of specific weapons categories: (1) electronic warfare and cyber, (2) stealth, (3) unmanned aerial and ground systems, (4) combat aircraft/fighters and (5) ground combat vehicles (main battle tanks, armored combat vehicles, and large caliber artillery). Before examining individual areas, however, it is worth getting a broad overview of worldwide exports of all categories of defense systems. Insights into the broad strokes of the market are provided by the following figures and tables prepared by the Congressional Research Service based on data from the U.S. Government regarding arms transfer agreements and deliveries to developing nations in two periods: 2008-2011 and 2012-2015.¹

Figure 1 provides some interesting macro-level insights. Market share of Russia, China, Western Europe, and “all others” grew modestly from 1% to 6% between 2012 and 2015 from the 2008 to 2011 period, but the U.S. share declined by 12% between these same two periods. Figure 2 shows that the U.S. market share increased by only 3% between 2014 and 2015, compared to 5% for China, 4% for Russia, and 18% for Major Western European States.

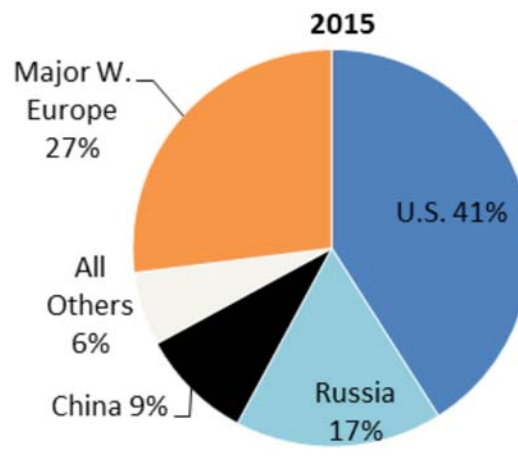
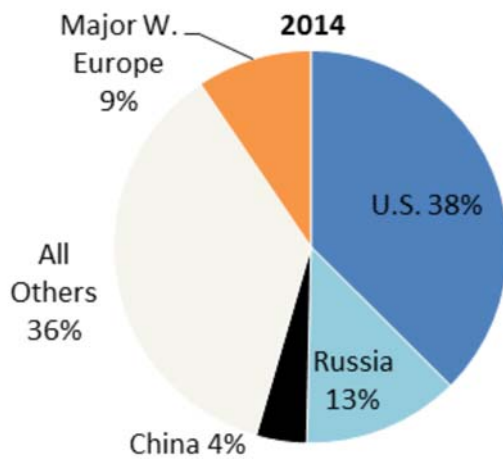
One must, however, be careful of placing too much significance on the variance of just a two-year period, since one or two major contracts can skew the overall results.

¹ Catherine A. Theohary, “Conventional Arms Transfers to Developing Nations, 2008-2015,” Congressional Research Service, December 19, 2017. Accessed on 25 January 2017 at <https://fas.org/sgp/crs/weapons/R44716.pdf>.



Source: U.S. Government

**Figure 1. Arms Transfer Agreements Worldwide to Developing Nations
2008-2011 and 2012-2015 (Supplier Percentages of Value)**



Source: U.S. Government

**Figure 2. Arms Transfer Agreements Worldwide to Developing Nations
2014 and 2015 (Supplier Percentages of Value)**

Table 1. Overview of Number of Weapons Delivered to Developing Nations, 2008 to 2011²

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	348	630	490	360	550	50
Artillery	155	110	340	140	600	190
APCs and Armored Cars	188	570	620	420	1,630	580
Major Surface Combatants	0	2	3	5	5	4
Minor Surface Combatants	0	8	113	64	52	118
Guided Missile Boats	0	2	0	0	0	4
Submarines	0	2	0	4	1	0
Supersonic Combat Aircraft	58	170	30	40	130	50
Subsonic Combat Aircraft	0	0	20	50	20	80
Other Aircraft	62	20	130	50	160	40
Helicopters	35	270	20	150	70	50
Surface-to-Air Missiles	1,088	8,160	2,080	360	650	500
Surface-to-Surface Missiles	1,285	70	0	0	0	10
Anti-Ship Missiles	133	260	80	80	10	50

Source: U.S. Government.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

² For a breakdown of deliveries by region from 2008 to 2011, see Appendix A.

Table 2. Overview of Number of Weapons Delivered to Developing Nations, 2012 to 2015³

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	76	430	130	80	390	10
Artillery	232	130	250	40	630	430
APCs and Armored Cars	1	680	760	960	920	460
Major Surface Combatants	0	3	6	13	2	4
Minor Surface Combatants	0	8	19	67	67	86
Guided Missile Boats	0	0	2	2	0	7
Submarines	0	4	0	8	0	2
Supersonic Combat Aircraft	45	100	20	20	20	40
Subsonic Combat Aircraft	0	0	0	20	10	30
Other Aircraft	35	20	50	130	260	50
Helicopters	2	280	40	140	30	50
Surface-to-Air Missiles	346	6,300	1,310	1,130	240	630
Surface-to-Surface Missiles	163	80	10	0	0	0
Anti-Ship Missiles	116	40	110	210	0	20

Source: U.S. Government.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

³ For a breakdown of deliveries by region from 2012 to 2015, see Appendix A.

Table 3. Arms Transfer Agreements to Developing Nations by Supplier, 2008 to 2015
(In Millions of Current 2015 U.S. Dollars)

	2008	2009	2010	2011	2012	2013	2014	2015	2008-2015
United States	27,200	13,119	14,695	56,131	11,331	17,835	29,735	26,743	194,264
Russia	5,400	14,900	6,800	5,700	16,700	10,700	10,200	11,000	81,400
France	5,600	9,300	1,900	4,700	3,100	3,800	5,600	15,200	49,200
United Kingdom	0	1,100	1,200	500	5,700	3,600	400	700	13,200
China	2,200	3,000	2,000	3,200	3,500	4,300	3,300	6,000	27,500
Germany	3,000	2,200	100	100	4,900	7,000	400	700	18,400
Italy	1,400	1,300	1,200	1,100	1,500	900	1,100	1,000	9,500
All Other European	4,100	4,600	2,800	2,900	5,800	3,600	24,400	2,900	51,100
All Others	2,000	4,200	1,500	3,200	3,000	4,700	4,200	1,000	23,800
TOTAL	50,900	53,719	32,195	77,531	55,531	56,435	79,335	65,243	468,364

Source: U.S. government.

Notes: Developing nations category excludes the United States, Europe, Canada, Japan, Australia, and New Zealand. All data are for the calendar year given except for U.S. MAP (Military Assistance Program), IMET (International Military Education and Training), and Excess Defense Article data, which are included for the particular fiscal year. All amounts given include the values of all categories of weapons, spare parts, construction, all associated services, military assistance, excess defense articles, and training programs. Statistics for foreign countries are based upon estimated selling prices. All foreign data are rounded to the nearest \$100 million.

Table 4. Regional Arms Transfer Agreements to Developing Nations by Supplier, 2008 to 2015
(In Millions of Current 2015 U.S. Dollars)

	Asia		Near East		Latin America		Africa	
	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015
United States	16,791	26,358	86,450	54,659	2,404	2,611	2,974	2,016
Russia	16,000	17,700	6,300	27,900	9,100	1,100	1,400	1,800
France	6,000	6,100	6,200	20,700	8,900	500	400	300
United Kingdom	1,400	1,300	1,100	8,800	300	200	0	0
China	4,900	7,100	2,800	3,400	800	2,700	1,700	3,900
Germany	1,800	3,800	3,200	8,700	300	400	100	0
Italy	1,200	1,000	2,700	2,800	900	300	100	300
All Other European	5,800	4,400	5,200	23,500	1,900	6,900	1,400	1,500
All Others	7,100	4,400	1,200	5,700	1,600	1,800	1,000	900
Major West European ^a	10,400	12,200	13,200	41,000	10,400	1,400	600	600
TOTAL	60,991	72,158	115,150	156,159	26,204	16,511	9,074	10,716

Source: U.S. government.

Notes: All foreign data rounded to the nearest \$100 million.

a. Major West European category includes France, United Kingdom, Germany, and Italy.

Table 5. Percentage of Each Supplier's Agreements Value to Developing Nations by Region, 2008 to 2015

	Asia		Near East		Latin America		Africa		TOTAL	
	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015
United States	15.46%	30.78%	79.59%	63.82%	2.21%	3.05%	2.74%	2.35%	100.00%	100.00%
Russia	48.78%	75.97%	19.21%	57.53%	27.74%	4.72%	4.27%	7.73%	100.00%	100.00%
France	27.91%	22.10%	28.84%	75.00%	41.40%	1.81%	1.86%	1.09%	100.00%	100.00%
United Kingdom	50.00%	12.62%	39.29%	85.44%	10.71%	1.94%	0.00%	0.00%	100.00%	100.00%
China	48.04%	41.52%	27.45%	19.88%	7.84%	15.79%	16.67%	22.81%	100.00%	100.00%
Germany	33.33%	29.46%	59.26%	67.44%	5.56%	3.10%	1.85%	0.00%	100.00%	100.00%
Italy	24.49%	22.73%	55.10%	63.64%	18.37%	6.82%	2.04%	6.82%	100.00%	100.00%
All Other European	40.56%	12.12%	36.36%	64.74%	13.29%	19.01%	9.79%	4.13%	100.00%	100.00%
All Others	65.14%	34.38%	11.01%	44.53%	14.68%	14.06%	9.17%	7.03%	100.00%	100.00%
Major West European ^a	30.06%	22.10%	38.15%	74.28%	30.06%	2.54%	1.73%	1.09%	100.00%	100.00%
TOTAL	28.85%	31.33%	54.47%	61.11%	12.39%	7.17%	4.29%	4.19%	100.00%	100.00%

Source: U.S. government.

a. Major West European category includes France, United Kingdom, Germany, and Italy.

Table 6. Percentage of Total Agreements Value by Supplier to Developing Nations, 2008 to 2015

	Asia		Near East		Latin America		Africa	
	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015	2008-2011	2012-2015
United States	27.53%	36.53%	75.08%	35.00%	9.17%	15.81%	32.77%	18.81%
Russia	26.23%	24.53%	5.47%	17.87%	34.73%	6.66%	15.43%	16.80%
France	9.84%	8.45%	5.38%	13.26%	33.96%	3.03%	4.41%	2.80%
United Kingdom	2.30%	1.80%	0.96%	5.64%	1.14%	1.21%	0.00%	0.00%
China	8.03%	9.84%	2.43%	2.18%	3.05%	16.35%	18.73%	36.40%
Germany	2.95%	5.27%	2.78%	5.57%	1.14%	2.42%	1.10%	0.00%
Italy	1.97%	1.39%	2.34%	1.79%	3.43%	1.82%	1.10%	2.80%
All Other European	9.51%	6.10%	4.52%	15.05%	7.25%	41.79%	15.43%	14.00%
All Others	11.64%	6.10%	1.04%	3.65%	6.11%	10.90%	11.02%	8.40%
Major West European ^a	17.05%	16.91%	11.46%	26.02%	39.69%	8.48%	6.61%	5.60%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: U.S. government.

a. Major West European category includes France, United Kingdom, Germany, and Italy.

B. Electronic Warfare and Cyber

1. Cyber Market

Two decades ago, little attention was devoted to cyber products and services at international arms shows. However, as CYBERBIT (an Elbit subsidiary) currently observes on its website: “The cyber security market has been going through tremendous changes recently.” About five years ago, arms shows began having larger cyber components – mostly focused on cyber defense. Defense Services Asia (DSA) 2016 and Eurosatory 2016 both had “clusters” at the exhibition dedicated to cyber-related companies and sessions at associated conferences focused specifically on cyber. The CyberDef-CyberSec cluster at Eurosatory 2016 had more than 60 exhibitors dedicated to cyber defense and cyber security. This is a sharp contrast from Eurosatory 2012, where cyber was not even listed as a major exhibitor category. Cyber products are also marketed heavily at police equipment shows (e.g., Milipol in Paris).

There are some variations in the specifics of the global cyber market size and projected growth by 2020. Although there is disagreement about the specifics, the general message is the same: the global market for cyber security is large, growing rapidly, and will be significant by 2020. Examples of individual forecasts are:

- The founder and Editor-in-Chief of *Cybersecurity* provided some quantitative metrics illustrating the growth of the global cyber security market from 2004. According to him, the global cyber security market was worth \$3.5 billion in 2004, grew to \$75 billion in 2015, and he forecasts it will reach \$170 billion by 2020.⁴ He notes that, “The cybersecurity market grew by roughly 35X over 13 years.” He also said, “Cybersecurity is the fastest growing tech sector.”⁵ Growth has been driven mostly by the civil market’s need to deal with cyber crime.
- *PRNewswire* expects the global security market to grow from \$106.32 billion in 2015 to \$170.21 billion in 2020.⁶
- *BusinessWire* reports that Research and Markets estimates the global cybersecurity market will surpass \$137 billion in 2021.⁷

⁴ “Cybersecurity Market Report: Q3 2016,” Editors of Cybersecurity Ventures, 2016. Accessed on 21 September 2016 at <http://cybersecurityventures.com/cybersecurity-market-report/>.

⁵ Steve Morgan, quoted in “Cybersecurity Market Report: Q3 2016,” Editors of Cybersecurity Ventures, 2016, op. cit.

⁶ “Cyber Security Market by Solution – Global Forecast to 2020,” *PRNewswire: ReportBuyer*, July 1, 2015. Accessed on 22 September 2016 at <http://www.prnewswire.com/news-releases/cyber-security-market-by-solution---global-forecast-to-2020-300107788.html>.

⁷ Research and Markets cited in “Global Security Market Worth USD \$137 Billion by 2021 – Growth Trend of BYOD – Research and Markets,” *BusinessWire*, June 15, 2016. Accessed on 22 September 2016 at <http://www.businesswire.com/news/home/20160615005921/en/Global-Cyber-Security-Market-Worth-USD-137>.

- MicroMarketMonitor says the global cybersecurity market was worth \$95.60 billion in 2014 and expects it to increase to \$155.75 billion in 2019.⁸

According to an article in *Forbes*, Israel is second only to the U.S. as the largest exporter of cyber products and its products constituted 10% of the global export market in 2014.⁹ *Cybersecurity Review* claims that cyber-related products and services in 2014 surpassed the amount of Israeli defense contracts signed in 2014.¹⁰

The claim that the U.S. is the largest exporter of cyber products does not coincide with the experience of the authors at international arms shows, where the footprint of U.S. vendors is typically very small. Possible explanations include sales taking place through commercial channels directly to firms and governments, making attendance at arms exhibitions an unnecessary marketing cost. Another possibility is that cyber products may be marketed at non-defense trade shows.

The market has evolved in a short time from offering defensive cyber products only to “full spectrum” cyber capabilities today. “Full spectrum” means that companies are marketing both defensive and offensive capabilities.

a. Defensive Cyber Products

The French association of land and air defense companies, *Groupement des industries de défense et de sécurité terrestres et aéroterrestres* (GICAT), distributed a booklet at Eurosatory 2016 that presented a range of cybersecurity capabilities based on solutions provided by the products and services of the companies belonging to the GICAT security cluster and the HEXATRUST alliance. These solutions are independent but often complementary, and can be selected globally to meet a specific requirement. In collaboration with research institutes, the companies presented in this booklet, including innovative software publishers, offer a range of products adapted to every operational context and regulatory constraint in the world. The booklet breaks down the capabilities of French industry into the following categories:

- **Identification and Authentication:** *Controlling access to a site is an essential security measure which ensures the physical protection of the information and information system and the authenticity of the hardware. To provide these guarantees, these measures must first be capable of physically recognizing a person or device; this is the identification aspect. They must then be capable of verifying*

⁸ “Global Cyber Security Market Research Report,” *MicroMarketMonitor*. Accessed on 22 September 2016 at <http://www.micromarketmonitor.com/market-report/cyber-security-reports-7651948375.html>.

⁹ National Cyber Bureau figures cited by Steve Morgan, “Cybersecurity Market Reaches \$75 Billion in 2015; Expected to Reach \$170 billion By 2020,” *Forbes*, December 20, 2015. Accessed on 21 September 2016 at <http://www.forbes.com/sites/stevemorgan/2015/12/20/cybersecurity%E2%80%8B%E2%80%8Bmarket-reaches-75-billion-in-2015%E2%80%8B%E2%80%8B%E2%80%8Bexpected-to-reach-170-billion-by-2020/#2b7fd4a32191>.

¹⁰ *Cybersecurity Review* cited by Steve Morgan in “Cybersecurity Market Reaches \$75 Billion in 2015; Expected to Reach \$170 billion By 2020,” *Forbes*, December 20, 2015, op. cit.

their authenticity; this is the authentication aspect. In the digital world, as in the physical world, it is essential to confirm people's identity and authenticity using means such as physical identity, biometrics and cryptography, etc.

- **Identity and Access Management:** *In this interconnected world, an organization's information assets are a vital resource. The disclosure of digital information can be a serious blow to an organization. For any entity that possesses sensitive information, information traceability and imputability of actions are major priorities. The purpose of an identity and access management system is to control "who has access to what", such that only authorized people or devices have access to the resources (data, information, etc.) they are allowed to access. The processes for requesting or revoking rights of access must be managed continuously and in an audited and controlled manner, in accordance with the security policy.*
- **Data Security:** *The loss of data due to an incident, whether voluntary or not, can be catastrophic or even fatal to an entity. The availability of processed information always needs to be taken into account when securing an information system. It is essential that the confidentiality, integrity and traceability of information be guaranteed, especially through the use of cryptographic means. An electronic signature allows a person to commit to data (non-repudiation) and to vouch for the data's integrity. It is also important to ensure data integrity in the long term and to conserve the legal value of digital proof over time. Encryption tools are used to manage data confidentiality, both between different people within a company and any time data is shared, exchanged or stored.*
- **Infrastructure and Equipment Security:** *An information system's infrastructure is a vital element, and the security of its architecture needs to be ensured by guaranteeing the confidentiality, availability and integrity of every brick that makes up the system. This is achieved by securing the entire system, i.e., every device and technology, the interconnections and the configuration parameters. Hidden channels and transmission via interfering signals must also be taken into account to prevent the leakage of sensitive information.*
- **Command and Control, Decision Support:** *Sensitive info-structures require around-the-clock surveillance, 24-7, in order to detect security incidents affecting the information system. The tools used for this surveillance need to manage the activity logging for the system's components and analyze the data flows to provide the security teams with information. For better detection of complex attacks, they must also be able to associate related events and provide the appropriate summary reports.*
- **Providing and Collecting Information:** *In cyberspace, information is the raw material and represents a vital resource. Controlling information has therefore become a major priority for companies and government agencies. With the growth*

of data transfer platforms and social networks, surveillance of these channels is essential. The diversity and volume of multilingual information exchanged in the digital world means increasingly effective, high-performance tools are needed to collect, analyze, and provide relevant information with confirmed value.

- **Investigating and Gathering Proof:** *After a security incident, it is important to investigate what happened in order to take legal action and/or keep this type of event from happening again. The digital investigation must: (1) ensure the integrity of the digital proof and that all items of evidence are properly conserved, (2) analyze this proof which can be complex, and (3) provide an investigation report that can be understood by non-experts in the field.*
- **Auditing, Consulting, Operations and Training:** *Guaranteeing the protection of information assets is of utmost importance. Securing the information system and keeping it secure over time is an action that every entity needs to implement. Given the complexity and diversity of interconnected technology systems, achieving system security requires experts well-versed in not only information system security, but also every technology used to handle information. These specialists have the necessary qualifications to contain an incident on the system and respond quickly and effectively in order to limit its impact. These consultants are able to provide services at every level: governance, control and design/integration. Every link in the chain of an information system plays a part in its security, and cybersecurity trainings are essential in ensuring info-structure security.*

Several companies offer cyber simulation tools that can simulate cyber attacks and realistic incidents, as well as evaluate tactics for cyber defense.

- **Thales Cyber Range (Netherlands):** Thales has signed a contract to create a virtual center for evaluating and training in cyber security for cyber commandos for the Netherlands Ministry of Defense. This “Cyber Range” will simulate cyber attacks and realistic incidents and evaluate tactics for cyber defense. Cyber attacks, accidents and safety measures can be simulated and tested in the virtual center on several defense systems in different computing environments and on various media.
- **ByteLife Solutions CybExer (Estonia):** This company combines all the necessary hardware, software, and services needed to conduct full-scale cyber defense exercises, including services such as Train-the-Trainer and Red Team (i.e., offense).
- **Sypris Electronics (U.S.) and NEC Asia Pacific (Japan):** These two companies announced at Defense and Security International (DSEi) 2015 the award of a contract in 2014 to develop a Cyber Security Laboratory for the Singapore government. The contract involved deploying a simulation-based training and modeling platform to provide a safe, realistic hands-on environment for the participants to hone their skills in countering cyber attacks.

- **CYBERBIT Ltd (a subsidiary of Elbit Systems) CyberShield-Cyber Security Trainer and Simulator (Israel):** This simulator enables users, individually or as a group, to detect, respond, and prevent cyber attacks, while experiencing advanced up-to-date attacks under real network protection conditions. The simulator presents various network protection scenarios, conducts follow-up debriefing, and evaluates the results. The system will enable simultaneous training for multiple users on attacks directed at IT networks, as well as industrial control networks (Supervisory Control and Data Acquisition (SCADA)) used in most utilities. CYBERBIT Ltd announced in January 2016 that it had been awarded a contract for CyberShield by an unnamed nation in the Asia-Pacific area.



Figure 3. Elbit Systems North America CyberShield Training and Simulation Brochure at Milipol 2015

b. Offensive Cyber Products

The first time we came across a mention of “offensive cyber security” at arms shows was in a booth from the Hacking Team at International Defense Exhibition (IDEX) 2013. The Hacking Team advertised that it provides “easy-to-use offensive technology to the worldwide law enforcement and intelligence communities.”

The Hacking Team is not the only company to advertise offensive cyber capabilities in the international arms market. Several other companies have also done so, including:

- **TAR Ideal Concepts Social Media Data Collector System (part number TA08029) (Israel):** This system’s method of web intelligence enables deep social media exploration and exploitation. Using false avatars, the system can stay close to possible threats by “befriending” the threat and joining similar groups. The system

collects data and analyzes social media users' activities, comments, shares, interests, and personal networks to identify additional threats and accomplices. The Social Media Data Collector System provides the user with intelligence data reports. The Data Management System uses the data from the Social Media Data Collector System to help government and countrywide officials and organizations to identify and stop threats in the flesh.

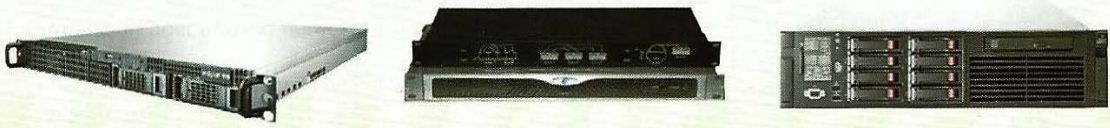
- **Poly Technologies Internet Watcher (China):** According to a Poly Technologies brochure distributed at DSA 2016 (see Figure 4), Internet Watcher is an Internet monitoring system that can recover the newest protocols and passwords, as well as decrypt Hypertext Transfer Protocol (HTTP) over a Secure Sockets Layer (SSL) in real time. It is a combination of passive monitoring capabilities and active attacking capability by injecting a Trojan horse.

General Description >

Internet Watcher is an Internet target monitoring system that can recover the newest protocols & passwords decrypt Https & SLL in real time, and It is a combination of passive monitoring capabilities and active attacking capability by injecting Trojan horse.

Functions >

- Supports various network access behaviors, recover contents: WEB access, sent and received Pop emails, instant messaging chat, online chat, remote access
- Obtain dozens of main webmail accountants and password, such as Hotmail, Gmail, Yahoo, Soho; capture accountant, password, chatting contents of IM, such as MSN, Yahoo messenger
- Real-time decryption of HTTPS & SSL
- Decrypt all sorts of decrypted websites to recover access contents and log-in accountant and password, information browsed and posted
- Convenient Trojan horse injection method to control computer of key targets



Server for Decryption Center Node Monitoring Device Manage Center

Figure 4. Internet Watcher Brochure at DSA 2016

Offensive cyber capabilities are also being advertised at security and police exhibitions such as Milipol 2015. At that exhibition, WolfCyber Intelligence *Gesellschaft mit beschränkter Haftung* (GmbH) (Germany) described itself as “an ace in offensive security.” Rayzone Group (Israel) advertised at Milipol 2015 that it provides cyber offensive capabilities for government and federal agencies to gather information covertly from elements of interest with systems such as: (1) Trojan system for computers, (2) Trojan system for mobile devices, and (3) apps and cloud interception.

Rayzone claims that these cyber capabilities provide clients with intelligence information regarding a target's (1) files, (2) photos, (3) calendar, (4) web browsing, (5) passwords, (6) e-mails, (7) regular and VOIP calls, (8) Skype conversations and chats, (9) contact list, (10) SMS and instant messages (whatsapp, line etc.), (11) hosting services (dropbox, google drive, icloud etc.), (12) device details and system information and (13) locations (cell signal info, GPS info). Companies insist that these offensive capabilities are available only to governments and law enforcement agencies. Some universities now advertise training in offensive cyber techniques at international arms shows. CY4GATE University/Academy (Italy) advertised Master's degree-level courses on "cyberattack & computer network exploitation" at the Paris Air Show 2015. Cyberattack subjects include: (1) fingerprinting and vulnerability classification, (2) exploit writing/coding and payload development, (3) data exfiltration, (4) distributed denial of service attacks, and (5) backdoor development.

CY4GATE University/Academy also advertised its "The Hacking College," which is described as

...a special and unique training module which revolves around an in-lab learning-by-doing approach, without compromising on essential theoretical foundations. Hacking techniques, management of digital information, cyber security, Internet, systems engineering, networks, big data analysis are at the core of the College.¹¹

Training at the Hacking College is based on: (1) a learn-by-doing approach, (2) possibility of customized hands-on training, and (3) refresher-training and courses on demand. Hacking College requires the full-time presence of participants in order to attend lectures, lab experiences, and seminars from internal and external experts.

A firm called Cyber Security Intelligence offers a number of reasons why offensive cyber capabilities are becoming available commercially.¹²

- **Offensive Cyber Is Becoming Reputable:** *With the endorsement from governments the stigma is being wiped clean. Historically, economic incentives aligned against legitimate players in security and defense industries desiring to explore offensive technology. The removal of penalties will unlock the shackles from these groups to conduct research and development of viable capabilities. Not all companies will take this path, but economic forces will shift direction and allow emerging market needs to be fulfilled.*
- **Unlocking the Money:** *At the same time, defense companies witnessed a dramatic shrinking of conventional weapons budgets, supplanted by a meteoric rise in cyber spends, both defensive and offensive in nature. Recognizing the business threat, they*

¹¹ "Academy," CY4GATE. Accessed on 10 October 2016 at http://www.cy4gate.com/brochure_pdf/ACADEMY.pdf.

¹² "Offensive Cyber Security Changes the Industry," *Cyber Security Intelligence*, July 7, 2015. Accessed on 10 October 2016 at <https://www.cybersecurityintelligence.com/blog/offensive-cyber-security-changes-the-industry-455.html>.

began adapting to the situation by discretely investing in the retooling of their operations to expand into digital technologies with the intent of securing future cyber contracts. With the potential of profit and lucrative deals, discovery of vulnerabilities, exploits, and other malware has quickly transition from what [were] once intellectual research projects to revenue opportunities.

- **Jobs Are Created:** *The upswing in offensive security technologies will create demand in many different roles, including offensive, defensive, administrative, and support functions. With money flowing, organizations across the landscape will look seek out needed talent. The desired skills and experience are specialized and rare. The limited supply of experts and increasing demand across a number of industries, drives the need for more aggressive recruiting. With the stigma removed, candidate recruitment becomes very open in nature. Expect more job postings, sans the term ‘hacker’, to emerge. The label ‘hacker’, with its negative connotations, will likely evolve and align with the new and respected roles. I am partial to derivatives of “offensive cyber software engineer” or “cyber analyst/operative”, both which have professional undertones to them.*
- **Talent Pool Grows:** *The group of experts in the offensive world has always been relatively small. With lucrative offers capturing this echelon, the already shallow pool is quickly running dry. The free market will respond quickly to fill the void. With the stigma removed, the field opens to white hat and general technology professionals. Money fueling new jobs attracts attention and interest from prospective entrants. Academic institutions will seize the opportunity to formally train and certify the next generation of workers. Consultation and outsourcing firms as well as in-house training will expand current skillset reach of employees. The job outlook will highlight the long term opportunities for upcoming professionals to attain positions in the potentially lucrative field of cyber security. Over time, more experts in a vast variety of direct and supporting functions will fill the ranks in support of the changes being driven by offensive security.*

2. Structural Differences in the Cyber and Electronic Warfare Markets

Before moving to the next section, it is necessary to note that there are some major differences between the current cyber and electronic war markets. First and most important, the cyber market has equally strong demand from civil and military customers. Crossover and “spin-on” technologies are the norm, not the exception with cyber products. Because of its relative youth, the cyber market is more freewheeling and has a bit of a “wild west” feel to it.

The traditional electronic warfare market is different. It serves only military and security organizations. Electronic warfare companies are primarily defense or intelligence community companies, with few non-national security sidelines. Electronic warfare has long been embedded in military organizations and its role in military operations is well defined. There is little

acknowledged technology transfer from outside the electronic warfare field, though this may change in the future if increased use of commercial information technologies to enable electronic warfare applications occurs. The rules for electronic warfare technologies and systems are well established. These rules include military-only orientation to product development and a cloaking of products in secrecy. Also, exported electronic warfare systems tend to be less capable examples of systems in domestic service with the developing country.

3. Electronic Warfare (EW) Market

The evolving electronic warfare market is dynamic in two ways. First, demand for electronic warfare systems is predicted to grow appreciably in the future. Second, (as will be discussed in the next section) electronic warfare and cyber domains are converging. Globalized advances in information technology are enablers of these two trends.

First Deputy Chief Executive Officer of Russia's Concern Radio-Electronic Technologies (KRET) Vladimir Mikheev believes, "Electronic warfare is an interesting topic in high demand, because we all know that we stand on the brink of electronic warfare."¹³ According to him, electronic warfare is growing by 15% to 20% annually.

Russia is an active player in the export market for electronic warfare systems. According to Vladimir Mikheev, his firm is well prepared and eager to export its products:¹⁴

To address the issue of delivery of our products abroad, an entire operation has been organized to prepare a proposal, conduct lengthy negotiations, and identify financial opportunities for partners and their degree of friendliness. Only after that at the state level can a decision be made on the supply of arms. We supply turnkey facilities, and we must take into account all the wishes and possibilities of the customer.

Sometimes we develop new products for foreign customers. It should be said that the US does not deliver new electronic warfare equipment abroad, because they understand that it can be used against them. We have traditionally done so, because we provide "smart" EW systems that can be used throughout the world but that cannot harm Russia.

Also according to Mikheev, "About five years ago, when we realized that we needed to change the next generation of technology, we began creating a whole range of products."¹⁵ These products included the multi-functional Rtut-BM system that protects personnel and other ground forces on the battlefield from precision weapons by blocking communication systems. Another

¹³ "Vladimir Mikheev, We stand on the threshold of an electronic war," official website of Concern Radio-Electronic Technologies (KRET), 1 April 2015. Accessed on 13 October 2016 at <http://kret.com/en/news/3734/>.

¹⁴ Ibid.

¹⁵ Ibid.

product is the Rychang helicopter EW system, which prevents the enemy from using aircraft missiles, bombs, and more from “a very great distance.”¹⁶

Other active players in the export market are companies from China and Belarus. China has been especially active marketing EW equipment in the international arms market over the past five years. Belarusian firms have only become aggressive in the last few years. Companies from Israel, Bulgaria, Turkey, Czech Republic, and Europe also attend international arms exhibitions. Most have offered individual pieces of EW equipment in traditional areas, like direction finding, interception, and signal jamming.

EW systems now being offered have much greater capability than those available just a few years ago. New equipment is “smart” in the sense of being adaptive and multifaceted. Some are even capable of generating false targets. EW systems also integrate several types of electronic warfare capabilities into a single system or complex.

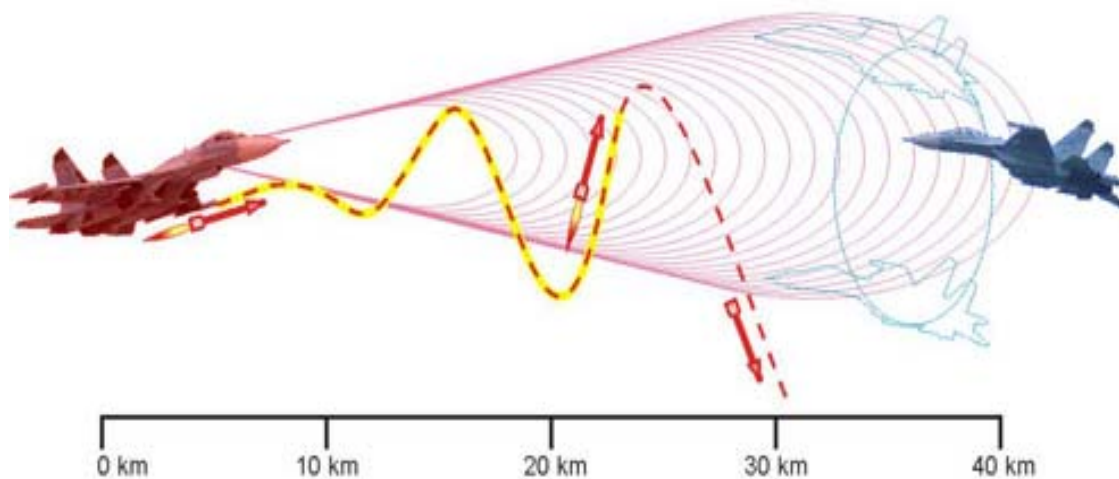


**Figure 5. Belarus 558 ARP's Satellite and Satellite-M Jamming Pods
Illustrating the Ability to Generate False Targets Brochure at MAKS 2009**

Some companies are exploring ways to revolutionize how EW is organized and conducted. Several military defense electronic research and development firms in Europe, Russia, China, and Israel are also now investigating the merging of multiple sensors, radars, signal collectors, and jammers into multi-purpose/multi-mission electronic systems in closed-loop adaptive electronic systems. This is being facilitated using digital radio frequency memory (DRFM) systems coupled with smart to brilliant software that can merge these previously separate concepts, disciplines, and hardware architectures into a single unifying software/hardware approach. The development of a smart EW pod or, better stated, a comprehensive electronic system that could collect on the fly an

¹⁶ Ibid.

electronic emission or signal; analyze the signal; devise a set of attack techniques; and then attack or mitigate that threat in near-real time is a very real future path for EW.

Efforts to develop closed-loop adaptive systems could result in a single vehicle being used for passive/active surveillance, acquisition, and air defense engagement, along with intelligence collection and signal denial or jamming. The merging of these separate disciplines into multi-mission platforms could revolutionize the air defense, intelligence, and EW markets. Couple these capabilities with adaptive learning and intelligence software and one has an electronic warfare system that requires a much smaller support infrastructure and is more adaptive and flexible. The convergence of these technologies could produce large efficiency gains and a significant reduction in acquisition and operation and maintenance (O&M) costs resulting in an overall revolution in the worldwide electronic warfare business.

Some vendors, particularly those from China, are trying to move away from selling individual pieces of equipment and toward networked systems and centers for processing and analyzing information from distributed EW assets.

China Electronic Technology Corporation International (CETC) advertised “Electronic Air Defense” on a placard at International Defense Exhibition (IDEX) 2011. According to the placard, electronic air defense adapts to jam information support systems of hostile airborne enemy strike systems. This is done to degrade the operational efficiency of the enemy’s reconnaissance, early-warning, command and control, and fire strike system in order to provide air defense. The electronic air defense system is billed as an “integrated ground-to-air EW system” that consists of L-band, C-band, S-band, and X/Ku-band jamming stations acting in concert.



**Figure 6. China's CETC “Electronic Air Defense”
Placard at IDEX 2011**

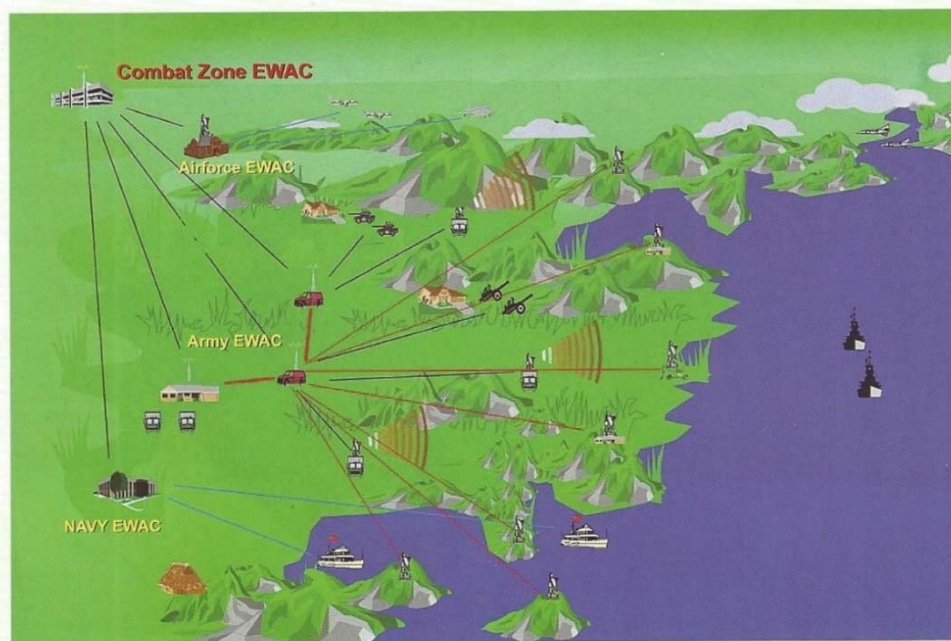
CETC also advertised a “Communication EW System Family” at IDEX 2011. This family integrates aircraft and helicopter-borne electronic warfare systems with expendable jammers delivered by parachute and multiple ground-based V/UHF direction finding/jamming vehicles.



Figure 7. China's CETC “Communication EW System Family” Placard at IDEX 2011

Chinese firms have also moved to offering EW centers. Poly Technologies at DSA 2016 offered a number of electronic warfare analysis centers, including:

- The AC999 to do analysis and processing of information obtained by radar electronic intelligence (ELINT) equipment. It is used by EW troops of the army, navy, and air force or their intelligence analysis and management departments for electronic intelligence reconnaissance. The AC999 helps systematize the operation of individual ELINT equipment to an ELINT network for upgrading the information to useful intelligence. Functions of the AC999 include: (1) information gathering, (2) intelligence analysis and processing, (3) data recording, and (4) intelligence receiving and distribution.



General Description >

AC999 is used to perform analysis and processing of the information obtained by the radar ELINT equipment. It is used by EW troops of army, navy and air force or their intelligence analysis and management departments for electronic intelligence reconnaissance. AC999 helps to systematize the individual operation of ELINT equipment to a ELINT network for upgrading the "information" to useful "intelligence".

Functions and Features >

- Information Gathering
- Intelligence Analysis & Processing
- Data Record
- Intelligence Receiving and Distribution



Figure 8. China's Poly Technologies AC999 EW Analysis Center Brochure at DSA 2016

- National EW Command and Control Center supporting EW troops. It provides intelligence support and coordination of all ELINT units. The functions of this National EW center are: (1) command and control, (2) intelligence processing, (3) spectrum planning, (4) information dispatch, (5) electro-magnetic situation display, and (6) frequency spectrum monitoring. The National EW Command and Control Center consists of: (1) communication support and video control equipment, (2) database server, (3) information distribution server, (4) video switch array, (5) DLP (12 LCD), (6) printer, (7) communications equipment, (8) retrieval software, and (9) mission seat computer stations.



Figure 9. China's Poly Technologies National EW Command and Control Center Brochure at DSA 2016

In the last few years, vendors have begun advertising artillery fuze-jamming equipment. KB Radar Design Bureau (Belarus) advertised the SPR-3 and SPR-4 Artillery Ammunition Radio Fuze Jammers at DSA 2016. They are designed to protect troops and facilities from lethal effects of radio fuze-initiated artillery munitions (gun, mortar shells, and rockets) by generating special active radio fuze jamming, resulting in premature detonation of the round at a safe distance from the protected facilities (zones).

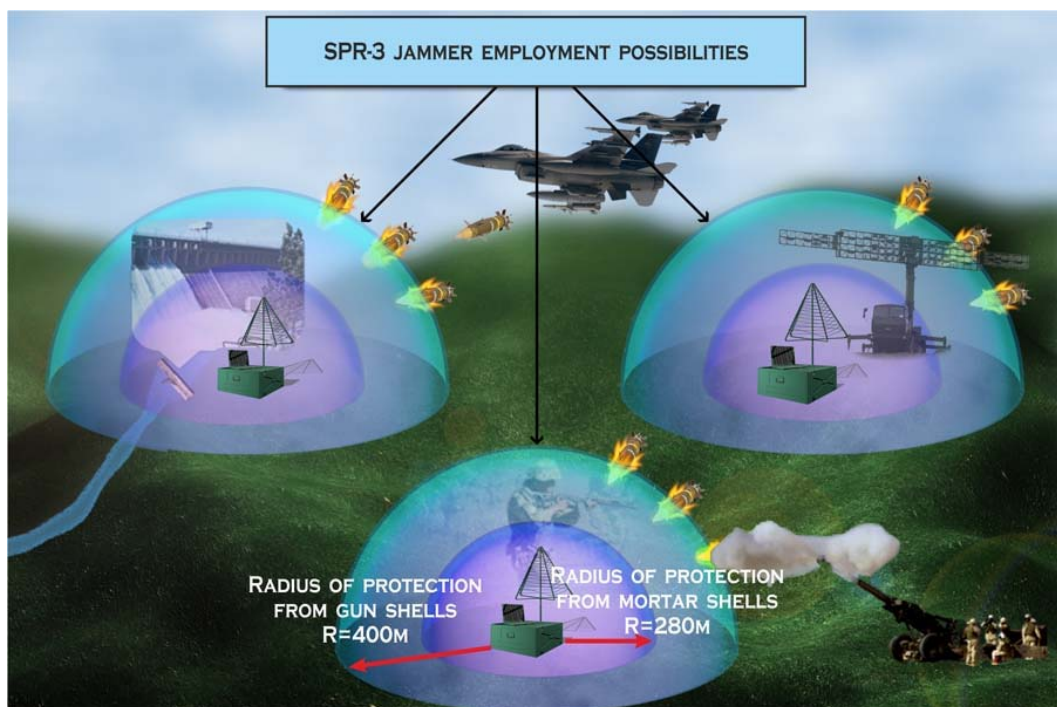


Figure 10. Belarus' KB Radar Design Bureau SPR-3 Artillery Ammunition Radio Fuze Jammer Concept of Operations Brochure at DSA 2016

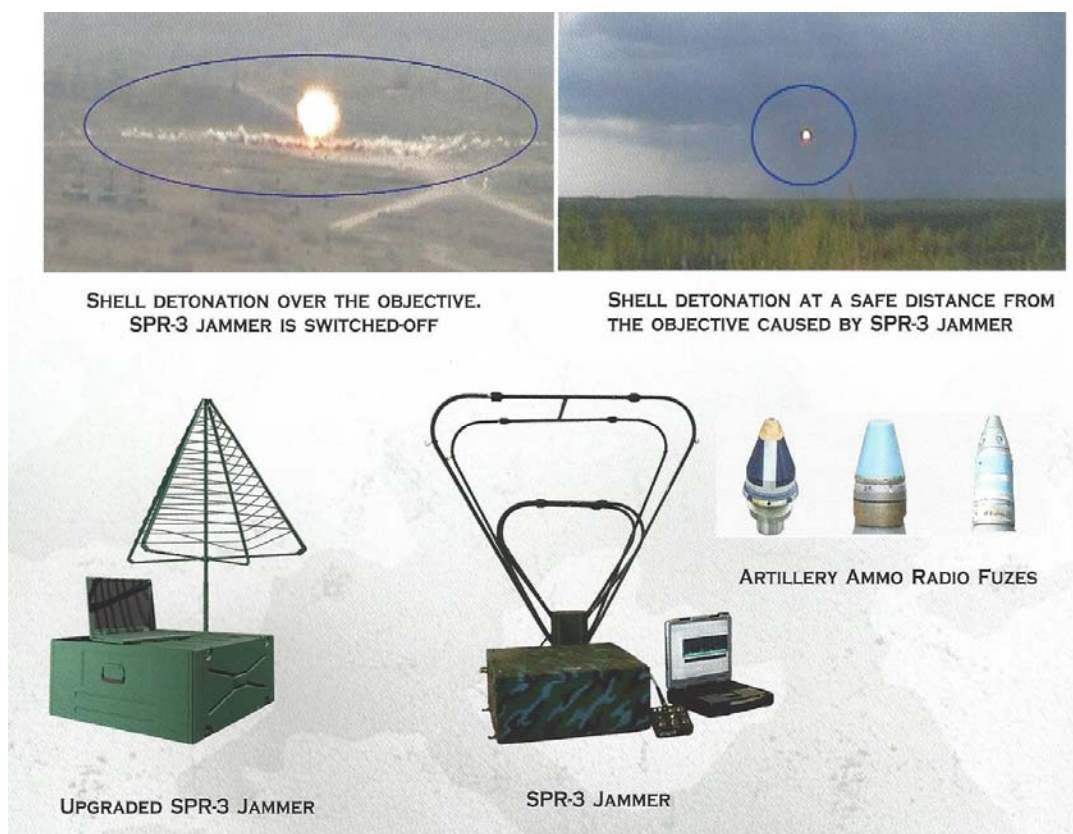


Figure 11. Belarus' KB Radar Design Bureau Upgraded SPR-3 Jammer (left) SPR-3 Jammer (right) Artillery Ammunition Radio Fuze Jammer Brochure at DSA 2016

KB Radar Design Bureau also produces the “Multi-functional system of protection of key facilities against precision weapons.” This system is designed to protect key facilities against precision weapons by ruling out or minimizing the lethal effects of precision munitions on the facility protected. Radio fuze jamming is only one aspect of the system. Other protective measures are (1) anti-radiation missiles’ pull-off subsystem, (2) laser homing missiles’ pull-off subsystem, (3) television (TV) and infrared (IR) homing missiles’ spoofing subsystem, and (4) cruise missile navigation systems’ jamming subsystems.

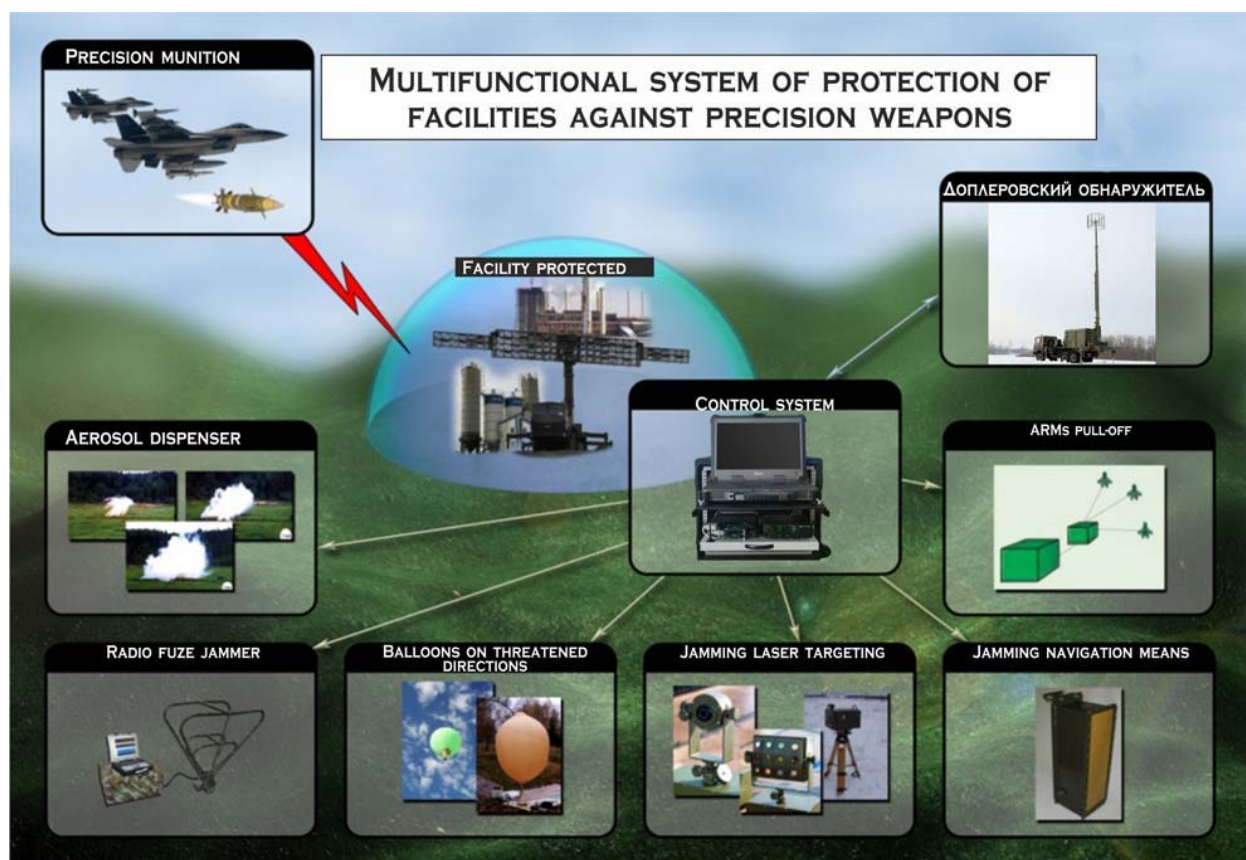
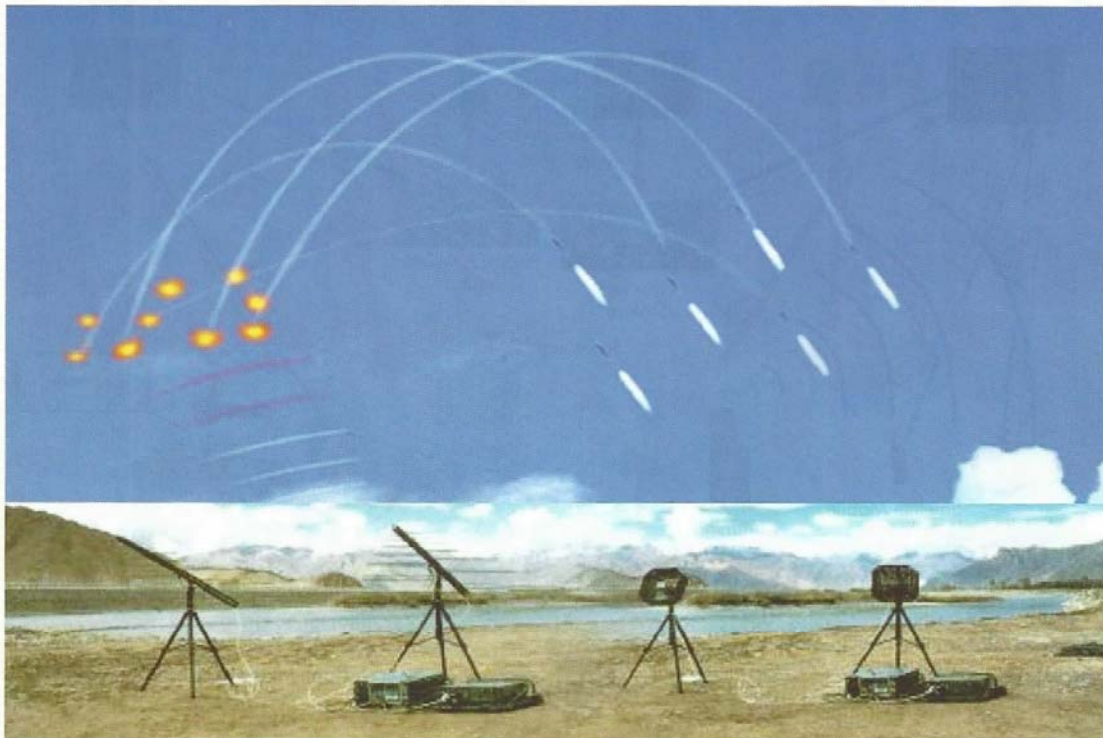


Figure 12. Belarus’ KB Radar Design Bureau Multifunctional System for Protection of Facilities Against Precision Weapons Brochure at DSA 2016

Poly Technologies (China) also advertises the DG9085/DG9086 Portable Radio Fuze Jammer at DSA 2016. The DG9085/DG9086 is designed to equip army ground force EW troops to intercept and jam radio fuze signals to detonate artillery shell, mortars, bombs, and rockets in advance or neutralize the fuze before they approach a friendly target. It detects, identifies, and measures the incoming ammunition fuze (such as proximity fuze, etc.), issues a radio ranging signal, and makes the ammunition explode in the wrong position. Because of its small size, DG9085/DG9086 can be packed by soldiers or carried by small vehicles. It can also be tailored for installation on ships and aircraft for self-protection.



General Description >

DG9085/DG9086 is designed to equip ground EW troops in army to intercept and jam radio fuse signals to detonate the attacking artillery shells, bombshells and rocket shells in advance or to neutralize the fuse effectively so that shells get detonated while impacting the ground instead of occurring in the close proximity of the target.

Specifications >

Frequency Range	100-500 MHz (DG9085), 500-1,000 MHz (DG9086)
Sensitivity of Receiver	Better than -80 dBm
Dynamic Range of Receiver	Better than 40 dB
Guiding Method	Automatic Manual input guidance
System Response Time	≤ 0.5 s
Output Power of Transmitter	≥ 50 W



Figure 13. China's Poly Technologies DG9085/DG9086 Portable Radio Fuze Jammer Brochure at DSA 2016

Two other new market areas have emerged for EW equipment. Using EW to counter improvised explosive devices (IEDs) was an outgrowth of U.S. military involvement in Iraq and Afghanistan. Over the past decade, many U.S. and foreign vendors have offered EW solutions to the IED problem at international arms exhibitions. About three years ago, firms began introducing products to service in an emerging counter-UAV market which was largely spurred by the flood of small, relatively inexpensive UAVs being offered in the commercial market. The sheer number of such systems available now is staggering. A press release at the Consumer Electronics Show

(CES) 2016 from Consumer Technology Association projected that the sale of small commercial UAVs was expected to approach 2.8 million in 2016, up 149 percent over 2015. Military and law enforcement communities have become increasingly concerned about these small, individually operated UAVs as the number of overflights of sensitive military and critical infrastructure have grown.

There is now an emerging and robust market for counter-UAV systems, many of which electronically jam GPS/GLONASS/GALILEO navigation, command, and/or data link signals. So far, most of the EW counter-UAV solutions we have seen at international arms shows have come from foreign vendors. Systems shown at Eurosatory 2016 for countering small UAVs included: (1) Anti-UAV Defense Systems (AUDS) from Blighter Surveillance Systems (U.K.) that employed a passive RF tracker and a jamming system to deal with the drone's RF communication channels, (2) the HP 3962h UAV Drone Jamming System from HP Marketing and Consulting Wust GmbH (Germany), (3) Drone Dome from Rafael Advanced Defense Systems (Israel), which neutralizes UAVs by jamming its GPS or jamming the RF command link, (4) IHTAR Anti-Drone System from Aselan A.S., which uses an Active RF Jammer System and protects against mini UAS and model aircraft and (5) Red Sky-2 "Drone Defender" System from Israel Military Systems, which employs both jamming and laser kill mechanisms.



Figure 14. Israel's Israel Military Systems Red Sky-2 "Drone Defender" System Brochure at Eurosatory 2016

Jammers are also being miniaturized to the point where they can fit into a shirt pocket. The Turkish SJ 2003 Mini-Pocket Jammer, for example, is about the size of a pack of cigarettes.

Nevertheless, it can control the communication between the cellular system base stations and cellular phones, as well as obstruct RF signal transfers produced by cellular systems.

4. Convergence of Electronic Warfare and Cyber Domains

Despite the structural differences in the EW and cyber markets, the two domains are converging and their technical capabilities are becoming more technically similar.¹⁷ Likewise, a presentation by the Department of Defence Science and Technology of the Australian Government speaks of a “Cyber-EW Continuum” where there is a convergence of “cyber, signals intelligence (SIGINT), communications and EW.”¹⁸ The same theme is central to article in *The Cyber Defense Review* that starts by asserting that the convergence of cyberspace operations and electronic warfare effects “is the foundry for new possibilities...to achieve both offensive and defensive overmatch.”¹⁹

On December 31, 2015, China’s Central Military Commission announced the creation of a new organization called the People’s Liberation Army Strategic Support (战略支援部队) which official sources claim will form the core of China’s information warfare force.²⁰ Some Chinese military commentators believe the portfolio of the PLA Strategic Support Force includes space, cyberspace, and electronic warfare operations.²¹ The creation of new Strategic Support Force and its portfolio therefore may suggest that China has an advancing understanding of EW/cyber convergence.

This phenomenon is being recognized in the international arms market. The CYBERDEF - CYBERSEC FORUM at Eurosatory 2016 for instance had a presentation entitled “Electronic warfare and Cyber convergence on the Battlefield.” The presenter concentrated on the converging skill sets of the people working both areas, rather than the technology.

Company websites also speak of this convergence. The website of SRC Inc. (a company that has focused on electronic warfare for 35 years) reinforces the idea of the merging of the two

¹⁷ “7th Annual Cyber/Electronic Warfare Convergence Conference,” *Breaking Defense*. Accessed on 10 October 2016 at <https://www.google.com/#q=cyber+and+electronic+warfare+convergence>.

¹⁸ “Cyber and Electronic Warfare Division DST Partnerships Week 2016,” Department of Defence Science and Technology, Australian Government, 2016. Accessed on 10 October 2016 at <http://www.dst.defence.gov.au/sites/default/files/events/documents/CEWD%20Presentation.pdf>.

¹⁹ Maj. Michael Senft, “Convergence of Cyberspace Operations and Electronic Warfare Effects,” *The Cyber Defense Review*, January 4, 2016. Accessed on 10 September 2016 at <http://www.cyberdefensereview.org/2016/01/04/convergence-of-cyberspace-operations-and-electronic-warfare-effects/>.

²⁰ John Costello, “The Strategic Support Force: China’s Information Warfare Service,” Jamestown Foundation, August 8, 2016. Accessed on 12 January 2017 at <http://cimsec.org/strategic-support-force-chinas-information-warfare-service/27200>.

²¹ “China Takes Bold Steps Toward Military Reform,” STRATFOR, January 11, 2016. Accessed on 12 January 2017 at <https://www.stratfor.com/analysis/china-takes-bold-steps-toward-military-reform>.

domains. A section of the company's website is labeled "Electronic Warfare-Enabled Cyber" and states:

*The inclusion of cyber-attack techniques in the tools available to the EW designer and planner is a natural extension of EW system capabilities. SRC's EW systems are designed with the flexibility and programmability necessary to support EW-enabled cyber operations.*²²

The website of L-3 TRL Technology (United Kingdom) also emphasizes that electronic warfare and cyber techniques are converging. It goes on to say:

*British technology companies are leading the charge on the idea of battlespace cyber – the convergence between electronic warfare and cyber techniques – harnessing the innovation and skills of some of the world's most talented engineers to enable the integration of cutting-edge technology into military operations.*²³

Another sign of this convergence is that Georgia Tech University now offers a course entitled "Cyber Warfare/Electronic Warfare Convergence and Integration." The course description claims that benefits of taking the course include: (1) a "foundational knowledge of cyber warfare, electronic warfare and the convergence of the two," (2) an exploration of "network attack techniques and tools for assessing vulnerabilities," and (3) having an "opportunity to practice newly learned skills through workshops and other hands-on activities."²⁴

CY4GATE University also emphasizes the convergence of electronic warfare and cyber. In describing its overall mission, the CY4GATE web site notes that it provides governments "with disruptive software and hardware solutions to succeed in defensive and offensive operations through the use of electromagnetic spectrum (EMS), communications, operating systems, and wired networks."²⁵

C. Stealth

Discussing arms market trends regarding stealth products and technologies is perhaps the most difficult topic this study will address because stealth is an amorphous topic. Products designed to reduce the probability of detection go by many names: stealth, signature reduction, signature management, low observable technology, camouflage, or cover and concealment. Stealth technology (regardless of what it is called) covers a wide range of techniques that can be used with personnel, aircraft, ships, undersea craft, missiles, satellites, and buildings to make them less

²² "Electronic Warfare-Enabled Cyber," SRC Inc website. Accessed on 21 September 2016 at <http://www.srcinc.com/what-we-do/ew/ew-enabled-cyber.aspx>.

²³ "Cyber and Electronic Warfare converge," L-3 TRL Technology website. Accessed on 21 September 2016 at <http://www.trltech.co.uk/insights/cyber-convergence.aspx>.

²⁴ Course description: "Cyber Warfare/Electronic Warfare Convergence and Integration," Georgia Tech University. Accessed on 21 September 2016 at <https://pe.gatech.edu/courses/cyber-warfareelectronic-warfare-convergence-and-integration>.

²⁵ "Building for Enabled Minds to Think Higher," CY4GATE. Accessed on 10 October 2016 at <http://www.cy4gate.com/>.

visible to RF, near or far-IR, millimeter wave, acoustic, and optical sensors. Stealth technology can operate against a single band within one type of phenomenology or be multispectral.

Even when defense firms use the same term for comparable products, their meaning may be quite different. When U.S. vendors describe the F-22 fighter as stealthy, they mean the aircraft is nearly invisible to radar, but when the Chinese describe their next generation J-20 fighter as stealthy, they mean something else. A representative of the Aviation Industry Corporation of China (AVIC) told us at an air show that the J-20 was designed to be stealthy only in the sense of being able to defeat detection by sensors on-board AAMRAM missiles, not surveillance radars looking for the aircraft.

Because stealth is an amorphous term that covers multiple technologies and can be applied to such a wide range of end items, there are no records of worldwide sales or forecasts of market size. Discussion of trends related to stealth technology must be by impressions and examples drawn from the arms market.

Despite the amorphous nature of stealth technology, our experience attending international arms shows suggests the following taxonomy. At the broadest level, the market for stealth technology is divided into two categories: (1) high-end products, which seek to mask platforms and infrastructure from detection and (2) low-end products, which only aim to keep munitions from finding their targets. The next level can be divided into three categories: (1) integrated purpose-built platforms, which are designed from the beginning to incorporate materials and structures to reduce visibility, (2) permanent add-on upgrades (e.g., coatings or paints) to platforms, buildings, or missiles, which were not initially designed for low-signature, and (3) temporary add-ons (e.g., blankets, netting) to decrease the signature of objects not designed originally for low visibility. The main difference between categories 2 and 3 is that temporary add-ons can be removed or changed if desired. The last level of the taxonomy divides products into passive or active approaches to achieving signature reduction.

1. Purpose-Built Platforms

Twenty years ago, the only purpose-built stealth platforms that introduced signature reducing shapes, structures, and materials as part of the original design process publicly known to be in service were the F-117 fighter, B-2 bomber, and F-22 fighter just about to come online. None of these aircraft was available for export. At the time, the U.S. had an absolute technological advantage over all other nations in stealth technology. Over time, that situation has changed in several ways. Only much later did the U.S. allow export of the F-35 fighter to a select group of allies.

Several nations have recently fielded what are advertised as prototype stealth fighters: (1) Russian "Prospective Airborne Complex of Frontline Aviation" (PAK-FA)/T-50 and (2) Chinese J-20 for service in the People's Liberation Army Air Force and J-31/FC-31 exclusively for the export market. Others have such aircraft programs underway. Mitsubishi Heavy Industries is developing the X-2 *Shinshin*/F-3 stealth fighter for Japan. South Korea is developing the Korean

Fighter Xperimental (KF-X) fighter, which is sometimes described as a cutting-edge stealth fighter because of its composite structures and inherent stealth features. The Korean Agency for Defense Development estimates the first prototype will appear in the second half of 2020.²⁶ India's Aeronautical Development Agency and Hindustan Aeronautics Limited are also working on a fully indigenous Advanced Medium Combat Aircraft (AMCA) with a number of stealth features: (1) small radar cross section, (2) serpentine shaped air-intakes to reduce radar exposure to the fan blades, (3) internal weapons bay, and (4) composite materials.²⁷

It is unlikely that the signature reduction of Russian, Chinese, Japanese, and South Korean next-generation stealth fighters are comparable to the F-22 Raptor. Representatives from Russian aircraft industry have told us that the PAK-FA/T-50 fighter is optimized against F-35, not F-22. Likewise, the Chinese are marketing the J-31 as an alternative to F-35. Regardless of the actual signature reduction capabilities of foreign stealth fighters versus American ones, the central point is that America's once-absolute advantage in stealth aircraft technology is now only relative.

Another major change over the past two decades is that advertised low observable/"stealth" fighter aircraft are available for export.

- Six years ago, Pravda reported that the Russian Center for Analysis of the Global Arms Trade estimated that Sukhoi was capable of exporting 600 PAK-FA/T-50 aircraft, with 250 going to India.²⁸ Sukhoi also signed a co-development, licensed-production agreement whereby a derivative of the PAK-FA/T-50 would be built in India under the name Sukhoi/HAL Fifth Generation Fighter Aircraft (FGFA) project, known in India as the Perspective Multi-role Fighter (PMF) by Hindustan Aeronautics Ltd.²⁹ Full implementation of this agreement, however, is still in some doubt. Indian media reported in January 2016 that undisclosed "top air marshals" during a high-level meeting in New Delhi alleged that the FGFA would not meet Indian expectations. Objections raised by ranking Indian Air Force officers at that meeting included: (1) The Russians would not share critical design information with India; (2) the engines are inadequate, being mere upgrades of the Sukhoi-30MKI's engines; and (3) the \$6 billion required to co-develop the FGFA would mean that,

²⁶ "Contracts & Key Events," *Defense Industry Daily*, August 12, 2016. Accessed on 13 October 2016 at <http://www.defenseindustrydaily.com/kf-x-paper-pushing-or-peer-fighter-program-010647/>.

²⁷ "Gururag Kalanidhi, What is the status and specifications of the Indian home grown AMCA project for the air force?" *Quora*, September 2, 2015 accessed on 13 October 2016 at <https://www.quora.com/What-is-the-status-and-specifications-of-the-Indian-home-grown-AMCA-project-for-the-air-force>.

²⁸ "Russia to export 600 Sukhoi PAK FA fifth generation jets," *Pravda*, September 13, 2010. Accessed on 13 October 2016 at <http://www.pravdareport.com/russia/economics/13-09-2010/114900-sukhoi-0/>.

²⁹ Franz-Stefan Grady, "India and Russia Reach Agreement Over 5th Generation Fighter Aircraft," *The Diplomat*, September 12, 2016. Accessed on 13 October 2016 at <http://thediplomat.com/2016/09/india-and-russia-reach-agreement-over-5th-generation-fighter-aircraft/>.

“a large percentage of IAF’s capital budget will be locked up.”³⁰ But for now, the joint project is still a go. Also according to Alexander Fomin, the head of the Russian Federal Service for Military-Technical Cooperation, Russia offered Brazil an opportunity for joint development of the PAK-FA/T-50 in the 2011-2013 timeframe.³¹ Brazil ultimately decided not to participate.

- The Shenyang Aircraft Corporation developed the J-31/FC-31 next generation fighter even though the PLA Air Force had no requirement for it. According to an article in *China Military Online* (the new official English-language website of the Chinese People’s Liberation Army), J-31/FC-1 is being targeted at the export market as a low-cost competitor to the American F-35.³² The Chinese have already had preliminary discussions with Pakistan about buying the aircraft.³³
- Korea Aerospace Industries (KAI) is also interested in exporting the KF-X fighter. To that end, KAI signed a joint engineering agreement with the Indonesian government in November 2015, whereby KAI would pay 80% of the engineering and development costs with Indonesia paying the other 20%. According to the agreement, Indonesia’s state-owned aerospace manufacturer, PT Dirgantara Indonesia (PTDI), will participate in the design phase of the aircraft and produce unidentified components.³⁴ Turkey has also had discussions concerning the KF-X fighter.

Purpose-built stealth aircraft platforms are no longer confined to manned aircraft. Although the idea of purpose-built stealth UAV and unmanned combat aerial vehicles (UCAV) platforms is by no means new, a June 2015 report by a Senate Committee in the Australian Parliament asserted that increasingly large UAVs will have to operate in a contested or denied environment and that this, in turn, will increase the importance of low observability of UAVs.³⁵

³⁰ Ajai Shukla, “Indian, Russian negotiators agree on FGFA development,” *Business Standard*, January 25, 2016. Accessed on 13 October 2016 at http://www.business-standard.com/article/economy-policy/indian-russian-negotiators-agree-on-fgfa-development-116012500035_1.html.

³¹ “Russia Offers Brazil Joint Development of PAK-FA Stealth Fighter, *Asian Defence News*. Accessed on 13 October 2016 at <http://www.asian-defence.net/2014/03/russia-offers-brazil-joint-development>.

³² “Expert: External Attachment Points of J-31 Stealth Fighter Will Facilitate Exports,” republication of a September 6, 2016 article from *China Military Online* in *Defense-Aerospace*. Accessed on 13 October 2016 at http://www.defense-aerospace.com/articles-view/release/3/176788/china-sees-foreign-interest-for-j_31-stealth-fighter-export.html.

³³ “Pakistan in Talks to Buy China’s FC-31 Stealth Fighter,” *DEFENSETECH*, November 26, 2014. Accessed on 11 January 2017 at <http://defensetech.org/2014/11/26/pakistan-in-talks-to-buy-chinas-fc-31-stealth-fighter/>.

³⁴ Jon Grevatt, “Korea Aerospace Industries agrees KFX investment deal with Indonesia,” *HIS Jane’s 360*, November 23, 2015. Accessed on 13 October 2016 at <http://www.janes.com/article/56161/korea-aerospace-industries-agrees-kfx-investment-deal-with-indonesia>.

³⁵ *Use of unmanned air, maritime and land platforms by the Australian Defence Force*, Foreign Affairs, Defence and Trade References Committee, Senate, Australian Parliament, June 2015. Accessed on 20 October 2016 at

Examples of purpose-built stealthy UAVs and unmanned combat aerial vehicle concepts and platforms include:

- **Denel Seraph UAV (South Africa):** Representatives of Denel at the Paris Air Show 2001 said that designers of the Seraph UAV had taken a multi-faceted design approach to reducing its radar cross section. This included the application of special signature-reduction coatings and external shaping. As part of the stealth process, Denel engineers treated the engine face and walls of the serpentine air inlet with radar-absorbing materials. A particular design problem for the South Africans was the engine inlet lip. Another focus for the South African team was reducing the infrared signature from the engine exhaust. The designers hid the engine internally and placed the single inlet on top of the UAV to reduce its infrared signature.
- **Dassault Aviation nEUROn and AVE UCAV (France):** Dassault Aviation has also worked on two technology demonstrators of stealthy unmanned aerial combat vehicles: (1) AVE in the 2000 to 2005 timeframe, and (2) nEUROn, displayed in model form at Eurosatory 2010 and the Paris Air Show 2005. Signature reduction features of nEUROn included: (1) aerodynamic innovative composite structure, (2) internal weapon bay, and (3) related to low observability.



Figure 15. South Africa's Denel Seraph Stealthy UAV Model at Paris Air Show 2001

http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Foreign_Affairs_Defence_and_Trade/Defence_Unmanned_Platform/Report.



Figure 16. France's Dassault Aviation nEURon Unmanned Combat Aerial Vehicle Model at Paris Air Show 2015

- UAC Low Observable Unmanned Aerial Vehicles (Russia):** Russian efforts include an unmanned combat air vehicle based on the PAK-FA/T-50 fighter, which was said to be at a “preliminary research stage” by the President of Russia’s United Aircraft Corporation (UAC) at the Moscow Air Show 2013.³⁶ First Deputy Chief Executive Officer Vladimir Mikheev of KRET told reporters at the Moscow Air Show 2015 that his company and UAC are also working a low-observable F-35-hunting UAV that uses deeply integrated electronic warfare systems to stay hidden from radar.³⁷ UAC also unveiled a model of another low-observable UAV at the Moscow Air Show 2015.

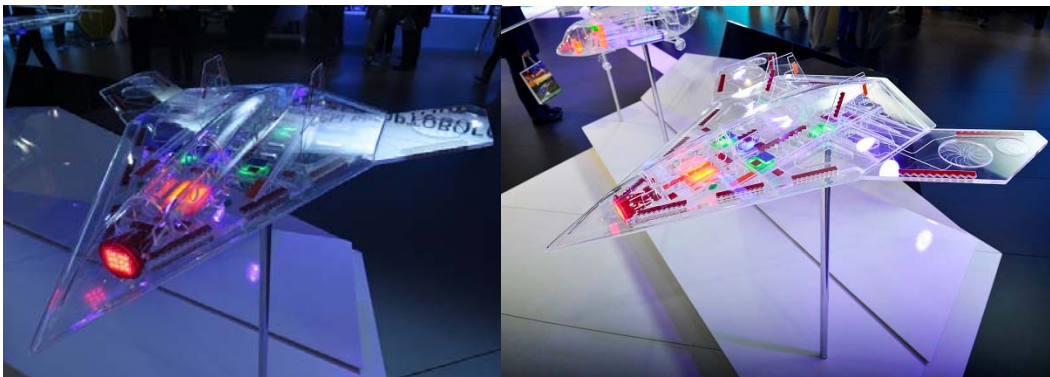


Figure 17. Russia's United Aircraft Corporation Stealth UAV Concept Model at Moscow Air Show 2015

³⁶ “Russia Developing Attack Drone from T-50 Fighter Jet – UAC,” *Sputnik News*, August 30, 2013. Accessed on 13 October 2016 at <https://sputniknews.com/military/20130830183068603-Russia-Developing-Attack-Drone-From-T-50-Fighter-Jet--UAC/>.

³⁷ “MAKS: Is Russia developing an F-35-hunting UAV?” *Global Flight*, August 26, 2015. Accessed on 13 October 2016 at <https://www.flightglobal.com/news/articles/maks-is-russia-developing-an-f-35-hunting-uav-416065/>.

- **Korea Aerospace Industries (KAI) Low Observable UCAV (South Korea):** KAI unveiled a sub-scale model of an unmanned combat aerial vehicle at the Paris Air Show 2015 that was designed to be low observable. This was the first extensive display on this program at an international exhibition.



Figure 18. South Korea's KAI Unmanned Combat Aerial Vehicle Model at Paris Air Show 2015

Shipbuilding was the next sector to adopt integrated purpose-built stealth platforms. Examples of such vessels include:

- **Saab MCMV 47 Koster Class Mine Countermeasures Vessel (Sweden):** It has a number of low-observable characteristics including: (1) low magnetic signature, (2) low acoustic signature (insulation), (3) low infrared signature (insulation), (4) low electric (UEP/ELFE) signatures, and (5) low pressure signature.
- **Saab Visby Class Corvette (Sweden):** It is described by the Saab's official website as the "first vessel in the world to have fully developed stealth technology" and Visby represents "stealth all the way."³⁸ Stealth features include sandwich-construction carbon fiber reinforced plastic for low radar and magnetic signatures. The hull is designed with large, flat angled surfaces and every feature possible either built in or concealed under specially designed hatches.

³⁸ "Visby Class Corvette Defining Stealth at Sea," Saab official website. Accessed on 14 October 2016 at <http://saab.com/naval/submarines-and-warships/naval-surface-ships/visby-class-corvette/>.



Figure 19. Sweden's Saab Visby Class Corvette³⁹

- **DCNS La Fayette Class Frigate (France):** Has a shaped hull and superstructures designed to reduce the ship's radar cross section. Its construction uses reinforced plastic and Kevlar to further reduce its signature.
- **China State Shipbuilding Corporation (CSSC) C28A Corvette (China):** Is equipped with some signature reduction features, such as exhaust gas funnels located on the hull at the waterline to reduce the IR signature.
- **Umoe Mandal Skjold Class Fast Patrol Boat (Norway):** The hull was developed using low-observable structural design principles and its hull, superstructure, and fittings are largely fabricated of radar-absorbing composite materials.



Figure 20. Norway's Umoe Mandel Skjold Class Fast Patrol Boat⁴⁰

³⁹ Ibid.

⁴⁰ "Skjold Class Corvette," Umoe Mandal AS website. Accessed on 14 October 2016 at <http://www.um.no/WEB/um200.nsf/pages/C10AC32D5D>.

- **Safehaven Marine SV11 Barracuda “Stealth” Interceptor/Patrol Vessel (Ireland):** Innovative design uses various stealth technologies to produce a lower radar cross section (RCS), allowing it to operate with a high degree of invisibility to an adversary’s radar. Stealth technologies are employed in the superstructure and hull design, using flat plane principles on its forward surfaces (and to a lesser extent, side projections) to deflect radar beams with radar absorbing material (RAM) and specialized outfitting, including minimal metallic fittings exposed above decks, or fully recessed where necessary.



Figure 21. Ireland’s Safehaven Marine Barracuda “Stealth” Interceptor/Patrol Vessel at DSEi 2015

Designers of armored vehicles were much slower to embrace whole vehicle, integrated, purpose-built stealth designs. The first attempt to design a purpose-built, reduced-signature armored vehicle came from *Groupement des Industries de l’Armée de Terre* (GIAT Industries), working under contract to the French *Délégation Générale pour l’Armement* (DGA). GIAT Industries developed and produced a tank demonstrator known as the AMX-30 Stealth Tank between 2000 and 2005. Stealth features of the AMX-30 included specially designed radar absorbing materials, a device that pumped cold air and water over the hull to reduce its thermal signature, and special shaping of the hull and turret to reduce the radar signature. GIAT claimed that the AMX-30 underwent a series of trials very successfully, but never went into service. One blogger writing in 2005 claimed that Leclerc (both designers and tankers) mostly agreed on something in the line of “fine, but how will the RAM [radar absorbing material] coating behave when showered with mud, rocks, trees, ice, shell splinters, bouncing AT [anti-tank] rounds, SA [small arms] fire... A tank is no plane and has to be rugged enough to survive on the field, and stealth coatings tend to be fragile.”⁴¹

⁴¹ PlasmaKrab, “Stealth Tanks,” *Shrapnel Games Forum*, August 30, 2005. Accessed on 14 September 2016 at <http://forum.shrapnelgames.com/archive/index.php/t-25668.html>.



Figure 22. France's Nexter AMX-30 "Stealth" Tank Placard at Eurosatory 2002

A decade later there are still no integrated, purpose-built stealth armored vehicles. That may soon change.

- **BAE Systems PL-01 "Stealth" Tank (Poland and United Kingdom):** BAE Systems (United Kingdom) and OBRUM (Poland) are jointly developing a new tank designated the PL-01. Last year it was expected that a prototype would appear in 2016 and that mass production would begin in 2018. The goal of the designers is to produce a tank with as low an IR, radar, and visual signature as possible. To achieve this goal, the vehicle is fitted with temperature controlled hexagonal panels on the exterior to ensure that the tank's IR signature matches that of the background. The PL-01 is also covered with radar absorbing material and hull and turret structures are shaped to reduce radar returns.⁴²
- **Uralvagonzavod T-14 "Armata" Tank (Russia):** Vyacheslav Khalitov, Deputy General Director for Special Equipment at Russia's Uralvagonzavod, claimed in a July 3, 2015, interview with the *Ekho Moskvy* radio station that "We essentially made the invisible tank..."⁴³ Signature reduction features include placing easily detectable components of the tank deep within to mask infrared signatures from

⁴² "The future tanks of Poland, Russia, and Germany," *Baltic Defense*, March 2015. Accessed on 14 October 2016 at <http://balticdefense.blogspot.com/2015/03/the-future-tanks-of-poland-russia-and.html>.

⁴³ Remarks by Vyacheslav Khalitov, in an interview with the *Ekho Moskvy* radio station as reported by Mathew Bodner in "Russia's New Armata Tank 'Invisible,' Says Manufacturer," *Moscow Times*, August 4, 2015. Accessed 2 February 2016 at <http://www.themoscowtimes.com/business/business/article/russias-new-armata-tank-invisible-says-manufacturer/526974.html>.

optical sensors. Khalitov also claimed that the vehicle's hull is coated with special radar-absorbing paint and other materials and appliques that make it difficult to detect.⁴⁴ *Sputnik News* also quotes Khalitov as saying in an interview with svpressa.ru internet portal, "We are using GALS-technology — a special coating with reflective surface that does not allow the determining of what the object is, no matter what means of detection the enemy employs: optical, radar or infrared"⁴⁵ He went on to claim that the special coatings make tanks four times less visible to radar and three times less visible to thermal sensors. The first batch of T-14 "Armata" main battle tanks has already been delivered to the Russian Army for trials.

- **Future Ready Combat Vehicle (India):** The Indian Ministry of Defense issued a global request for information in June 2015 to develop a multi-purpose Future Ready Combat Vehicle to replace older license-built Soviet/Russian T-72 main battle tanks. One of the requirements stated that the vehicle "should incorporate signature reduction technologies."⁴⁶

Roxel Propulsion Systems has even offered complete control of signature to reduce detection and improve through-plume transmission for command signals of tactical rocket motors. Roxel claims to reduce the signature of rockets in the ultra-violet, visible, radar, and infrared spectrums. According to a company representative at DSEi 2013, Roxel has been unable to convince most customers to buy these "stealthy" propellants. (As of 2013, only one company had purchased this option.)

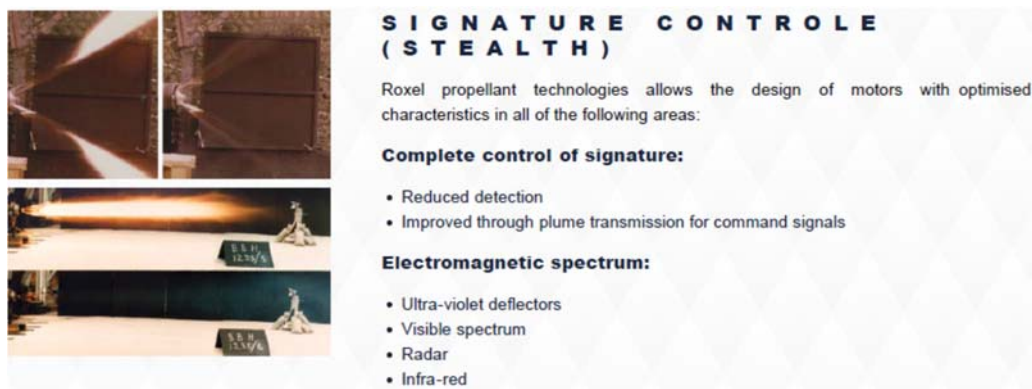


Figure 23. Europe's Roxel Signature Control Propellants Brochure at Eurosatory 2014

⁴⁴ "Russian Builder of T-14 Armata claims it has radar and infrared invisibility," August 16, 2015. Accessed 2 February 2016 at <http://nextbigfuture.com/2015/08/russian-builder-of-t-14-armata-it-has.html>.

⁴⁵ Vyacheslav Khalitov quoted in "You Won't See 'Em: Designers Come Up With New Ideas to Make Tanks Invisible," *Sputnik News*, May 15, 2016. Accessed on 14 October 2016 at <https://sputniknews.com/russia/201605151039641684-russia-tanks-stealth/>.

⁴⁶ "Request for Information from Vendors for Designs for a Future Ready Combat Vehicle for the Indian Army," Directorate General of Mechanized Forces, Defense HQ PO, New Delhi -- 110011, 10 June 2015. Accessed 20 July 2016 at <http://indianarmy.nic.in/writereaddata/RFI/445/FRCV%20RFI.pdf>.

2. Permanent Add-Ons

The next category of signature reduction products consists of items that are permanent add-ons to the vehicle. Most of these were designed for ground force vehicles. Many products come from Western and former East-bloc countries. But surprisingly, many others come from countries (e.g., Greece and Malaysia) where it would have been unimaginable 20 years ago, demonstrating the worldwide diffusion of signature reduction technology.

Examples of permanent add-on productions for armored vehicles include:

- **Krauss-Maffei Wegmann and Rheinmetall Landsysteme Puma Infantry Fighting Vehicles (Germany):** Have a number of add-on signature reducing features: composite armor, side skirts, and thermal signature reducing paint.
- **BAE Systems Future Protected Vehicle Program (United Kingdom):** A science-technology development program was undertaken by BAE Systems to help the U.K. Ministry of Defense understand the high-tech battlefield of tomorrow. Future features envisioned by BAE Systems in 2010 included electronic ink camouflage systems. BAE Systems also described a “sweating” armored vehicle, which would emit water from the propulsion system through “pores” in the vehicle’s armor to reduce thermal signature. BAE Systems showcased the “sweating” armor concept in a workshop held in Qatar in April 2011.
- **SAAB Barracuda AB Mobile Camouflage System (Sweden):** The Mobile Camouflage System (MCS) provides an individual camouflage kit for armored vehicles during movement and in combat. MCS is available in different versions composed of a combination of camouflage materials with signature reduction properties. These include: (1) visual and near infrared protection, (2) thermal protection, (3) radar protection, and (4) heat transfer system.
- **PPG Aerospace IR and Radar Reducing Paints (France/Germany/South Africa/United Kingdom/United Arab Emirates):** PPG Aerospace paints are used for a wide variety of military applications, including military vehicles, electronics housings of mobile radar, missiles, and low-flying surveillance aircraft. Low emissivity is “turnable” and PPG Aerospace will develop materials to specific operational needs of individual customers.
- **Products from the Kharkov Morozov Machine-Building Design Bureau (Ukraine):** The official website of this design bureau emphasizes that it offers protective systems for reduction of signatures of tanks. These features are designed for reducing the range and probability of the tank detection by reconnaissance equipment and homing devices of high precision ammunitions. The website claims that its products reduce: (1) thermal signature by five to seven times, (2) radar

signature by three to five times, and (3) visual signature by 1.5 times.⁴⁷ Only a few signature-reducing products are mentioned on the website – side skirts to cover the running gear, thermal insulation of the top deck of the engine compartment, and a thermal sleeve to cover the gun barrel.

- **Intermat Defense Coatings Chameleon's Skin Self-Adhesive Camouflage System (Greece):** Anti-thermal Chameleon's Skin is delivered in the form of self-adhesive (decal) tape that can be quickly applied by vehicle crews to blend with rocky, desert, jungle, or urban environments. It includes windshield and tire covers to camouflage as well. The product can be customized in sizes and patterns to meet a customer's operational requirements.
- **Metro Koats Technology (MKT) KT-SKREN Windshield Camouflage System (Malaysia):** MKT offers a full line of camouflage products designed to defeat visual and near-IR sensors. One of these products is the KT-SKREN windshield camouflage system. KT-SKREN is a stick-on, layer-on system that allows passengers inside the vehicle to see outside, while the outside of the windshield has the same camouflage paint scheme as the rest of the vehicle. This system also eliminates the "dead-give-away" reflections from glass surfaces. The color scheme of the windshield is in accord with the Royal Malaysia Army's "harimau belang" color code and has approved IR-reflecting characteristics.



Figure 24. Malaysia's KT-SKREN Applied to the Windows of a Light Wheeled Vehicle Brochure at DSA 2010

⁴⁷ "Reduction of Tank Signatures," official website of the Kharkov Morozov Machine-Building Design Bureau. Accessed on 17 October 2016 at <http://www.morozovkmdb.com/eng/body/addconc.php>.

- **Oto Melara Radar and IR Signature Reduction Kits (Italy):** Oto Melara has advertised a kit that reduces the radar and IR signatures of land vehicles. Oto Melara claims that the kit, which is light and easy to install, provides “total protection against multi-spectral sensor threat.” More specifically, an Oto Melara placard states that the kit provides protection against radar, thermal infrared (TIR), near infrared (NIR), ultraviolet/visible (UV/VIS), radiometric, and laser illuminator sensors. Oto Melara achieves this effect by applying composite radar-absorbing structural panels and radar-absorbing paint to various parts of the vehicle. (See the diagram from the placard in Figure 25.)

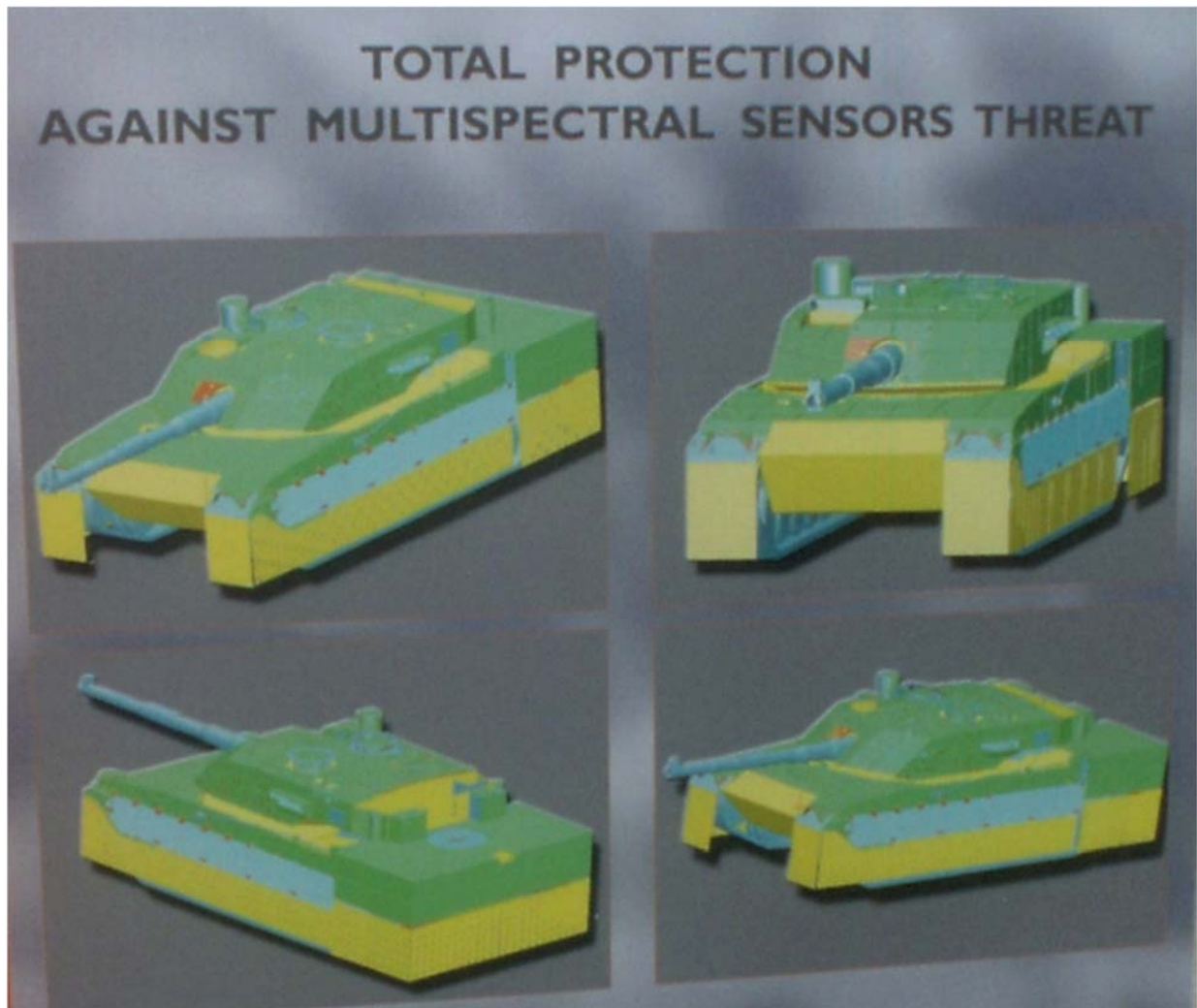


Figure 25. Italy's Oto Melara's Signature Reduction Panels Placement Placard at Eurosatory 2002

Intermat Defense Coatings (Greece) claims to be the only company offering signature-reduction coatings for buildings, such as hangars, tarmacs, military facilities, and infrastructure.

The company claims its coatings make the facility blend with the nearby infrared background, thereby breaking “lock-on” by passive IR homing missiles.

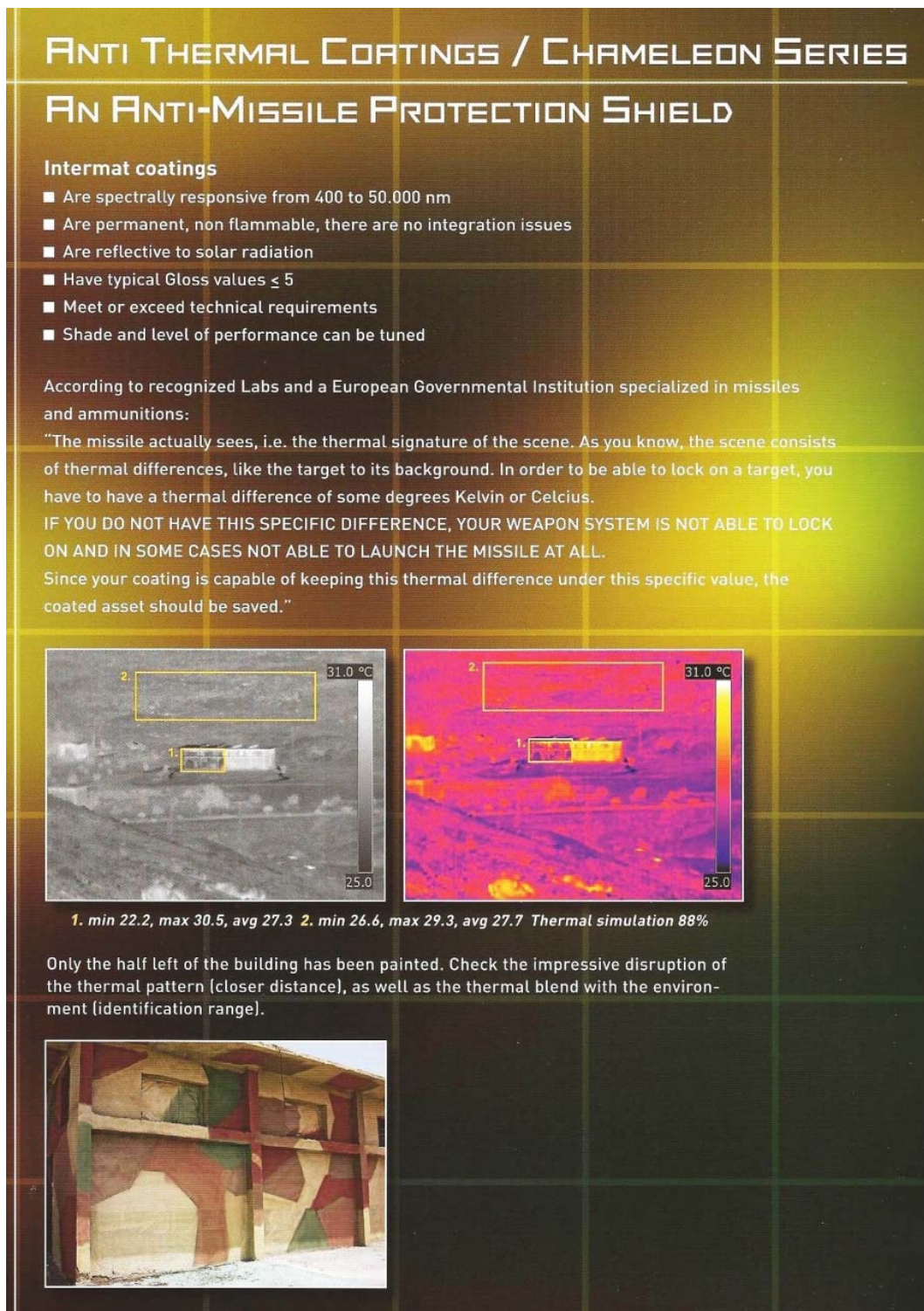


**Figure 26. Greece's Intermat Defense Coatings for Buildings
Brochure at IDEX 2013**

Several companies also offer to provide mobile structures with reduced signatures. Saab Barracuda LLC has been advertising the Mobile Camouflage Shelter System at least since DSEi 2008. The Mobile Camouflage Shelter is transportable by aircraft and can be deployed quickly without the aid of lifting devices or cranes to give multi-spectral protection to objects covered. The system is designed to protect fighter aircrafts, vehicles, materiel, and personnel. The Mobile Camouflage Shelter System consists of: (1) waterproof tarpaulin with visual, Near IR, and broadband radar protection, (2) support structure of the tarpaulin, (3) heating/ventilation system, (4) power/lighting system, and (5) storage units for transporting. It gives multi-spectral protection against the threats of the modern sensors working in the visual Near IR and radar bands of the electromagnetic spectrum. The heating/ventilation unit is also provided with Thermal IR protection. Aero Sekur also markets an air-transportable Mobile Camouflage Shelter providing multi-spectral protection (i.e., VIS, NIR, TIR, and broadband radar). Aero Sekur's shelter is designed to house aircraft, helicopters, vehicles, goods, and personnel.

Some permanent add-on signature reduction products are “universal” in the sense they can be applied to vehicles, ships, and even soldiers. V.N. Karazin National University in Kharkov and the Institute for Computer-Based Systems of the Ukrainian Academy of Sciences advertised Kontrasts KMS as a “next-generation” camouflage covering at Eurosatory 2006. Marketing literature described Kontrasts-KMS as a “full spectrum” camouflage cover that can be used for armored vehicles, naval ships, anti-aircraft systems, and even individual soldiers. It is designed for hiding equipment from radar and opto-electronic sensors and guidance systems on precision weapons. (Technical characteristics of Kontrast KMS are described in Figure 27.) Intermat Defense Coating also advertises that its products are applicable to a wide variety of objects (e.g., vehicles, buildings, vessels, air defense units).

Name of parameter	Units	Standard
Increased secrecy of the AME is provided in the range of waves: • radar • infrared • optical	cm μm μm	0.3 – 3.0 3.0 – 14.0 0.4 – 1.2
Reduced probability of the AME spotting under the KMS by air means of radar reconnaissance at a distance of 20 km	times	2
Level of signal power reduction from a camouflaged object in a millimeter range	dB	13
Level of signal power reduction from a camouflaged object in a centimeter range	dB	8 – 10
Visually-observed the AME under the KMS should not be recognized at a distance of	m	500
The KMS mass	kg	130 – 150
Overall dimensions: • length • width	m m	18 12
Range of temperatures at which the KMS preserves its camouflaged and operational properties	Degrees	-50°C+75°C
Permissible reduction of operational characteristics and camouflaged properties during 3 years' operation no more than	%	15
Water absorption of the KMS being in water for 24 hours no more than	%	8 – 10
Stability of the KMS to the action of water, diesel oil, oils, detergents		Provided

Figure 27. Technical Characteristics of Ukrainian's Kontrasts KMS Camouflage Covering Brochure at Eurosatory 2006

3. Temporary Add-On Signature Reduction Products

This category includes a wide variety of signature-reduction products (e.g., nets, blankets, suits, screens) and is probably the largest and most widely exported segment of the signature-reduction market over the last two decades. The *Global Sources* website lists 13,530 camouflage nets available from 3,194 suppliers.⁴⁸ Made-in-China.com lists 243 camouflage nets from 39

⁴⁸ "Products: Camouflage Net," Global Sources. Accessed on 17 October 2016 at <http://www.globalsources.com/manufacturers/Camouflage-Net.html>.

Chinese manufactures and suppliers.⁴⁹ Saab alone exports camouflage technology products to more than 50 countries.⁵⁰

This area differs from the other two in an important way. The market has both large civil and military customer bases. (Camouflage netting for hunters is even available on Walmart.com.)

There is a wide variety in temporary signature-reduction add-on products. Some offer protection against only one or two types of sensors, while others are advertised as multi-spectral. They also come in many forms (e.g., nets, blankets, mats, screens). A few illustrative examples of military-grade temporary signature-reduction add-ons are:

- **Obsidian Group Multi-Band Anti-Radar Camouflage Nets (China):** The Obsidian Group offers multi-band anti-radar camouflage nets that offer protection from optical, far-infrared and radar sensors. Their catalog distributed at IDEX 2015 emphasized the company's use of "unique thermal-infrared compensation technology" that can "segment hot spots and enhance thermal inertia" to improve signature-reduction characteristics of the nets. It goes on to state that composite materials help extend radar band "greatly."
- **SSZ Camouflage Technology AG Multi-Spectral Camouflage Nets (Switzerland):** SSZ advertises multi-spectral camouflage nets that use color and texture to reduce the visual signature, patterns that disrupt the IR signature, and reduction in the 2 to 100 GHz radar range.
- **Valpak Camouflage Screens (Greece):** Valpak screens reduce the threat posed by NIS, NIR, and radar imaging and targeting devices.
- **NII Stali Joint Stock Company Nakidka Signature Reduction Mats and Blankets (Russia):** Nakidka was displayed in at least six international arms exhibitions between 2000 and 2015. Nakidka mats and blankets are made of radar-absorbing materials to protect armored vehicles from precision-guided weapons. Producers claim that Nakidka reduces reduce visible and NIR (0.4 to 1.5 μm bands), thermal (3.5 to 5 and 8 to 16 μm bands), and radar (0.2 to 4.5 cm) signatures. They also claim that Nakidka reduces the chance of detection (1) by day/night and TV sensors to 30 percent, (2) by IR sensors by two or three times, and (3) probability and range of detection by radar by at least six times.

⁴⁹ "Products: Camouflage Netting," Made-in-China.com. Accessed on 17 October 2016 at http://www.made-in-china.com/products-search/hot-china-products/Camouflage_Netting.html.

⁵⁰ "Saab Reveals New Barracuda Mobile Camouflage System for Urban Warfare," Saab. Accessed on 17 October 2016 at <http://saabgroup.com/media/news-press/news/2015-09/saab-reveals-new-barracuda-mobile-camouflage-systems-for-urban-warfare/>.

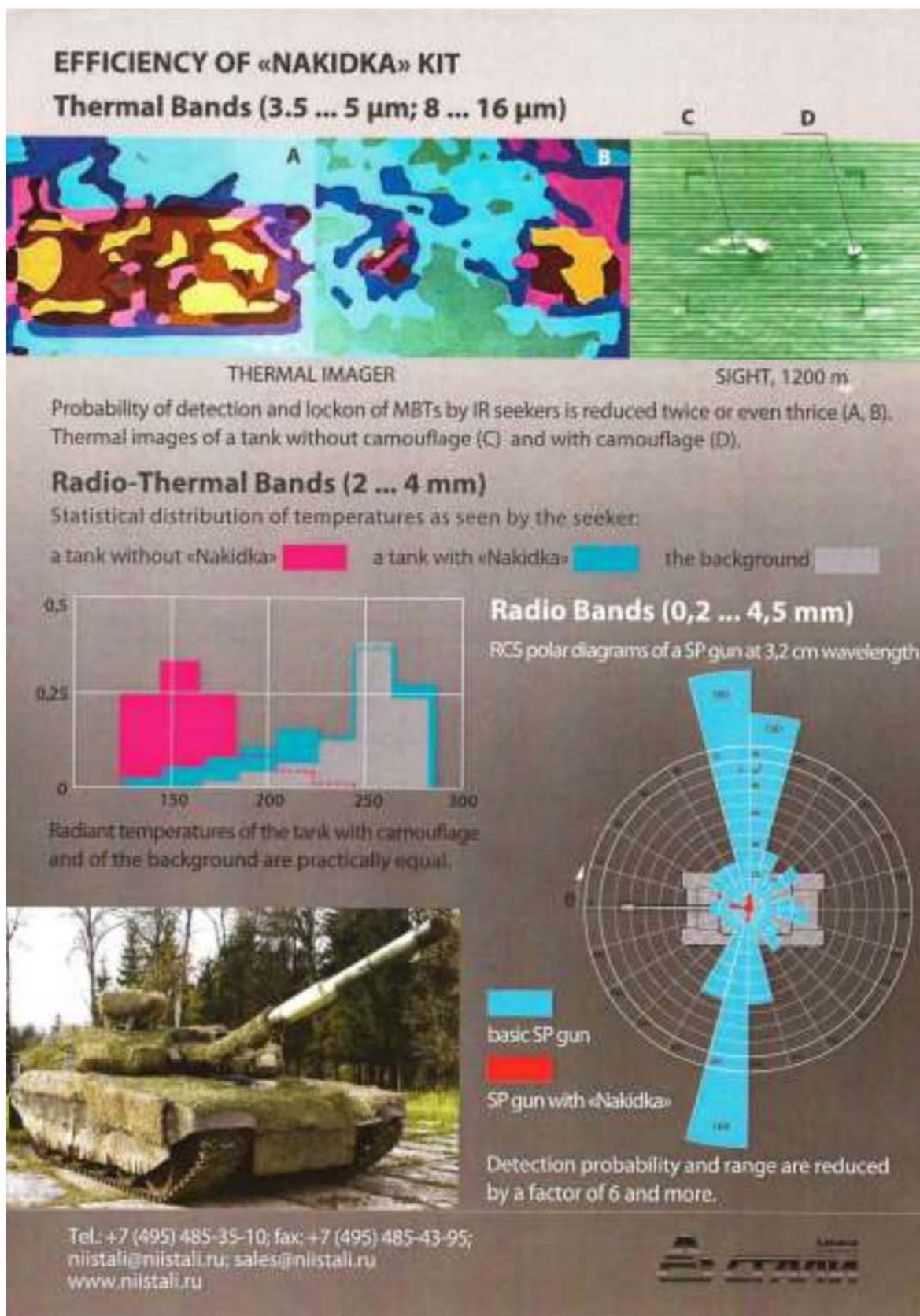


Figure 28. Russia's NII Stali Joint Stock Company
Brochure at IDEX 2013

4. Active or Adaptive Camouflage

Traditionally, signature reduction has been passive. Six years ago, however, active camouflage first appeared in the international arms market as a demonstration technology. Active camouflage adapts, often rapidly, to its surroundings and sometimes mimics other objects.

In May 2010, an Israeli startup company called Eltics Ltd. released a YouTube video showing an adaptive thermal/IR vehicle camouflage system for armored vehicles called Black Fox. The system was also marketed under other names, such as “Adaptive IR Stealth System,” “Electronic Thermal Infrared Countermeasure System (ETICS)”, and “multi-spectral signature control stealth technology.” The underlying principle involved the use of active camouflage plates collectively encased on the outside of a vehicle or ship plus two panoramic pan/tilt forward-looking IR cameras/sensors. These cameras continuously do a 360-degree scan and capture the thermal texture of the background environment, and then project the resulting thermal image onto the active plates mounted on the vehicle. The image mimics the background signature, creating a stealth illusion, by realistically representing the surrounding clutter and distinctive texture, thus effectively blending into the background.

Another active camouflage system called ADAPTIV debuted at DSEi 2011. ADAPTIV was developed and patented in Sweden after FMV and the Swedish Defense Materiel Administration commissioned BAE Systems in Örnköldsvik to produce full-scale technology for land vehicles to avoid detection from thermal sensor systems. ADAPTIV employs modules that can be either heated or cooled to cover the flanks of an armored vehicle. It can mimic its surroundings or copy other objects, such as trucks or automobiles. The BAE Systems website claims that ADAPTIV will be put into production in two years, primarily on the CV90 family of vehicles. Other potential uses include helicopters, warships, and buildings that can be fitted with larger panels of lower resolution.



Figure 29. ADAPTIV Mimicking an Automobile⁵¹

⁵¹ Image taken from “Innovation Adaptiv Car Signature,” BAE Systems 2012 reproduced in “Adaptiv,” *Wikipedia*. Accessed on 17 October 2017 at <https://en.wikipedia.org/wiki/Adaptiv>.

Nothing to see here

©NewScientist

Two groups of nine cameras located on each side of a tank capture the passing scene

The images are processed and sent to the LED display on the opposite side of the tank

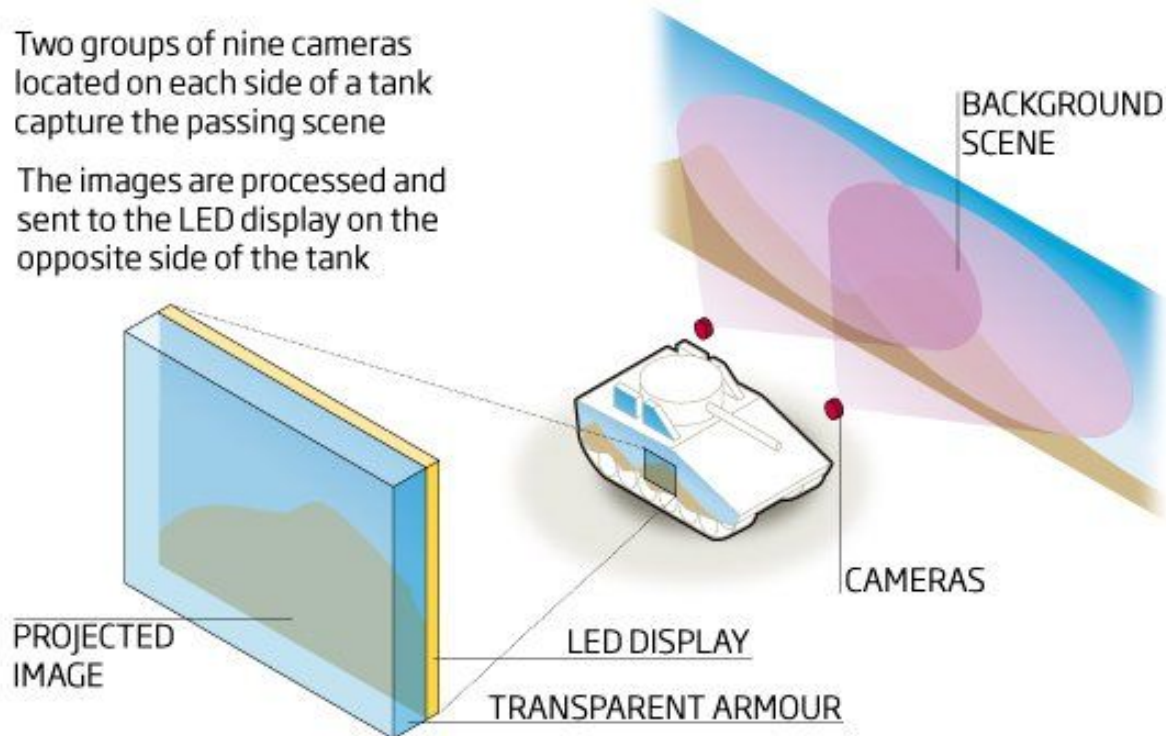


Figure 30. How ADAPTIV Works⁵²

Eltics Ltd. and BAE Systems are not alone in pursuing adaptive camouflage. A group of researchers from American and Chinese universities published a paper entitled “Adaptive optoelectronic camouflage systems with designs inspired by cephalopod skins.”⁵³ The authors discuss a set of materials, components, fabrication approaches, integration schemes, bioinspired designs, and coordinated operational modes for adaptive opto-electronic camouflage sheets. Their devices produce black-and-white patterns that spontaneously match their surroundings without human intervention.

⁵² Diagram from NewScientist reproduced in “System of visual camouflage armored vehicles from BAE Systems,” *Survincity.com* 2012. Accessed on 17 October 2017 at <http://survincity.com/2012/01/system-of-visual-camouflage-armored-vehicles-from/>.

⁵³ Cunjiang Yua et al. “Adaptive optoelectronic camouflage systems with designs inspired by cephalopod skins.” Accessed on 17 October 2016 at <http://rogers.matse.illinois.edu/files/2014/pnascamo.pdf>.

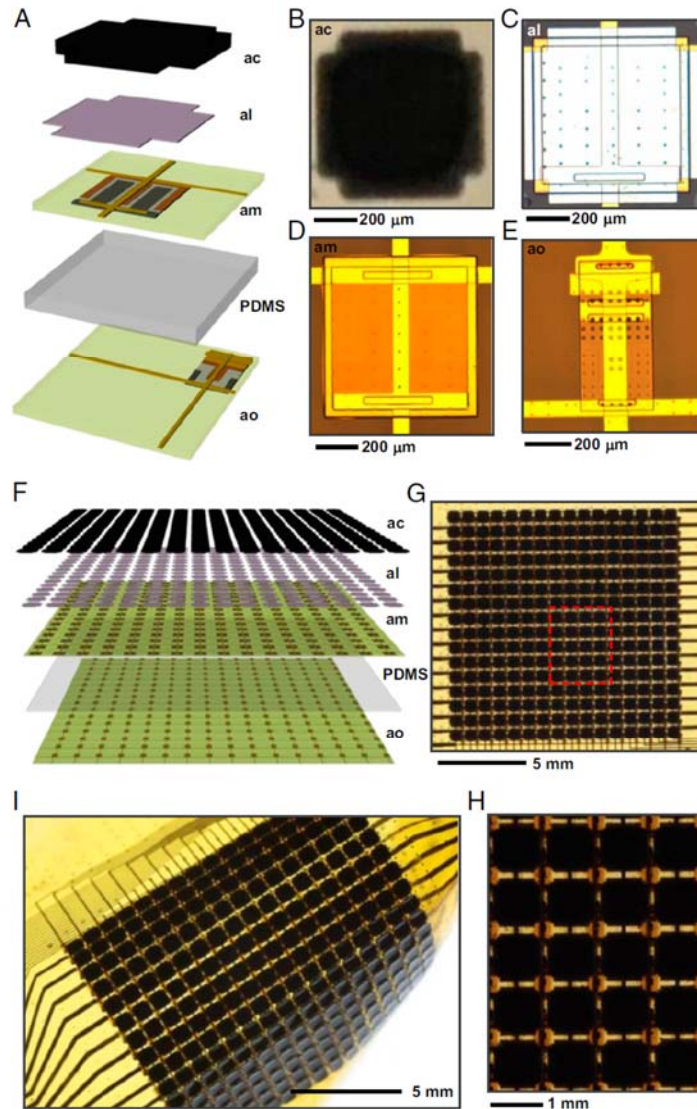


Figure 31. Schematic for Adaptive Opto-electronic Camouflage Systems with Designs Inspired by Cephalopod Skins⁵⁴

(A) Exploded view illustration of a single unit cell that highlights the different components and the multilayer architecture. The first and second layers from the top correspond to the leucodye composite (artificial chromatophore (ac)) and the Ag (silver) white reflective background (artificial leucodye (al)). The third layer supports an ultrathin silicon diode for actuation, with a role analogous to that of the muscle fibers that modulate the cephalopod's chromatophore (artificial muscle (am)). The bottom layer, separated from the third layer by PDMS (polydimethylsiloxane), provides distributed, multiplexed photodetection, similar to a postulated function of opsin proteins found throughout the cephalopod skin (artificial opsin (ao)).

⁵⁴ Ibid.

- (B) Optical image of a thermochromic equivalent to a chromatophore.
- (C) Optical micrograph of the Ag (silver) layer and the silicon diode.
- (D) Optical image of the diode.
- (E) Optical image of a photodiode and an associated blocking diode for multiplexing.
- (F) Exploded view of illustration of a 16×16 array of interconnected unit cells in a full, adaptive camouflage skin.
- (G) Top view image of such a device.
- (H) Image of the region highlighted by the red box in G.
- (I) Image of a device in a bent configuration.

Another group of researchers from Chinese Universities published a paper entitled “Fast Adaptive Thermal Camouflage Based on Flexible VO₂/Graphene/CNT Thin Films.”⁵⁵ Their paper demonstrates an active cloaking device capable of efficient thermal radiance control, which consists of a vanadium dioxide (VO₂) layer, with a negative differential thermal emissivity, coated on a graphene/carbon nanotube (CNT) thin film that they believe “will find wide applications” in artificial systems for IR camouflage or cloaking, as well as in energy-saving smart windows and thermos-optical modulators.

5. Measuring Signature Reduction

Reducing an object’s signature in any spectrum is difficult. If done improperly, measures taken to lower the object’s observability in one spectrum may make it even more visible to sensors monitoring another spectrum. To avoid such problems, signatures must be measured accurately. This creates difficulties for designers during the development process and for customers wishing to verify the claims of suppliers. Not every supplier or customer can afford the equipment to conduct signature measurements.

Consequently, a specialized niche has developed in the arms market to provide those services to both designers and customers. Examples of such firms are:

- **ISPAS Radar Cross Section Instrumentation Company (Norway):** The firm’s expertise covers all aspects of radiofrequency (RF) equipment, from radars for RCS measurements to custom-design RF equipment and radar/RF/RCS measurement assistance. ISPAS delivers products and services to both military and civilian customers. ISPAS has several years’ experience developing advanced turnkey RCS measurement radars for both indoor and outdoor applications.

⁵⁵ Lin Xiao, et al, “Fast Adaptive Thermal Camouflage Based on Flexible VO₂/Graphene/ CNT Thin Films,” *NANO Letters*, 2015, 15, 8365-8370. Accessed on 17 October 2016 at <http://pubs.acs.org/doi/pdf/10.1021/acs.nanolett.5b04090>.





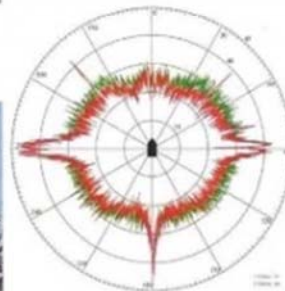

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RCS Measurement Radar

Calibrated radar measurement instrumentation

ISPAS' proven turnkey radar solutions for indoor/outdoor calibrated Radar Cross Section (RCS) measurements are based on more than 15 years experience with measuring radar backscattering and real-time monitoring both for military and civilian authorities.



Auxiliary instrumentation such as oceanographic and meteorological data are stored in a database with target RCS and movement data for easy post-processing. The post-processing includes statistical analysis, linear/polar-plots and 3D / ISAR imaging. The results are presented in an automatically generated report.

Frequency range	: 0.5 - 40 GHz
Pulse modulation	: FMCW / Stepped frequency
Polarization	: Simultaneous linear co / cross
Pulse repetition frequency (PRF)	: Variable 10 - 2000 Hz
Min. range resolution	: 0.1 m / 0.5 m (ICW/FMCW)
Antenna beam width	: Varying, application dependent
Operational distance	: 0.1 - 10 km

Figure 32. Norway's ISPAS RCS Measurement Radar
Brochure IDEX 2015

- **ECA Robotics Portable Magnetic Range (France):** The Company's Portable Magnetic Range measures the three-axis magnetic signature of a vessel in real time, visualizes the efficiency of the degaussing system, and corrects depth and heading.

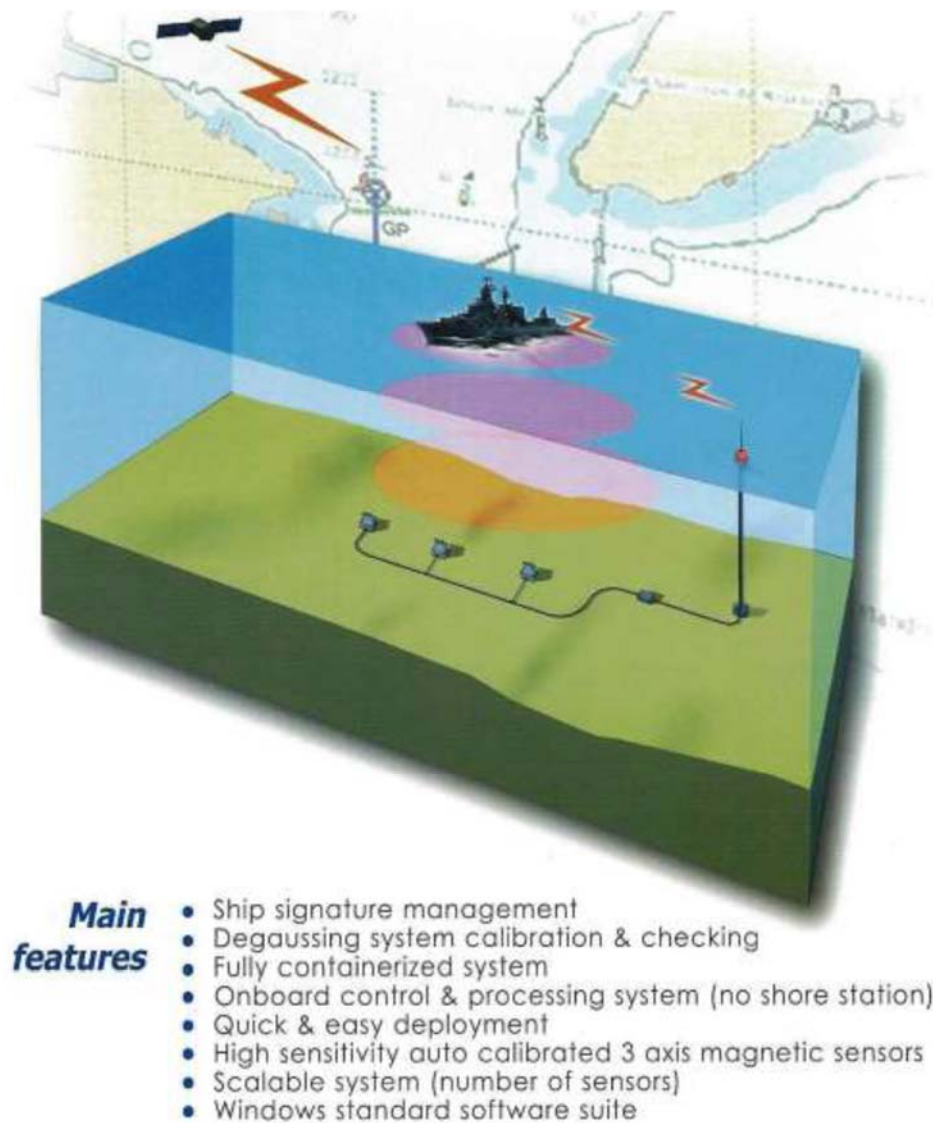


Figure 33. France's ECA Robotics' Portable Magnet Range
Brochure at DSA 2014

- **Systems Division of Polyamp AB (Sweden):** This firm specializes in the design, manufacture, and support of magnetic and electric signature-control equipment.
- **Atlas Elektronik Signature Measurement Ranges (United Kingdom):** This company's transportable Signature Measurement Ranges are a suite of modular ranging systems that do: (1) acoustic signature hygiene assessment, (2) keel and beam aspect acoustic measurements, (3) magnetic and electric signature measurement and prediction, and (4) static electric signature measurement and prediction.

- **Onera Testing Facilities (France):** Onera's Wind Tunnel Division test facilities offer many capabilities for testing missiles, including infrared signature. Onera's PRECISE Threat Kinematics and Signature Assessment Platform aims at providing a set of tools to simulate missile trajectories, as well as IR and radar signatures.

6. Counter-Stealth

The growing emphasis on reduced-signature aircraft has spawned vigorous efforts to develop and market passive sensors capable of detecting stealthy aircraft.

- **ERA VERA Passive Surveillance System (Czech):** The Czechs are pioneers, first marketing a VERA passive surveillance system about a decade ago and now offering an improved version called VERA-NG. VERA-NG uses passive emitter tracking and passive coherent location together with multilateration techniques to triangulate on a broad range of the emissions. A version (VERA-AP) is also being marketed for long-range civil air traffic control, raising the possibility that a nation denied defense imports by international embargo could acquire some counter-stealth capability under the guise of civil use.
- **KB Radar Design Bureau Marker-M Multilateration Aircraft Positioning Complex (Belarus):** Marker-M offers to track stealthy aerial targets using output from friend-or-foe identification (IFF), objects positioning control, and data interchange with automated control system for air traffic. It tracks objects using range differential by signals of IFF/SIF responders in the following modes: A, B, C, S, 1, 2, 3, and 4. The same company also advertises the Pyramid Multi-Position Passive Radar System, which is designed for search, detection, determination of the type and operation mode, position and nationality of airborne radio emission sources (RES), and tracking the detected aerial platforms by radiation of their on-board electronic equipment.
- **Selex ES Aulos Passive Covert Radar (Italy):** The Aulos Passive Covert Radar works by processing reflections from illumination sources such as commercial broadcast and communications signals. Aulos was developed based on a software-defined radar approach. This involves signal sampling directly at the carrier frequency using COTS devices for signal reception and digital processing, Multi-Core, and GPU technologies powered by personal computer.
- **Poly Technologies Argus Passive Surveillance Radar (China):** The Argus Passive Surveillance Radar utilizes civilian frequency modulation (FM) broadcast as its illumination source. It receives the echoes from FM broadcast signals reflected by a target to detect, locate, and track, especially for stealth targets and low-altitude, low velocity, small targets such as UAVs with full spatial coverage and early warning capabilities.

General Description >

This system is a kind of passive radar. Comparing with active radar, it works in silent status by means of utilizing civil frequency modulation (FM) broadcast as its illuminating source. It receives the echo of FM broadcast signal reflected by target to detect, locate and track, especially for stealth target and low altitude, low velocity, small target, with full spatial coverage and early warning capabilities.

Specifications >

Operating Frequency	85 ~ 110 MHz
Detection Area ($\sigma = 3 \text{ m}^2$)	200 Km
-Detection Range	0° ~ 360°
-Azimuth	0° ~ 40°
-Elevation	
Accuracy (RMS)	
-Range	$\leq 800 \text{ m}$
-DF Accuracy	$\leq 1.5^\circ$
Target Capability	$\geq 400 \text{ Batches}$

Functions >

- Middle and short range air detection and early warning
- Low altitude supplementation and air defense for key position
- Monitoring and detection for ocean
- National air defense network of great depth

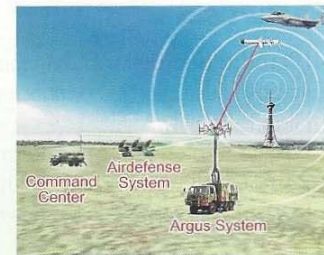
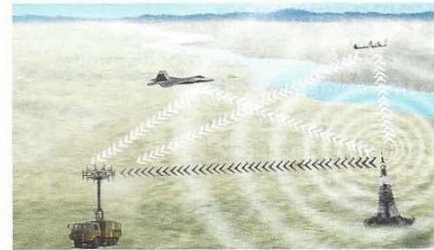


Figure 34. China's Poly Technologies Argus Passive Surveillance Radar Displaying How to Detect Stealthy Aerial Targets Brochure at DSA 2016

D. Unmanned Aerial Systems

1. U.S. Market Share in Worldwide Remotely Piloted Aircraft Export

The world market for UAVs is the most dynamic sector of the aerospace market, but it is very immature and underdeveloped. The market is significantly different from the fighter market. The fighter market is one distinct segment of the military aircraft market, and there are many other military aircraft types, including transports, trainers, helicopters, etc. In contrast, the broad category of UAVs covers a diverse range of types from very small, hand-launched mini-UAVs, such as the RQ-11 Raven, up to very large endurance UAVs, such as the RQ-4 Global Hawk. The primary focus here is on UAVs used for reconnaissance and armed strike missions; traditional UAVs, such as target drones, are not considered. Also, loitering munitions derived from UAV technology are not considered, since they are missiles in the operational sense.

Table 7. Current DOD UAV Categories

<i>DOD Group</i>	Take-off Weight (lb.)	Industry Usage
<i>Group 1</i>	0-20	Mini-UAV
<i>Group 2</i>	21-55	Small Tactical UAV (STUAS)
<i>Group 3</i>	56-1,320	Tactical UAV (TUAV)
<i>Group 4</i>	1,320+	Medium altitude, long endurance (MALE) UAV
<i>Group 5</i>	1,320+	High altitude, long endurance (HALE) UAV

In contrast to modern supersonic fighters, which require development costs measured in the tens-of-billions of dollars, mini-UAVs are technically similar to low-cost remote control model airplanes, and so can have development costs in the hundred-thousands of dollars. As a result, worldwide UAV manufacture, especially in the low-end, low-cost segment, is underway in dozens of countries. Many countries now regard UAVs as a cheap and easy entry point into the indigenous aerospace market. However, manufacture in the high-end segment, especially endurance UAVs such as the RQ-9 Reaper and RQ-4 Global Hawk, is largely confined to a handful of countries, such as the U.S., Israel, and China. It is worth noting that there has been little or no serial production of contemporary endurance UAVs in traditional world aerospace centers, such as Britain, France, Germany, Italy, Russia, or Japan.

a. Historical Trends

Serial manufacture of UAVs began in the 1930s in Britain, the U.S., and elsewhere as target drones, primarily for air defense training.⁵⁶ Several countries in World War II used UAV technology to develop assault drones and the U.S. Navy's TDR-1 assault drone was the first to see combat use in the Solomon Islands in late 1944. These early assault drones were in a grey area between modern conceptions of UCAVs and loitering munitions since some assault drones (such as the TDR-1) could be used to drop bombs and return to base, while others (such as the U.S. Air Force Aphrodite or U.S. Navy Anvil) were closer to contemporary loitering munitions.

The first UAV intended for the surveillance mission was the U.S. Army's SD-1 (later MQM-57 Falconer/AN/USD-1), a tactical reconnaissance drone using wet-film day or IR night cameras. About 1,445 were built from 1959-1966 and exported to NATO countries, including the U.K.. The first extensive combat use of reconnaissance drones began in 1964, with the use of U.S. Air Force Lightning Bug drones over Vietnam, China, and North Korea.⁵⁷ These were derived from the

⁵⁶ For a more detailed historical survey of early drones, see: Steven Zaloga, *Unmanned Aerial Vehicles: Robotic Air Warfare 1917-2007*, (Osprey Publishing: 2008).

⁵⁷ The Lightning Bugs were derivatives of the Teledyne Ryan BQM-34 Firebee target drone.

popular Teledyne-Ryan BQM-34 target drones. From 1964 to 1974, about 1,016 Lightning Bugs flew 3,435 sorties with an average life span of 7.3 missions.

Other nations built similar systems. For example, the Soviet Air Force TBR-1, based on the Lavochkin La-17 target drone, entered service in 1962. The most common drone in western European service at this time was the Canadair CL-87, with 500 manufactured in Canada from 1964-1983. It was followed in 1987 by the CL-287 Piver, which constituted the largest aerospace contract in Canadian history, valued at \$500 million for about 250 air vehicles and about 15 ground control stations, with Germany and France as the primary export clients. Canada has subsequently fallen out of the UAV business almost entirely. The main drawback of these early reconnaissance systems was the reliance on wet-film cameras, which meant no real-time surveillance capability. The UAV had to return to base, and have its film processed. Another issue was their relatively low reliability, due in part to the vagaries of early radio control and inertial navigation technologies.

Armed drone development in the Cold War years was overshadowed by the explosive growth of missile technology. Some armed drones did enter serial production, most notably the U.S. Navy QH-50 DASH (drone anti-submarine helicopter), a ship-based drone which was used to deliver torpedoes at extended ranges as part of a warship's ASW suite. A total of 810 QH-50 were manufactured from 1963 to 1969, and their principal export client was Japan. The type was short-lived due to a high attrition rate.

UAVs capable of delivering real-time imagery began to appear in the early 1980s, primarily in Israel. The principal Israeli innovation was the integration of low-cost, commercial video cameras with modestly sized UAVs. These were classified as tactical UAVs in contemporary parlance. The IAI Scout was first used in combat by the South African army during fighting in Angola in 1981, and was used by the Israeli air force in the 1982 war in Lebanon. Comparable development in the U.S., notably the U.S. Army MQM-105 Aquila, failed due to technology overreach. As a result, the U.S. acquired Israeli UAVs in the late 1980s, notably the Pioneer, which saw extensive use in the 1991 Operation Desert Storm.

In the early 1980s, General Atomics built the MQ-1 Predator reconnaissance and surveillance for the U.S. Air Force and Central Intelligence Agency. Predator has seen service in Afghanistan, Pakistan, and NATO's intervention in Bosnia, Serbia, Iraq, Yemen, Libyan civil war, Syria, and Somalia. Subsequently, General Atomics created a variant called Predator B or MQ-9 Reaper, which was able to fire two AGM-114 Hellfire air-to-ground missiles or other munitions. The MQ-9 Reaper has been used in a number of counterinsurgent/counterterrorist missions in the Middle East and Southwest Asia and anti-piracy missions in the Indian Ocean.⁵⁸

Through the 1990s, the UAV export market was very small and was dominated by Israeli firms, especially Israel Aircraft Industries' Malat branch. IAI Malat represented about 90% of the world production of real-time UAV systems in the 1990s, illustrating how small this market was

⁵⁸ For a more detailed look at the evolution of U.S. unmanned aerial vehicles see: Richard Van Atta et. al., *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs, Volume 2 - Detailed Assessments*, IDA Paper P-3698, November 2003. (Unclassified).

in spite of all of the publicity. Malat's annual business during the period averaged less than \$100 million. IAI produced only 600 UAVs through the beginning of 1998, and less than 100 UAV systems.

There has been rapid growth in the UAV market in the last decade, due to large-scale acquisition by the U.S. armed forces for operations in Iraq, Afghanistan, and elsewhere. The U.S. represents an unusually large fraction of worldwide UAV acquisition, totaling about 59% of the UAVs acquired worldwide in 2005-2015.

b. Contemporary Export Trends

Unlike the situation with combat aircraft, export data on UAVs outside the United States is available only on a very sporadic basis. In particular, comprehensive unclassified data on Israeli exports is lacking. This is significant, since Israel has been the world's largest UAV exporter for more than two decades. A 2008 study covering the years 2004-2008 concluded that Israel exported 85% of the worldwide market, about 142 UAVs of the 167 UAVs exported in this period.⁵⁹ This represented about 73% of the value of the market, about \$1.1 billion of the worldwide \$1.54 billion. The U.S. exports, according to this study, amounted to about 5% of the number of exported UAVs (9) with a market value share of 22% (\$346 million). Note that Israel has often exceeded the U.S. in the total numbers of exported UAV, but that the U.S. often represents a larger share of the worldwide UAV market than this small number suggests, since U.S. exports have tended to be in the area of MALE systems, such as the MQ-1 Predator and MQ-9 Reaper which are on the higher end of the cost scale.

The Israeli UAV industry is largely geared toward the export market, since the internal market is so small. For example, Aeronautics exports about 85% of their production.⁶⁰ The largest Israeli aerospace firm, IAI, puts the export share of its production at around 80%.⁶¹ Note that Elbit claims that 80% of the Israeli UAV inventory comes from their production. A more recent study suggested that Israeli UAV sales in 2005-2012 were \$4.6 billion, or about \$578 million annually.⁶² This compares to about \$225 million annually in 2004-2008, as mentioned earlier. About half of the recent sales were to Europe. There is no comprehensive database on Israeli UAV sales, and sales data is treated as a commercial secret. Available published data that was compiled by Stockholm International Peace Research Institute (SIPRI) indicates that between 2000 and 2015, Israeli firms exported 461 UAVs worldwide. This probably undercounts overall sales, due to Israeli secrecy. Also, the SIPRI database does not include mini-UAVs such as the Elbit Skylark,

⁵⁹ Nikolai Novichkov and Valery Barkovsky, "Unmanned Aerial Vehicles Market," *Arms Markets*, Vol. 8, No. 11, 2008, p.27.

⁶⁰ Amir Rapaport, "Solutions Based on UAVs, Aerostats & Rotorcraft," *Israel Defense*, December 2015, p.14.

⁶¹ Andrew White, "Leading Edge," *Jane's Defence Weekly*, July 22, 2015, p. 30.

⁶² "Israel said to be world leader in UAV exports," UPI, May 20, 2013. These figures come from a 2013 study by the consultancy Frost & Sullivan.

which has more than a dozen international clients.⁶³ Nevertheless, it provides a useful gauge of the scale of sales of tactical and endurance UAVs.

Table 8. Israeli UAV Export Sales by Region

Region	UAV (aircraft)	Share
Asia	255	55%
Europe	169	37%
Americas	26	6%
Africa	11	2%

Table 9. Israeli UAV Export Sales by Company

Company	UAV (aircraft)	Share
IAI	337	73%
Elbit	80	17%
Aerostar	41	9%
Other	3	<1%

c. European UAV Export

European UAV export has been extremely limited over the past decade, due to a lack of product and failure to consolidate the European industry. European firms have manufactured mini-UAVs and small tactical UAVs, such as the German Luna and French DRAC, which have had modest success in the export market. For example, the Luna is manufactured under license in Saudi Arabia, though details of the extent of the production is lacking. However, the European designs face stiff competition, not only from Israeli and U.S. types, but also from the tendency of many countries to treat the mini-UAV field as a good entry point for local industries.

The market for tactical UAVs in the size range of the U.S. RQ-7 Ranger/Israeli Seeker has not been profitable for European industry. There have been some European products sold, such as the Leonardo/Finmeccanica Falco exported in modest numbers to Pakistan and others, and the French Sagem Sperwer. The Sperwer sales have haunted the European industry since quality issues and high attrition rates led customers to retire their fleets prematurely. Some European systems available from 1990-2005, such as the British Phoenix, proved too troublesome for extensive export, while others, such as the German Tucan, were simply too expensive.

Although the consolidation of the European aerospace industry from 1990-2010 might have been expected to lead to the emergence of joint UAV programs, this was not the case. The German/French cooperative venture for a new tactical UAV in the 1990s collapsed in acrimony,

⁶³ SIRPI includes UAVs under their “aircraft” heading and this presumably restricts the count to larger UAVs in the tactical and endurance categories.

with France acquiring the Sperwer and Germany acquiring the Tucan. Britain has largely gone its own way on tactical UAVs, first with Phoenix, and more recently with Watchkeeper, the latter a derivative of an Israeli design.

A cooperative venture would have been most likely in the area of endurance/MALE/HALE UAVs, since these programs have relatively high Research, Development, Testing and Evaluation (RDT&E) costs, which would have benefited from a multi-national approach. Yet attempts to create a common European MALE UAV have failed repeatedly. The French-led Euro-MALE program started in 2005 gradually fell apart due to conflicting French and German priorities and timelines. European requirements for MALE UAVs for peacekeeping missions in Iraq and Afghanistan were largely satisfied through lease deals with Israeli firms, providing a temporary stopgap. The 2010 Lancaster House agreement between Britain and France included a joint MALE UAV program, but this has fallen into limbo. A revival of the French-German MALE effort began again around 2015 in the wake of the failed Euro-MALE/Talarion and Anglo-French projects. This new program has already slid, first being called Euro-MALE 2020 and now being called EuroMALE 2025. Instead, the major European air forces have mostly purchased the American RQ-1 Predator/RQ-9 Reaper, with Germany opting for the Israeli Heron TP. Europe has proven to be one of the most significant markets for U.S. and Israeli UAVs, largely due to the failure of European aerospace companies to develop adequate systems.

d. U.S. UAV Export

U.S. aerospace companies have had mixed results in the export market. Sales of mini-UAVs have been significant in terms of numbers, though relatively small in overall dollar value. This market is dominated by AeroVironment Inc. They produce the iconic RQ-11 Raven, which has been purchased in larger numbers than any other UAV (about 19,000 built through 2016). The RQ-11 has been exported to over 24 countries, including Australia, Colombia, the Czech Republic, Denmark, Estonia, Spain, Iraq, Italy, Kenya, Lebanon, Macedonia, Netherlands, Norway, Pakistan, Romania, Saudi Arabia, U.K., Uganda, and Yemen. Among recent export contracts were an October 2007 Danish contract for DKK 19 million (\$3.6 million) for 36 Raven B and a May 2008 Dutch award for \$7.7 million for the Raven B.

U.S. exports of larger UAVs have not been especially numerous. The AAI RQ-7 Shadow tactical UAV has been exported to five countries, totaling about 60 aircraft. The General Atomics RQ-1 Predator and MQ-9 Reaper have become the standard endurance UAVs on the export market, with the sale of 12 RQ-1 Predators to two countries and 20 MQ-9 Reapers to three countries. There are several RQ-9 sales pending, as well as sales of the export-oriented Predator XP. U.S. sales of endurance UAVs have been adversely affected by export restrictions, particularly those that have tied UAV exports to the Missile Technology Control Regime (MTCR).⁶⁴

⁶⁴ *UAV Export Controls and Regulatory Challenges*, Stimson Center, September 2015. Accessed on 3 March 2017 at <https://www.stimson.org/sites/default/files/file-attachments/ECRC%20Working%20Group%20Report.pdf>.

Table 10. U.S. DOD UAV Inventory Trends

Group	Category	2002	2005	2006	2007	2009	2010	2011	2013	2014
1	Mini	400	1,020	2,700	3,400	5,800	6,700	6,810	9,570	9,365
2 & 3	Small	35	140	210	265	320	385	490	693	725
4	MALE	65	65	110	155	148	230	265	297	280
5	HALE	—	—	15	25	32	90	105	134	197
Total		500	1,225	3,035	3,845	6,300	7,405	7,670	10,730	10,567

Table 11. World Production by Type⁶⁵

(Units, Air Vehicles)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Mini-UAVs	855	1,770	597	1,806	2,670	2,445	2,082	2,097	1,855	2,255	1,957
STUAVs⁶⁶							64	186	231	243	205
TUAVs	97	210	233	269	262	129	200	175	145	170	110
Naval UAVs		3	4	1	4	6	4	14	9	38	20
MALE	36	48	32	43	77	77	44	87	93	104	84
HALE	7	2	1	7	8	9	11	6	4	0	1
UCAVs	0	0	3	3	0	2	2	1	1	0	0
Total	995	2,033	870	2,129	3,021	2,668	2,407	2,566	2,338	2,810	2,377

Table 12. World UAV Acquisition by Region

(Units, Air Vehicles)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
USA	493	1,733	349	1,441	2,267	1,663	1,778	1,550	821	1,052	1,269
Rest-of-World	502	300	521	688	754	1,005	629	1,016	1,517	1,758	1,108
Europe	61	145	254	368	348	424	207	438	613	573	351
Mid-East	47	53	117	150	161	274	202	280	357	604	250
Africa	6	13	18	21	23	6	20	18	79	91	64
Asia-Pacific	382	84	122	119	188	276	150	221	383	361	369
Americas	6	5	10	30	34	25	50	59	85	129	74
World Total	995	2,333	870	2,129	3,021	2,668	2,407	2,566	2,338	2,810	2,377

⁶⁵ Data for Tables 10 and 11 comes from various editions of the annual Teal Group Corp. study, “World Unmanned Aerial Vehicle Systems Market Profile and Forecast.” Note that these are estimates, since detailed data on worldwide production and acquisition is largely unavailable.

⁶⁶ Small tactical UAVs included in “Mini-UAV” category prior to 2011.

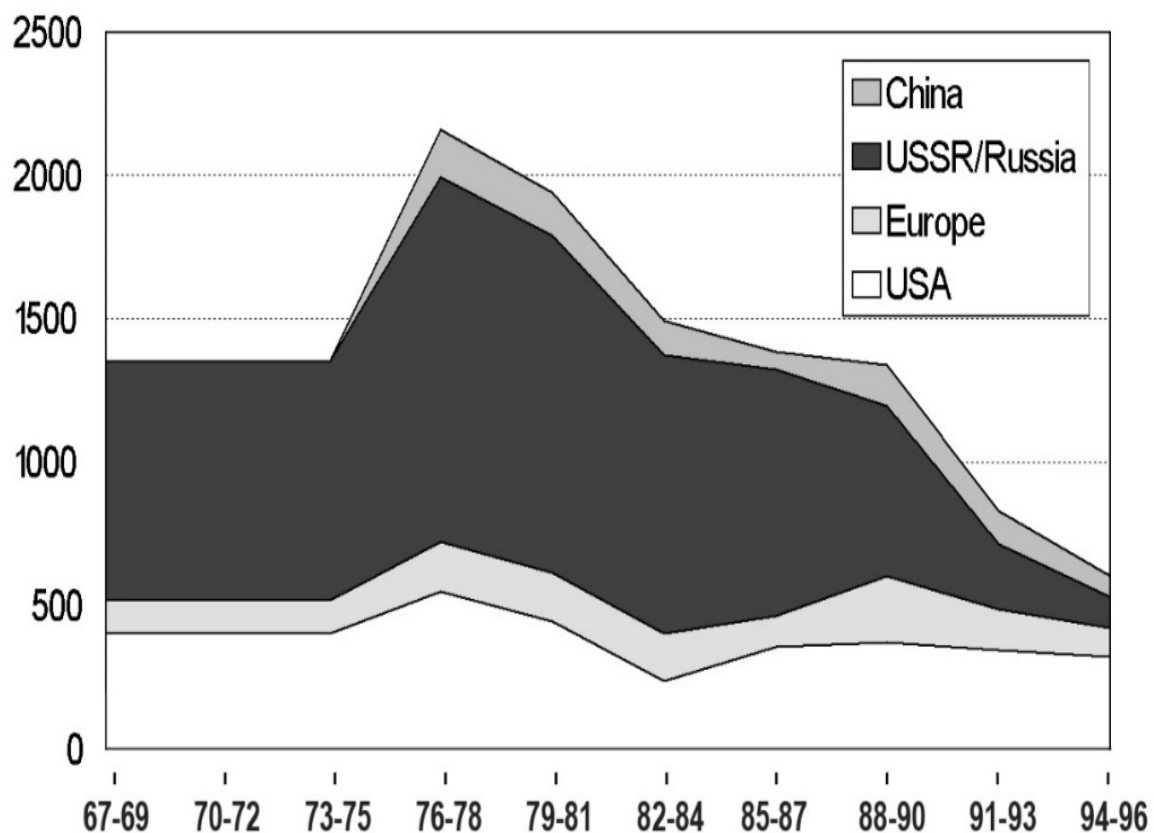
E. Combat Platforms

1. Combat Aircraft

a. U.S. Market Share in Worldwide Fighter Export

The U.S. market share of the worldwide market for jet fighter aircraft has varied over time. In the past decade, the U.S. has enjoyed a larger share of the market than in the Cold War years, and there are expectations that this will increase in the future.

In the Cold War era, the U.S. captured about 24% of the fighter export market, while the Soviet Union had about 58%. Europe had about a 12% share and China about 5%. The collapse of the Soviet Union and the end of the Cold War had a very dramatic effect on fighter sales, both in terms of overall numbers of international sales and relative shares of the market.



**1967-84 developing world only; all world after 1984*

Figure 35. Jet Fighter Exports 1967 to 1996 (Units in 3 Year Increments)

Table 13. Worldwide Fighter Export 1967-1997⁶⁷

	67-76	76-80	81-85	84-86	86-88	89-91	92-94	95-97	Total
U.S.	1,344	915	394	202	436	340	350	310	4,291
Europe	394	290	275	340	260	220	100	100	1,979
USSR/ Russia	2,772	2,120	1,620	950	680	550	70	130	8,892
China	0	275	200	80	50	190	80	70	945
Total	4,510	3,600	2,489	1,572	1,426	1,300	600	610	16,107

b. Impact of the Soviet Collapse on International Fighter Sales

To begin with, the Soviet collapse shrank the overall Russian share of the market after 1991. The primary reasons for this were Russia's economic decline in the 1991-2010 period and the end of the Soviet practice of subsidized military aid. While countries in the developing world were often "charged" for various Soviet military products, they were actually obtained at subsidized prices. Furthermore, the costs for the programs were often forgiven or not collected. As a result, many developing countries obtained supersonic fighter aircraft with no particular operational requirement for such aircraft. This was essentially military aid disguised as sales. After the Soviet collapse, the Russian government was unwilling and unable to subsidize these "sales" and the Russian defense industry turned increasingly to hard-cash arms sales to make up for the lack of Russian state orders. The industry suffered a deep decline as a result of these economic and policy changes.

For example, from 1967-1991, the Soviet aircraft industry exported about 360 supersonic fighter aircraft annually. In sharp contrast, total Russian fighter production from 1995-2015 was only about 45 aircraft annually, including both Russian state orders and export orders.

Aside from the lack of subsidies for Russian arms sales, the industry has been unwilling and unable to address the needs of the export market and has depended largely on the sale of Cold War types designed for Soviet requirements. Russian sales over the past two decades have been almost exclusively the MiG-29 and Su-27 aircraft and their variants. What is lacking in the Russian export catalog is an inexpensive, single-engine fighter comparable to the older MiG-21 or MiG-23, which made up the bulk of the sales in the Cold War years. The large and expensive Su-27 may be suitable for a limited selection of Russian clients, such as China and India, but it cannot attract large-scale

⁶⁷ Data is from various editions of *World Military Expenditures and Arms Transfers*, Arms Control and Disarmament Agency (ACDA). ACDA uses the term "Supersonic Combat Aircraft" for this tally, which closely equates to modern jet fighter aircraft but excludes older subsonic jet fighters. Data for 1967-1984 covers only exports to the developing world; data after that covers the entire world. ACDA no longer published *World Military Expenditures and Arms Transfers* after the 1998 edition (April 2000).

sales from developing countries in the Asia-Pacific region, Africa, or Latin America. Note that the primary U.S. export fighter over the past two decades has been the single-engine F-16.

This situation is unlikely to change in the next decade. The current Russian focus is on the Sukhoi PAK-FA/T-50, an analog of the high-end USAF F-22 Raptor. This is even less suitable for the export market, except for sales to high-end customers such as India and China.

c. European Fighter Competition

Europe has traditionally represented the main competition to U.S. aircraft manufacturers in traditional U.S. export markets. For example, Saudi Arabia over the years has purchased U.S. fighter aircraft, but also French fighters and aircraft from the European consortium, such as the Panavia Tornado and the Eurofighter Typhoon. European firms captured about 12% of the fighter market from 1967-1997, with sales averaging about 65 units annually. But the European firms did not receive a large boost from the Soviet collapse.

The problems facing the European countries in fighter export are due to the declines in RDT&E funding in Europe in the wake of the Cold War, coupled with the lingering fragmentation of the European defense industry. Rather than developing multiple aircraft types to satisfy the varying requirements of the international fighter market, the European firms have developed parallel types, such as the Rafale/Typhoon, which cater to the national market but do not address the export market for low-cost, single-engine fighters. France provides a clear example. French fighter sales declined since the 1970s and 1980s when the single-engine Mirage 2000 and Mirage F1 fighters were replaced by the much larger and more expensive Rafale. For example, 293 of the 612 Mirage 2000s manufactured were exported, (48%) while to date, the Rafale has only 48 units on order by Egypt and Qatar (with another possible 36 units to India), despite having been on the market for more than 15 years.⁶⁸ Likewise, export sales of Eurofighter Typhoons outside of Europe have been modest, with its only major export customer being Saudi Arabia.

Saab's JAS 39 Gripen fighter is the only major European aircraft type to appeal to the market for low-cost single engine fighters. Nevertheless, export sales have been underwhelming and most JAS 39 Gripens flying in foreign colors, such as the Czech Republic and Hungary, are leased aircraft that were taken from batches of Swedish air force aircraft considered redundant due to force draw-downs in the wake of the end of the Cold War. The only major overseas successes were Brazil and South African orders. However, there are several promising orders for the upgraded next-generation JAS 39 Gripen. One problem is that the JAS 39 Gripen employs a substantial number of American sub-systems, including the power plant and radar, and therefore export is, to some extent, contingent on U.S. sales approval.

Aside from the JAS 39 Gripen, the future market for European fighter export is grim. Both Rafale and Typhoon have been on the market for over a decade with weak international sales.

⁶⁸ Tyler Rogoway, "Rafale Has Gone From Long-Time Export Flop to Huge Success in 45 Days," *Foxtrot Alpha*, April 30, 2015. Accessed on 13 January 2017 at <http://foxtrotalpha.jalopnik.com/rafale-has-gone-from-long-time-export-flop-to-huge-succ-1701174913>.

There is currently no European program for a follow-on fighter for either the Typhoon or Rafale. Many European countries have joined the U.S.-sponsored F-35 fighter program; Britain and Italy have taken on substantial production shares of the F-35 program. A recent fighter market survey forecast that about 390 Typhoon, Rafale, and JAS 39 Gripen fighters will be built from 2016-2025, representing about 13% of total worldwide fighter production.⁶⁹ This suggests that European participation in the international fighter market will continue to decline from about 12% in the Cold War years, to 10% in the quarter century since the Soviet collapse, to perhaps 5-6% of the market over the next decade.

Europe is losing its competitive position in aerospace due to its shrunken defense budgets and continued fragmentation of the market. For example, in 2015, total European defense RDT&E amounted to about \$10.2 billion, compared to about \$65.1 billion for the United States.⁷⁰ Modern fighter programs have become prohibitively expensive. The system design and development (SDD) phase of the current F-35 fighter program is about \$45 billion, comparable to about five years of total European RDT&E spending. However, the Europeans cannot take advantage of their total spending potential, since national priorities are often at odds. While the argument can be made that the diffusion of resources evident in the current Rafale/Typhoon/ JAS 39 Gripen generation can be attributed to Cold War issues, the consolidation of European defense efforts still has not occurred 25 years after the fall of the Soviet Union.

d. Chinese Influence

China's role in the international fighter export market has been small. Most Chinese fighter export has been to client states such as Pakistan, or as military aid to allies in Asia and Africa. Chinese fighters have not been widely displayed at major international air shows. This is largely due to the late arrival of indigenous designs that were up to international standards. Well into the new century, the only significant fighter exports were license-produced copies of older Soviet types, such as the J-6 (MiG-19 copy). Pakistan acquired the F-7PG (MiG-21 derivative) as late as 2001. Export of the indigenous JF-17 Thunder began in 2007, to its primary client, Pakistan. Underscoring Chinese weakness in this market, the JF-17 was developed with considerable Russian support, depending on a Russian engine.

⁶⁹ Richard Aboulafia, *World Military and Civil Aircraft Briefing*, Teal Group Corp., Fairfax, VA, 2016. This report does not include Chinese fighter production for domestic or export markets.

⁷⁰ Steven Zaloga, *International Defense Briefing*, Teal Group Corp., Fairfax, VA, 2016.

Over the past decade, China has developed a broad range of new fighter designs that are much closer in technical features to contemporary U.S., Russian, and European designs. China still has some significant bottlenecks in technology, notably engine design, but Chinese fighters could finally become competitive in the international market in the next decade.

Table 14. Contemporary Fighter Production to 2015: Domestic vs. Export⁷¹

Country	Type	Dates of production	Total production to date	Total Domestic	(%)	Total Export	(%)
USA	F-15	1981-	1,496	1,130	75.5	366	24.4
USA	F-16*	1979-	4,583	2,260	49.3	2,323	50.6
USA	F/A-18	1982-	2,143	1,723	80.4	420	19.5
USA	F-22	2002-2012	186	186	100	0	0
USA	F-35	2009-	181	171	94.4	10	5.5
Russia	MiG-29	1984-	1,459	539	36.9	920	63.0
Russia	Su-27/-35	1986-	1,127	715	63.4	412	36.5
Europe	Tornado	1982-1998	992	872	87.9	120	12.0
Europe	Typhoon	2002-	471	400	84.9	71	15.0
Europe	Mirage 2000	1983-2007	612	319	52.1	293	47.9
Europe	Rafale	2000-	149	149	100	0	0
Europe	Gripen	1993-	236	210	89.0	26	11.0
Japan	Mitsubishi F-15J, F-2	1981-	124	124	100	0	0
Total			13,759	8,798	63.9	4,961	36.0

*F-16 data includes 958 aircraft built as knock-down kits and assembled by Fokker, Sabca, Samsung, and TUSAS

⁷¹ Data not available for Chinese production. Some marginal types excluded (Jaguar license production in India by HAL, Ching Kuo in Taiwan). Production data from: Richard Aboulaffia, *World Military and Civil Aircraft Briefing*, (various editions and reports), Teal Group Corp., Fairfax, VA.

Table 15. Worldwide Fighter Production 1995-2015⁷²

	F -15	F -16	F/A -18	F -22	F -35	MiG- 29	Su-27/ 35	Tornado	Typhoon	M.2000	Rafale	Gripen	Japan*	Total
1995	4	78	46				32			14		8	8	190
1996	11	84	38				16	8		32		14	3+4	210
1997	20	101	57				12	20		31		19	6	266
1998	39	112	49				4	20		38		15	8	285
1999	35	114	38				9			11		15	1	223
2000	5	44	42				36			9	3	17	9	165
2001	0	24	36				50			3	3	15	16	147
2002	3	31	40	4			34		2	1	4	14	10	143
2003	4	61	44	10			45		12	13	4	16	10	219
2004	3	72	48	20			62		28	40	4	16	10	303
2005	6	50	42	23			34		35	3	8	15	8	224
2006	12	70	42	22			30		32		13	18	8	247
2007	12	66	44	22			54		35		13	22	7	275
2008	14	28	45	22			46		20		13	9	7	204
2009	13	39	49	20	2	9	35		42		13	5	5	232
2010	13	23	50	20	9	4	43		57		11	5	2	237
2011	15	26	49	19	19	12	49		55		11	4	2	261
2012	8	37	48	4	35	4	47		43		11			237
2013	14	9	48		35	27	49		40		11			233
2014	14	17	44		36	22	66		26		11			236
2015	12	16	35		45	18	64		37		11			238
Total	257	1102	934	186	181	96	817	48	464	195	144	227	124	4,775
USA: 2,660					Russia: 913			Europe: 1,078						

*F-15J to 1999, F-2 (F-16 copy) from 1996

⁷² Data not available for Chinese production. Some marginal types excluded (Jaguar license production in India by HAL, Ching Kuo in Taiwan). Production data from: Richard Aboulaffia, *World Military and Civil Aircraft Briefing*, (various editions and reports), Teal Group Corp., Fairfax, VA.

F. Ground Combat Vehicles

1. Overview

The ground combat vehicles market encompasses main battle tanks (MBT), infantry fighting vehicles (IFV), armored personnel carriers (APC) and self-propelled (SP) artillery systems. The market for these products has been robust and highly competitive since the collapse of the Soviet Union. Initially the market for these systems was dominated by suppliers from Western Europe, Russia, and the United States. More recently, new market entrants from the Ukraine, Poland, Turkey, and South Korea plus the emergence of a “new” China with a wider and more technologically advanced range of vehicles have pushed traditional suppliers for exports. Even some non-producers, such as the Netherlands, have become players for short periods by selling off their in-service inventory of modern, high-quality used armored vehicles in excess of revised military requirements and/or defense budgetary constraints.

2. Main Battle Tanks

The post-Soviet Union market place for MBTs has been shaped by a number of major events. One of those events was the drastic contraction of the German *Bundeswehr* in the early 2000s. The *Bundeswehr*’s stock of MBTs plummeted from 2,528 to 350, infantry fighting vehicles from 2,077 to 410, and artillery pieces from 1,055 to 120. These vehicles were dumped on the market at greatly reduced prices in what came to be known as the great *Deutsche Panzer Schlussverkauf* (i.e., German Panzer fire sale). Redundant German Army Leopard 2 MBTs were purchased by Germany, Austria, Canada, Chile, Denmark, Finland, Greece, the Netherlands, Norway, Poland, Spain, Singapore, Switzerland, Sweden, and Turkey. Leopards became the de facto MBT of choice for European militaries. Krauss-Maffei Wegmann (KMW), the Leopard’s manufacture, even started calling Leopard 2 MBTs *Euro Leopards* in its marketing campaign.

The second major event was the demise of the Warsaw Pact and the splinter off of Ukraine from Russia. In the wake of these events, the once monolithic, centrally coordinated Soviet MBT marketing effort split into separate competing entities, each actively promoting indigenous derivatives of the Soviet-era T-72s and T-80s for export. Some also offered surplus-to-requirements used MBTs. The list of potential MBT suppliers increased even more with second-tier suppliers (e.g., Turkey, South Korea) heavily pushing marketing efforts at international arms shows, hoping to become major players in regional MBT export markets. To date, Turkey and South Korea have had little success in actually exporting MBTs, but they dream of becoming major export players in the world MBT market. Chinese defense industries also “upped” their game by turning from offering modified models of Russian designs at much lower prices to producing an indigenous line of MBTs capable of competing with European, Russian, and Ukrainian export MBTs based on cost and improved manufacturing quality. Bottom line: competition has become much stiffer over time.

The third major event affecting the international MBT market was really two events – Operation Desert Storm and Operation Iraqi Freedom. During these two operations, the U.S. enemy fire proved ineffective in destroying the U.S. Abrams MBT, although a few were destroyed by “friendly fire.” A number of others were damaged, but later repaired and returned to action. Subsequently, only 28 of the 140 refurbished Abrams M1A1s sold to Iraq between 2010 and 2012 have been damaged in fighting with Iraqi militant forces armed with anti-tank guided missiles (ATGMs) and rocket propelled grenade launchers. These successes have allowed Abrams to be advertised as “combat proven” – an important advertising/marketing point.

Unfortunately, export sales of Abrams MBTs have not been as robust as might be predicted based upon its combat successes. The reasons are varied and include relatively high cost compared to some competing models, U.S. export controls, and the unpopularity of its expensive, thirsty, and noisy AGT1500 gas turbine engine. The future does not look bright for reversing this trend.

Lastly, despite the best efforts and serious marketing campaigns, some MBTs have failed to have any export success. Examples of these MBTs include Italy’s *Ariete* (which is now out of production), the Israeli *Merkava*, and South Korea’s K1 and K2 *Black Panther*.

Israeli attempts to export *Merkava* illustrate the obstacles some countries face. The Israeli Defense Ministry’s Director-General decided to start exporting *Merkava* in 2010 with visions of big money export sales, expanding domestic production line, and further research and development (R&D).⁷³ Timing was bad. Israel was entering the MBT export market at precisely the time that some of the world’s armies (especially European armies) were reducing tank inventories, thereby creating a glut of slightly used MBTs at low prices. Sales to potentially lucrative market areas like Arab nations were precluded by policy considerations of both the seller and potential buyers. The Israeli security establishment was opposed to transfers of technology (often a primary demand of would-be customers) fearing exposure of the secrets of *Merkava*’s advanced armor and other unique systems.⁷⁴ Israeli efforts to export were also hampered by low production rates, resulting in high per unit costs and export restrictions. Those restrictions came from both the United States, which supplied a significant number of components and partially funded development, and the Israeli Ministry of Defense. Despite all these obstacles, Israel remains optimistic. The *Merkava* Tank Program Administration Director told a reporter in 2014: “We will find a country that wants to procure the *Merkava*, and we’ll be able to continue developing this industry in Israel.”⁷⁵

⁷³ Yuval Azulai, “Merkava tank battles for export deals,” *Globes*, February 27, 2014. Accessed on 21 December 2016 at <http://www.globes.co.il/en/article-merkava-tank-battle-for-exports-deals-100092047>.

⁷⁴ Hezi Sternlicht, “Israel to make first sale of Merkava tank to foreign army,” *Israel Hayom, Newsletter*, June 9, 2014. Accessed on 21 December 2016 at http://www.israelhayom.com/site/newsletter_article.php?id=18015.

⁷⁵ Comments by Brigadier General Baruch Maziliach, *Merkava* Tank Program Administration Director, quoted by Yuval Azulai in “Merkava tank battles for export deals,” op. cit.

Table 16. Characteristics of Select MBTs⁷⁶

	M-1A2 SEP V2 U.S.	T-90S RUSSIA	T-14 Armata RUSSIA	MBT-3000 CHINA	Challenger 2 U.K.	Leopard 2A7 GERMANY	Merkava Mk4 ISRAEL
							
YEAR INTRODUCED	1992	1995	In development	2012	1993	2016	2004
CREW	4	3	3	3	4	4	4
COMBAT WEIGHT	69.5 tons	51.3 tons	48 tons	57 tons	62.5 tons	67.5 tons	65 tons
MAX SPEED	42 mph	40 mph	50 to 60 mph	43 mph	35 mph	45 mph	40 mph
UNREFUELED RANGE	265 miles	342 miles	> 310 miles	311 miles	280 miles	311 miles	311 miles
MAIN ARMAMENT	120 mm smoothbore (manual load)	125 mm smoothbore autoloader	125 mm smoothbore autoloader	125 mm smoothbore autoloader	120 mm rifled cannon	125 mm smoothbore cannon	120 mm smoothbore cannon
SPECIAL AMMO	• Depleted uranium AT • Advanced Multi-Purpose round (in development)	HE fragmentation round command detonated by FCS	Thermobaric gun-launched AT guided missile	Laser guided HE-AT rounds	DU AT	Multi-purpose HE PELE penetrator	• Anti personnel/anti material • Gun-launched AT guided missile
FIRE CONTROL SYSTEM	• 2nd gen FLIR • Thermal sights • Laser range finder	• 2nd gen French FLIR • Thermal sights • Laser range finder	• Kalina FCS w/ thermal imagers • Battle Mgmt System	• Thermal sights • Laser range finder • Inertial nav. system	• General Dynamics Canada FCS • Thermal sights	• Rheinmetall FCS • Thermal imaging	• Elbit Knight Mk 4 FCS • Thermal imaging
ARMOUR	Steel and advanced	Steel, advanced, and ERA	Modular composite steel	Steel, advanced, and ERA	2nd gen. Chobham and ERA option	Steel and advanced	Steel and advanced
APS	No	Yes	Yes Hard and soft kill	Yes	No	No	Yes
NBC PROTECTION	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SPECIAL FEATURES	• Common Remote Operated Weapons Station • Tank Urban Survival Kit	• Deep fording kit • Nose-mounted dozer blade	• Unmanned turret • Extended main gun range > 5,468 yds	Remote control 12.7 mm HMG	Nose-mounted dozer blade	• Mine protection kit • Urban ops kit • RPG protection kit	Front-mounted engine provides additional crew protection

Sources: Information from IHS Jane's Land Warfare Platforms Armoured Fighting Vehicles, 2016-2017; IHS Jane's Armour and Artillery, 2011-2012; and unclassified information provided to Congressional Research Service by the Army National Ground Intelligence Center (NGIC).

Table 17 and Table 18 provide the macro-level picture of MBT exports by country over the past two decades. Table 17 provides individual sales by exporting country, recipient, platform, delivery data, and quantity. Table 18 provides insight into market shares of individual countries based on aggregate sales of new production and used MBTs over the same period.

⁷⁶ Catherine A. Theohary, "Conventional Arms Transfers to Developing Nations, 2008-2015," op. cit.

Table 17. Individual Export Sales of New Production and Used MBTs from 1996 to 2014⁷⁷

	Belarus	China	Czech Republic	France	Germany	Netherlands
1996	9	3	15	58	1	0
1997	0	0	3	68	26	35
1998	40	232	5	95	35	123
1999	154	0	0	62	105	93
2000	115	0	118	32	51	93
2001	34	0	26	32	1	15
2002	15	0	37	31	63	47
2003	0	0	1	7	303	0
2004	0	10	1	5	30	0
2005	19	10	26	2	63	0
2006	41	10	38	0	205	0
2007	0	18	6	0	427	0
2008	0	0	11	1	195	109
2009	23	0	0	0	147	29
2010	66	16	72	0	207	0
2011	31	0	1	10	207	8
2012	76	13	20	45	49	6
2013	0	98	3	12	3	0
2014	0	0	5	0	121	0
Total	623	410	388	460	2,239	558

⁷⁷ United Nations Register of Conventional Arms, 2014. Accessed on 2 January 2017 at <https://www.unroca.org/>.

Table 17. (Continued): Individual Export Sales of New Production and Used MBTs from 1996 to 2014

	Poland	Russia	Ukraine	United Kingdom	United States
1996	0	162	0	6	453
1997	0	14	105	0	139
1998	0	4	137	0	128
1999	20	0	132	14	0
2000	0	31	13	91	20
2001	0	40	31	88	128
2002	16	84	15	88	158
2003	0	0	40	94	0
2004	2	0	3	44	0
2005	0	2	62	0	159
2006	7	30	38	2	20
2007	48	164	151	1	139
2008	22	77	34	0	55
2009	72	107	0	8	27
2010	3	47	246	3	31
2011	0	0	0	9	31
2012	0	128	109	7	174
2013	0	161	0	6	54
2014	0	65	0	1	5
Total	190	1,116	1,116	462	1,721

Table 18. Relative Market Share of MBT Exports of New Production and Used MBTs from 1996 to 2014

Export Country	Total MBTs Exported	Percentage of Total
Belarus	623	7%
China	410	4%
Czech Republic	388	4%
France	436	5%
Germany	2,239	24%
Netherlands	558	6%
Poland	190	2%
Russia	1,116	12%
Ukraine	1,116	12%
United Kingdom	462	5%
United States	1,721	18.5%
Totals	9,259	Total may not equal 100% because of rounding

3. Armored Combat Vehicles

Over the past 20 years, armored combat vehicle manufacturers have sought to expand their global markets by increasing the number of models. Table 20 shows the number of armored combat vehicles exported by a select group of countries by year from 1996 to 2014. The data comes from the United Nations (UN) Register of Conventional Arms. These figures include both new production and used equipment being transferred to another nation. The category “armored combat vehicles” is defined by the Register of Conventional Arms as follows:

*Tracked, semi-tracked or wheeled self-propelled vehicles, with armored protection and cross-country capability, either: (a) designed and equipped to transport a squad of four or more infantrymen, or (b) armed with an integral or organic weapon of at least 12.5 millimetres caliber or a missile launcher.*⁷⁸

The numbers presented in the UN Register of Conventional Arms are probably skewed. Export figures for Germany, for example, are skewed by the dumping of Soviet-style equipment acquired with German reunification and the great *Deutsche Panzer Schlussverkauf* (i.e., German Panzer fire sale). Chinese numbers are probably under reported because of Chinese unwillingness to provide export data to the UN, particularly in the early years. The authors believe that this data provides a good macro-level view of exports in the last two decades, such issues notwithstanding.

Table 19. Illustrative Characteristics of Infantry Fighting Vehicles⁷⁹

	M-2A3 U.S.	BMP-3M RUSSIA	T-15 RUSSIA	ZBD-04 (VN-11) CHINA	Warrior U.K.	Puma GERMANY	Namer ISRAEL
YEAR INTRODUCED	1981; A3 in 2001	1990	Undergoing trials	2006	1986	2010	2008
CREW	3	3	unknown	3	3	3	3
TROOP CARRYING CAP.	7	7	unknown	7	7	6	8
COMBAT WEIGHT	36 tons	18 tons	unknown	24 tons	28 tons	47 tons	68 tons
MAX SPEED	38 mph	44 mph	unknown	43 mph	47 mph	44 mph	34 mph
UNREFUELED RANGE	249 miles	373 miles	unknown	249 miles	377 miles	311 miles	unknown
AMPHIBIOUS CAPABILITY	no	yes	unknown	yes	no	no	unknown
MAIN ARMAMENT	• Turret-mounted 25 mm cannon • 2 turret-mounted TOW ATGM	• Turret-mounted 100 mm gun/missile launcher • 30 mm cannon	• Turret-mounted 30 mm cannon • KORNET ATGMs	Turret-mounted 100 mm cannon/missile launcher	Turret-mounted 30 mm cannon	Turret-mounted 30 mm cannon	Turret-mounted 12.7 mm HMG
SPECIAL AMMO	---	---	Thermobaric missiles	---	---	Air burst munitions	---
FIRE CONTROL SYSTEM	• Night vision • Laser range finder	• Night vision • Laser range finder	• Advanced sensors • Night vision • Thermal sights	• Night vision • Laser range finder	• Ultras FCS • Night vision • Thermal sights	• Rheinmetall FCS • Night vision • Thermal sights	• Night vision • Thermal sights
ARMOUR	Aluminum and applique	Aluminum	Steel and ERA	Aluminum and steel	Aluminum and steel	Steel and ERA	Steel and applique
APS	No	Available but not always mounted	Yes	Yes	No	Yes (“soft kill” i.e. electr. countermeas.)	Yes
NBC PROTECTION	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SPECIAL FEATURES	Bradley Urban Survival Kit	Most firepower of any tracked IFV	Tank-like levels of protection	---	---	High levels of protection	• High levels of protection • Underbelly mine protection

Sources: Information from IHS Jane’s Land Warfare Platforms Armoured Fighting Vehicles, 2016-2017; IHS Jane’s Armour and Artillery, 2011-2012; and unclassified information provided to Congressional Research Service by the Army National Ground Intelligence Center (NGIC).

⁷⁸ “The Global Reported Arms Trade,” *The UN Register of Conventional Arms*. Accessed on 23 December 2016 at <http://www.un-register.org/Background/Index.aspx>.

⁷⁹ Catherine A. Theohary, “Conventional Arms Transfers to Developing Nations, 2008-2015,” op. cit.

Table 20. Exports of Armored Combat Vehicles from Selected Countries 1996 to 2014⁸⁰

	Canada	China	Czech Republic	Finland	France	Germany	Italy
1996	212	0	10	10	37	164	12
1997	19	0	0	0	111	505	0
1998	8	0	100	24	16	107	0
1999	26	0	36	66	60	126	0
2000	4	0	2	31	36	69	0
2001	19	0	6	43	69	2	0
2002	2	0	1	1	96	36	0
2003	159	0	1	51	61	39	3
2004	136	0	3	34	51	40	8
2005	333	0	31	109	52	67	1
2006	163	12	32	33	28	100	0
2007	89	44	102	5	63	0	0
2008	15	20	68	9	25	199	401
2009	170	78	3	24	0	146	139
2010	50	0	34	0	0	256	173
2011	0	0	0	33	22	33	20
2012	227	18	102	1	34	3	3
2013	0	39	77	57	0	37	0
2014	69	12	15	0	102	88	0
Total	1,701	223	623	531	863	2,017	760

⁸⁰ United Nations Register of Conventional Arms, 2014. Accessed on 22 December 2016 at <https://www.unroca.org/>.

Table 20. (Continued): Exports of Armored Combat Vehicles from Selected Countries 1996 to 2014

	Netherlands	Poland	Russia	Sweden	Turkey	Ukraine	United Kingdom	United States
1996	615	0	321	4	0	6	199	812
1997	1	20	389	7	3	12	114	953
1998	34	0	276	24	0	36	65	441
1999	8	3	32	35	0	113	20	165
2000	93	10	41	40	57	76	1	354
2001	0	0	129	13	36	69	0	189
2002	0	67	109	16	80	20	84	487
2003	0	0	0	83	211	58	0	675
2004	0	0	130	110	98	124	10	317
2005	0	600	74	60	36	38	7	459
2006	143	579	114	137	454	83	37	390
2007	217	177	64	170	113	188	72	52
2008	18	49	46	149	203	165	162	2
2009	0	8	23	103	0	121	13	26
2010	0	14	225	375	111	90	19	370
2011	117	8	0	161	148	2	0	310
2012	271	12	276	44	158	209	67	479
2013	48	8	283	0	105	0	98	350
2014	148	21	78	0	0	0	107	1,272
Total	1,713	1,568	2,610	1,531	1,813	1,410	1,075	8,103

Table 21. Relative Market Share of Select Countries of Exports for New Production and Used Armored Combat Vehicles (1996 to 2014)

Export Country	Total Armored Combat Vehicles Exported	Percentage of Total
Canada*	1,701	6.5%
China	223	1%
Czech Republic	623	2%
Finland	531	2%
France	863	3%
Germany	2,017	7.5%
Italy	760	3%
Netherlands	1,713	6.5%
Poland	1,568	6%
Russia	2,610	10%
Sweden	1,531	6%
Turkey	1,813	7%
Ukraine	1,410	5%
United Kingdom	1,075	4%
United States	8,103	31%
Total	26,541	May not equal 100% because of rounding

*The UN Register of Conventional Arms does not include the sale of Stryker to the United States by General Dynamics Land Systems Canada. Thus, Canada could be considered a much bigger player in this market than suggested by data contained in the UN Register of Conventional Arms.

4. Large Caliber Artillery Systems

a. Self-Propelled (SP) Artillery

When it comes to SP artillery, the U.S. was by far the market leader until the 1990's with large numbers of: (1) 155 mm M109, (2) 175 mm M107 and (3) 203 mm (8-inch) M110 SP artillery systems being exported. Italy fitted the 221 M109s chassis with locally manufactured 155 mm ordnance, which were integrated by Oto Melara. Table 22 presents the numbers of various models of M109 self-propelled howitzers now in service worldwide.

Table 22. M109 Self-Propelled Howitzers in Now Service

Country	Model	Number
Austria	80 A2/A5Ö	80
Brazil	M109A2/A3	40
	M109A5	36
Chile	M109A3	12
	M109A5	12
	M-109 KAWEST	24
Denmark	M109A2/A3 (upgraded to M109A3DK)	2 to 6
Djibouti	M109	10
Ethiopia	M109	17
Egypt	M109A2	400
	M109A5	201
Greece	M109A1B	51
	M109A2	84
	M109A3GEA1	50
	M109A3GEA2	223
	M109A5	12
Iran	M109	440
Iraq	M109A5	24
Israel	M109A5	600
Italy	M109L	221
Jordan	M109A2/A2-90	356
Kuwait	M109A1B	5
Lebanon	M109A3	12 + 24 TBD
Morocco	M1091B	44
	M109A2	78
	M109A3	22
	M-109L47	40
	M109A4	4
	M109A5	70
Norway	M109A3GNM	14
Oman	M109A0	15
Pakistan	M10922	6
	M109A5	115
Portugal	M109A5 (upgrades from M109A2/A3)	18
Peru	M109	12
Republic of China (Taiwan)	M109A2/A5	225
Saudi Arabia	M109A2	60
	M109A5	36
Spain	M109A2/A3	6
	M109A5	96
Switzerland	M109 (upgraded to M109 KAWEST)	224
Thailand	M109A5	20
Tunisia	M109A2	19 to 20
United Arab Emirates	M109	40

While the U.S. could still sell surplus 155 mm M109 series SP artillery, including the 155 mm M109A5 and M109A6 Paladin, we do not believe that there is a potential export market for the M109A7 PIM, which is now in low-rate production by BAE Systems, as this still has the 155 mm/39-caliber ordnance. BAE Systems did develop to the prototype stage the M109 International fitted with a 155 mm/52-caliber ordnance for the export market. This was seen as a threat by the U.S. Army to the Crusader, which was itself cancelled. The U.S. then started on the Future Combat System (FCS) that included the 155 mm Non-Line of Sight - Cannon (NLOS - C) but this was also cancelled. Even if these two systems had entered production, we doubt that they would have achieved significant export sales.

The Republic of Korea (ROK) manufactured 1,040 M109A2 under license. Samsung Techwin then developed the indigenous K9 “Thunder” 155 mm/52-caliber SP artillery system and associated ammunition resupply vehicle. The K9 Thunder has already achieved export sales. Turkey built a version of this under the name of the Firtina (about 300 built), and more recently India has placed a contract for an initial batch. Poland has selected the hull/chassis of the K9 Thunder for its Crab 155 mm/52-caliber SP artillery system, which has a turret based on the BAE Systems AS90. A total of 179 of the latter were built, but no export sales were achieved and it is no longer being marketed by BAE Systems.

A number of countries have developed and placed in-production upgrade packages for the 155 mm M109.

- Rheinmetall of Germany has developed a 155 mm/52-caliber version called 155 mm M109L52, which remains at the prototype stage.
- The now defunct RDM Defence Technology upgraded M109 to the M109L47 standard with the 155 mm/47-caliber ordnance supplied by RUAG Defence of Switzerland, and 85 of these upgraded M109L47 were supplied to the United Arab Emirates (UAE). Three hundred forty-eight units were upgraded with a RUAG Defence 155mm/47 caliber ordnance and other enhancements.
- Switzerland took delivery of 581 M109s from the U.S. with 155 mm/47-caliber ordnance and other enhancements.
- RUAG has sold their complete artillery barrel manufacturing capability to India, so logically there can be no more exports of this 155 mm/47-caliber system from Switzerland. Switzerland has exported small batches of M109 that have not been upgraded to Chile (24) and the UAE (24), but Swiss export rules mean that any additional export sales are unlikely.
- The U.S. has continued to develop the M109 155 mm SP artillery system, with the latest models being the M109A6 and the M109A7 PIM. Both of these are fitted with 155 mm/39-caliber ordnance.

The M109A7 PIM is essentially an upgraded M109A6 turret integrated onto a brand new hull. No export sales of the M109A6 were made, but some sales of surplus U.S. Army M109A5

have been made. With the drawdown of the M109A6 as the M109A7 PIM comes into service, a significant number of these could become available for export.

However, few countries are now purchasing 155 mm/39-caliber SP artillery systems, as there is a clear trend toward the procurement of 155 mm/52-caliber systems in tracked and wheeled SP configurations, as well as towed.

The German Krauss-Maffei Wegmann (KMW) PzH 2000 155 mm/52-caliber system is the benchmark for SP weapons of this caliber, as it has a high rate of fire due to its semi-automatic loading system and carries 60 x 155 mm artillery projectiles plus associated Modular Charge Systems (MCSs). When compared to the M109A6/M109A7, the Panzerhaubitze 2000 (PzH 2000) has a higher rate of fire, longer range, and carries more ammunition. Table 23 shows the number of PzH 2000s produced.

Table 23. Number of PzH 2000s as of December 2016

Country	Total Armored PzH 2000	Date(s)
Croatia	12	2015 to 2016
Germany	185	1998 to Present
Greece	24	2003 to 2004
Italy	70	2015 to 2016
Lithuania	21	2015 to 2019
Netherlands	57	2004 to 2009
Qatar	24	2015 to 2017

PzH 2000 was originally developed to meet the requirements of the German Army to replace its fleet of 155 mm/39-caliber M109A3G. Following the introduction of the PzH 2000, at least 270 M109A3G were delivered to Greece free. KMW has also invested in the 155 mm/52-caliber Artillery Gun Module (AGM), which is a remote-controlled turret system that uses the same ordnance as the PzH 2000 and can be fitted to a variety of platforms, tracked, and wheeled. It was tested on a MLRS platform and was followed by the Donar, which was a dedicated platform developed by General Dynamics European Land Systems Santa Barbara Sistemas, but this combination has yet to be sold.

Krauss-Maffei Wegmann developed an air-portable self-propelled howitzer based on technology from the PzH 2000 AGM as a private venture project to meet potential German Army requirements. More recently, the 155 mm/52-caliber AGM turret was integrated onto the Boxer (8 x 8) Multi-Role Armored Vehicle (8 x 8). The German Army has a potential requirement for a 155 mm/52-caliber wheeled SP artillery system, which could be met by the Boxer/AGM combination.

GIAT Industries (now Nexter Systems) developed the *Grande Cadence de Tir* (GCT) 155 mm self-propelled gun beginning in 1969 and it entered production in 1977. The GCT was based on a modified AMX-30B MBT chassis and 155 mm towed artillery systems. A total of 241 units were delivered to the French Army beginning in July 1979. Exports included: (1) 85 units to Iraq

from 1983 to 1985, (2) 18 units to Kuwait, and (3) 51 units to Saudi Arabia with delivery beginning in 1978.

Although fully tracked self-propelled artillery is still being developed and advertised, the market is turning toward large-caliber artillery weapons mounted on trucks. The first to appear was Nexter Systems' CAESAR 155 mm/52-caliber howitzer mounted on a 6 x 6 truck-mounted system. The French Army has taken delivery of five prototype and 72 production systems on a Renault Trucks Defense (6 x 6) chassis, with additional orders expected in the future. Export sales have been made to Indonesia (37), Saudi Arabia (100 + 36) and Thailand (6) with some potential for future exports. The Saudi Arabian National Guard (SANG) CAESAR is on a Mercedes-Benz Unimog (6 x 6) chassis, while Indonesia and Thailand use the Renault Trucks Defense Sherpa (6 x 6) chassis. More recently, a new version with the ammunition load increased from 18 x 155 mm projectiles to 30 x 155 mm projectiles and charges has been introduced based on a Tatra (8 x 8) chassis, which can be fitted with a protected four-door protected cab.

Other countries also offer truck-mounted self-propelled howitzers. The Czech Republic introduced the Dana (8 x 8) 152 mm SP artillery system on a protected Tatra chassis as far back as 1980. It is still used by the Czech Republic and Slovakia and export sales have been made to Libya, Poland, and more recently Georgia. Serbia is also strong in the wheeled SP artillery market, with sales made to Bangladesh, Kenya, and Myanmar. These are marketed in 6 x 6 and 8 x 8 configurations.

In South Africa, Denel Land Systems developed the G6 155 mm/45-caliber (6 x 6) SP artillery system, with the South African Defence Force taking delivery of 43 systems, and export sales have been made to Oman (24) and the United Arab Emirates (78). More recently, Denel Land Systems developed the G6-52 155 mm/52-caliber turret, which has been tested on a number of tracked platforms but still awaits its first contract. The company has also developed the 155 mm/52-caliber Condor (8 x 8) truck-mounted SP artillery system, which is now being tested in Asia based on a Tatra chassis. Unlike many other contractors, Denel Land Systems can offer a complete package consisting not only of the weapon, but also the fire control system, reconnaissance systems, and ammunition suite. The latter is provided by Rheinmetall Denel Munitions, which is owned by Rheinmetall (51%) and Denel (49%). Since this merger, sales have increased and they are supplying the 155 mm ammunition suite for the PzH 2000 procured by Qatar.

China North Industries Corporation (NORINCO) moved to the NATO 155 mm/45-caliber many years ago and has already had some export success with its PLZ45 155 mm/45-caliber tracked SP systems, with export sales to Kuwait (27 + 27) and Saudi Arabia (54). These exports were won in direct competition with Western Defence contractors and formed part of a complete artillery system. Today, NORINCO markets a complete range of artillery systems (tracked, wheeled, and towed systems), including: (1) PLZ45 155 mm/45-caliber (tracked), (2) PLZ52 155 mm/52-caliber (tracked), (3) SH1 155 mm/52-caliber (6 x 6), (4) 6x6 truck-mounted SH2 122 mm, (5) 6 x 6 truck-mounted SH5 105 mm and (6) numerous towed weapons.

The Chinese have achieved major export sales in the Middle East and Africa and regard themselves as a “one-stop shop” for supplying a complete artillery package. There have been reports of a lower level of quality than western systems. They do, however, sell to countries that are closed to Western (U.S. and NATO) countries on political grounds.

b. Market Share of All Large Caliber Artillery Systems

Table 24 and Table 25 examine the market for large-caliber artillery systems based on data from the UN Conventional Arms Register for selected countries. The register defines large caliber artillery systems as:

*Guns, howitzers, artillery pieces, combining the characteristics of a gun or a howitzer, mortars or multiple-launch rocket systems, capable of engaging surface targets by delivering primarily indirect fire, with a calibre of 75 millimetres and above.*⁸¹

Table 24. Exports of Large Caliber Artillery Systems from Selected Countries 1996 to 2014⁸²

	France	China	Germany	Poland	Russia	Sweden	United Kingdom	United States
1996	55	18	0	0	19	0	53	124
1997	56	0	0	0	0	0	25	333
1998	1	236	0	1,018	12	0	41	100
1999	0	0	0	0	38	0	6	87
2000	71	60	50	0	307	0	12	322
2001	36	0	0	0	4	6	0	20
2002	36	0	0	0	0	18	0	44
2003	56	80	16	106	18	12	0	21
2004	0	122	32	0	0	42	0	31
2005	2	150	43	0	8	114	0	70
2006	4	221	23	19	100	6	0	9
2007	0	42	30	4	16	4	3	318
2008	0	0	10	0	12	0	2	47
2009	5	0	9	0	16	0	0	181
2010	0	8	0	0	8	2	0	48
2011	8	67	0	6	0	12	0	124
2012	20	86	0	135	94	1	5	213
2013	0	179	63	23	438	9	3	856
2014	29	202	0	76	124	0	1	237
Total	379	1,471	276	1,387	1,214	226	151	3,185

⁸¹ “The Global Reported Arms Trade,” *The UN Register of Conventional Arms*, op. cit.

⁸² United Nations Register of Conventional Arms, 2014. Accessed on 22 December 2016 at <https://www.unroca.org/>.

Table 25. Relative Market Share of Select Countries of Exports for Large Caliber Artillery Systems 1996 to 2014

Export Country	Total Armored Combat Vehicles Exported	Percentage of Total
France	379	.045%
China	1,471	18%
Germany	276	.03%
Poland	1,387	17%
Russia	1,214	14.6%
Sweden	226	.03%
United Kingdom	151	.02%
United States	3,185	38%
Total	8,289	

5. Forecast of Global Market for Armored Vehicles 2016 to 2026

In 2016, Defence iQ (under the sponsorship of Textron Systems) did a survey of senior executives and professionals in the commercial and military armored vehicle industry regarding the future of regional armored vehicle markets over the next 10 years.⁸³ Some of the results of that survey are presented in the following charts.

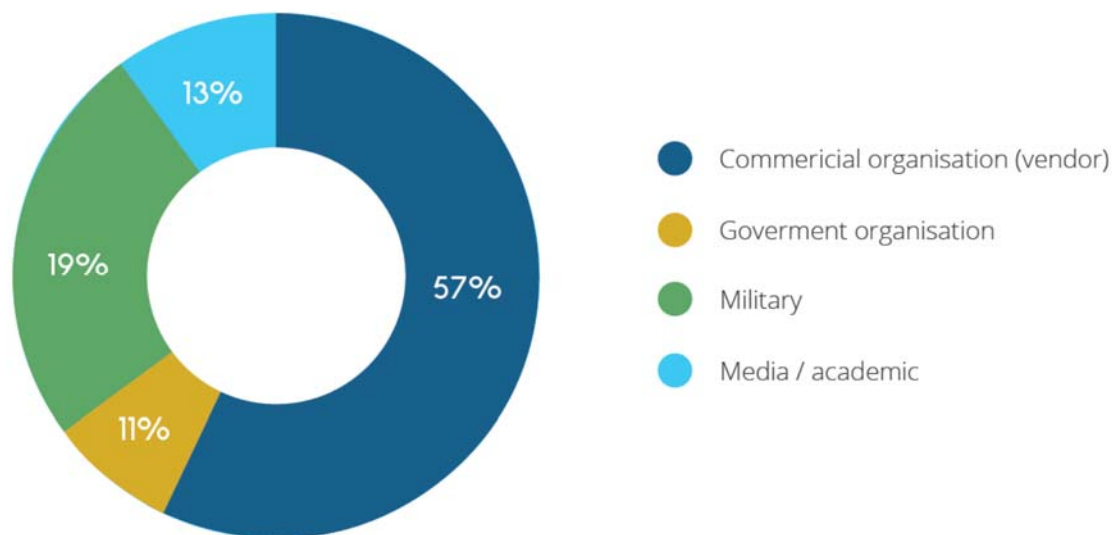


Figure 36. Types of People Responding to Defence iQ Survey

⁸³ *Global Armored Vehicles Market Report 2016*, Defence iQ, 2016. Accessed on 25 October 2016 at http://media.cygnus.com/files/base/OOH/document/2015/11/Global_Armored_Vehicles_Market_Report_2016.pdf.

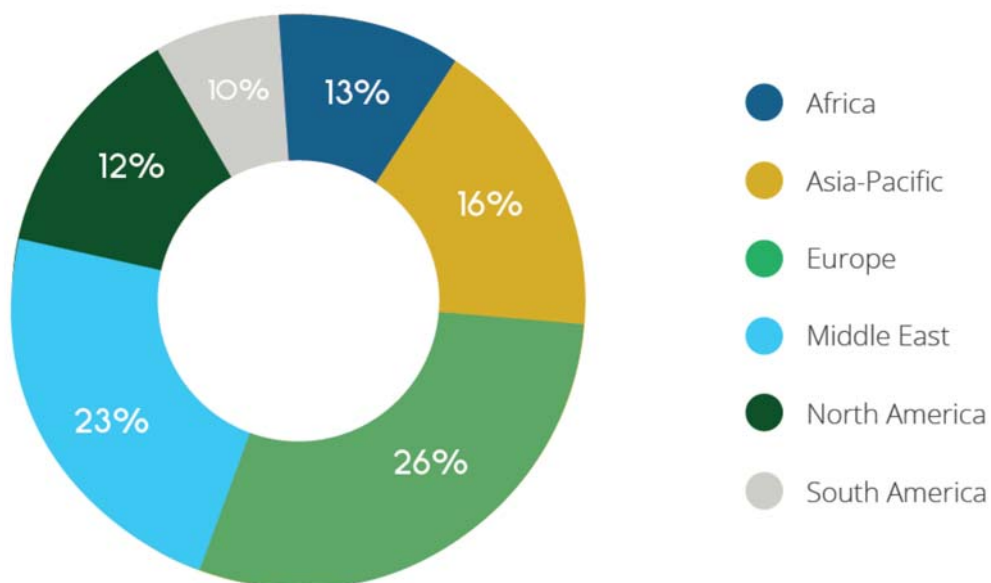


Figure 37. People Responding to Defence iQ Survey by Region

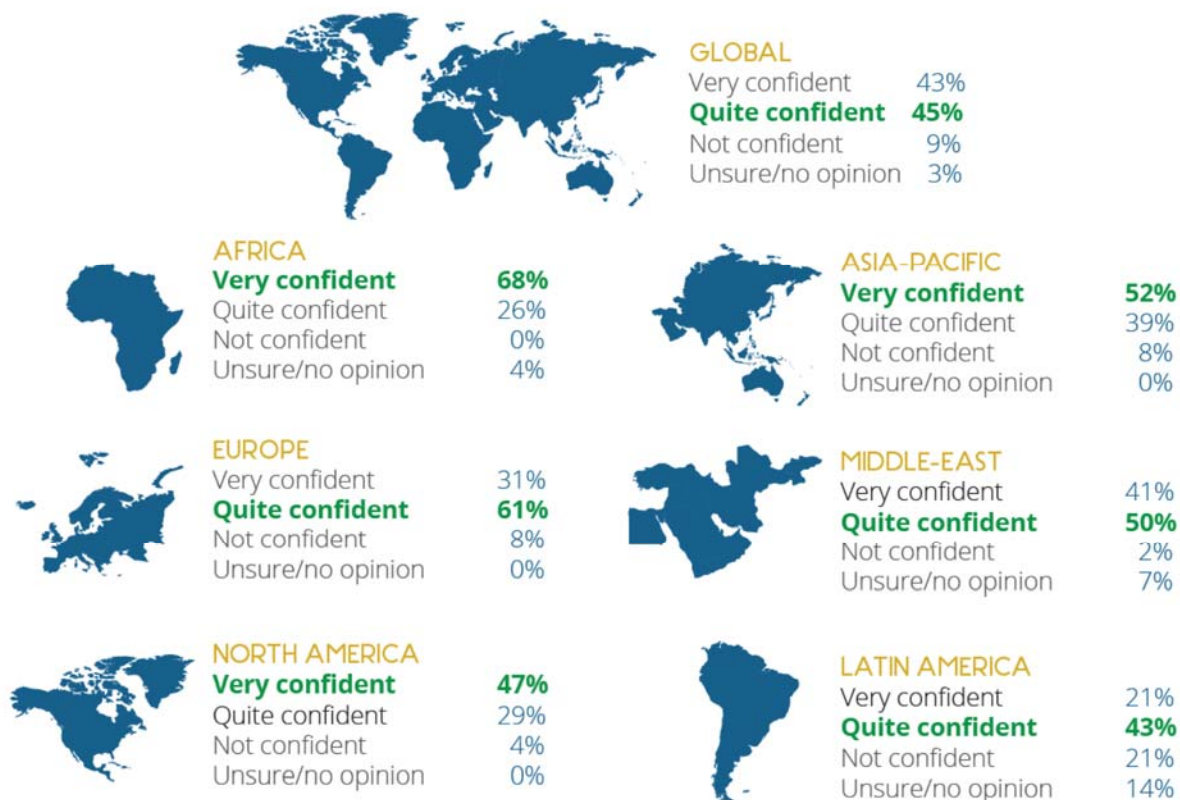


Figure 38. Confidence of Defence iQ Respondents to Future of Armored Vehicle Market in Their Region Over the Next 10 Years

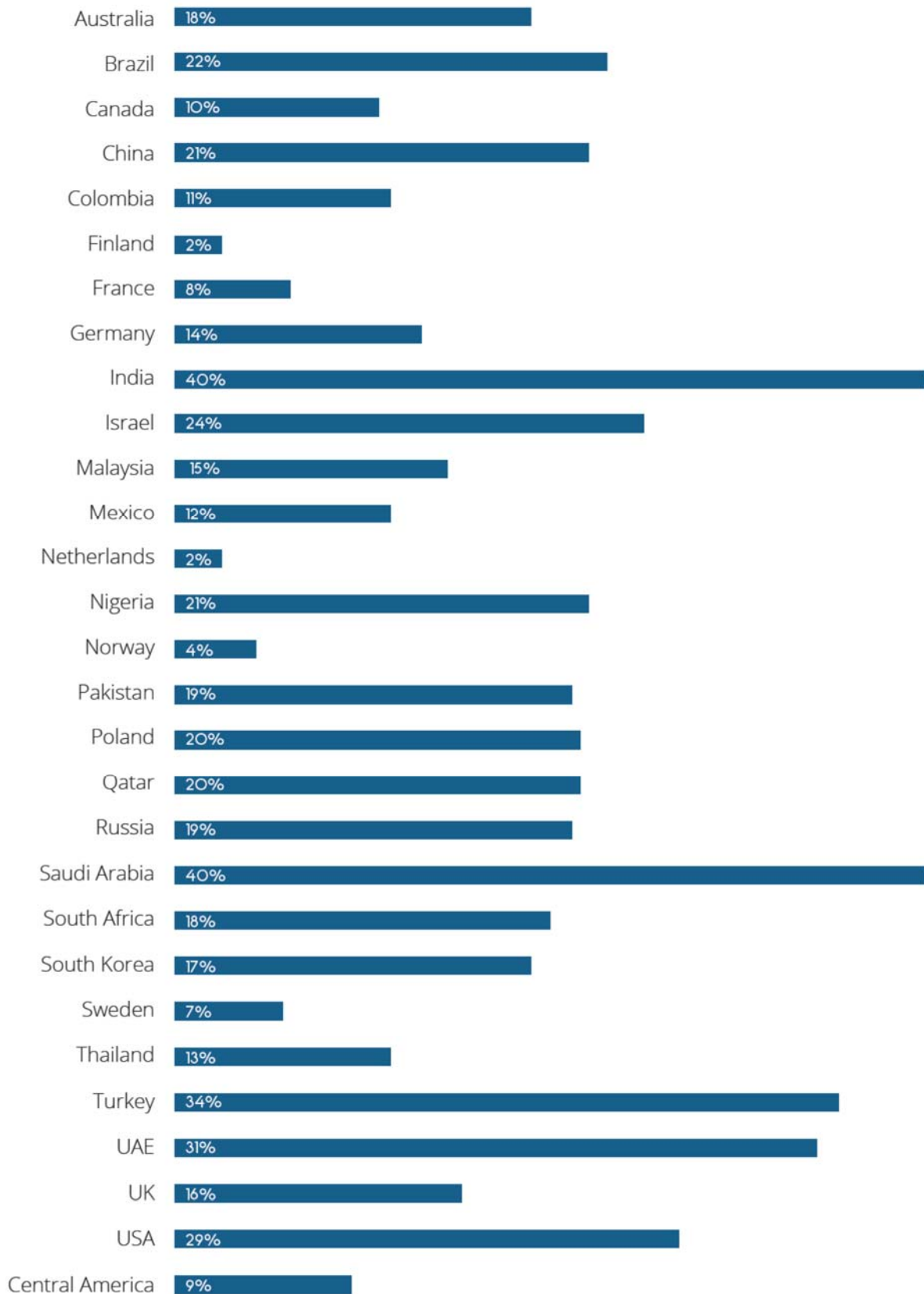


Figure 39. Countries Judged by Defence iQ Respondents to Have the Best Growth Potential for Armored Vehicles and Which Will be Targeted as a Priority Over Next 10 Years

	Unimportant	Somewhat important	Very important	Critical
Ballistic protection	1%	8%	46%	45%
Blast protection / counter-IED	1%	12%	31%	55%
Environmental control systems	9%	46%	39%	6%
Interoperable communications	1%	18%	51%	30%
Load carrying capacity	2%	36%	52%	10%
Mission range	2%	27%	57%	14%
Modular / interchangeable mission role (adaptability)	4%	27%	52%	17%
Power/weight ratio	6%	15%	61%	18%
Reducing repair/maintenance costs	4%	24%	47%	24%
Speed/ maneuverability	3%	21%	58%	18%
Easily transportable	4%	29%	54%	13%
Reduced unit cost out of factory	7%	40%	37%	17%
Reliability	0%	12%	45%	43%

Figure 40. Defence iQ Respondents Assessments of the Importance of Armored Vehicle Attributes for Armored Vehicle Requirements Over Next 10 Years

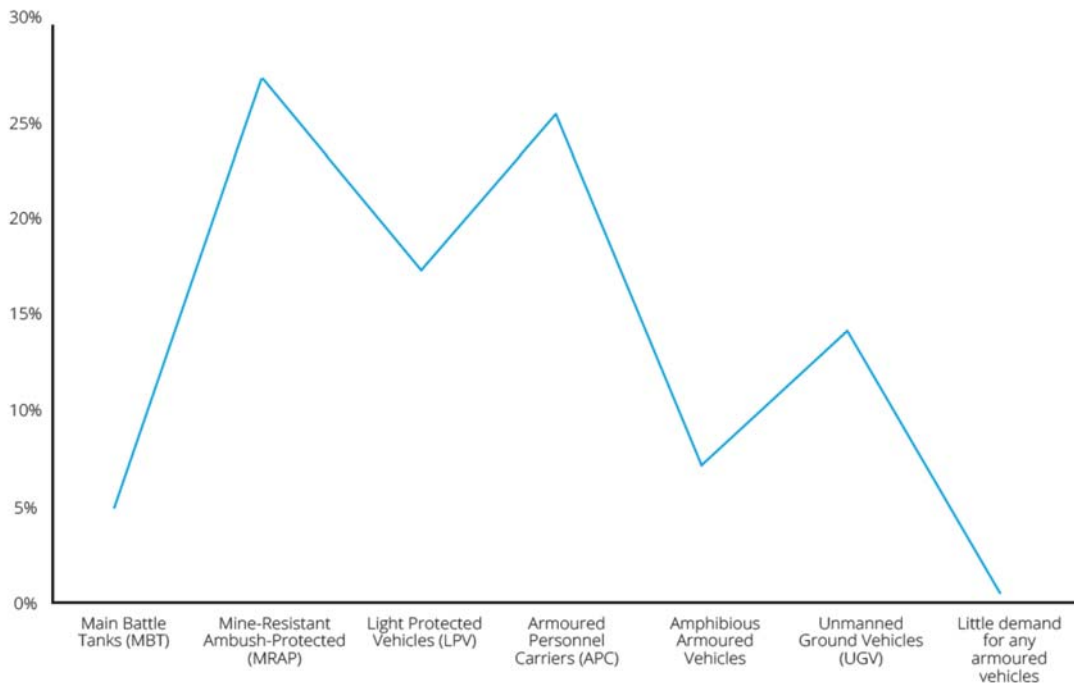


Figure 41. Assessment of Global Demand for Armored Vehicles by Type from 2016 to 2026 Based on Respondents to Defence iQ Survey

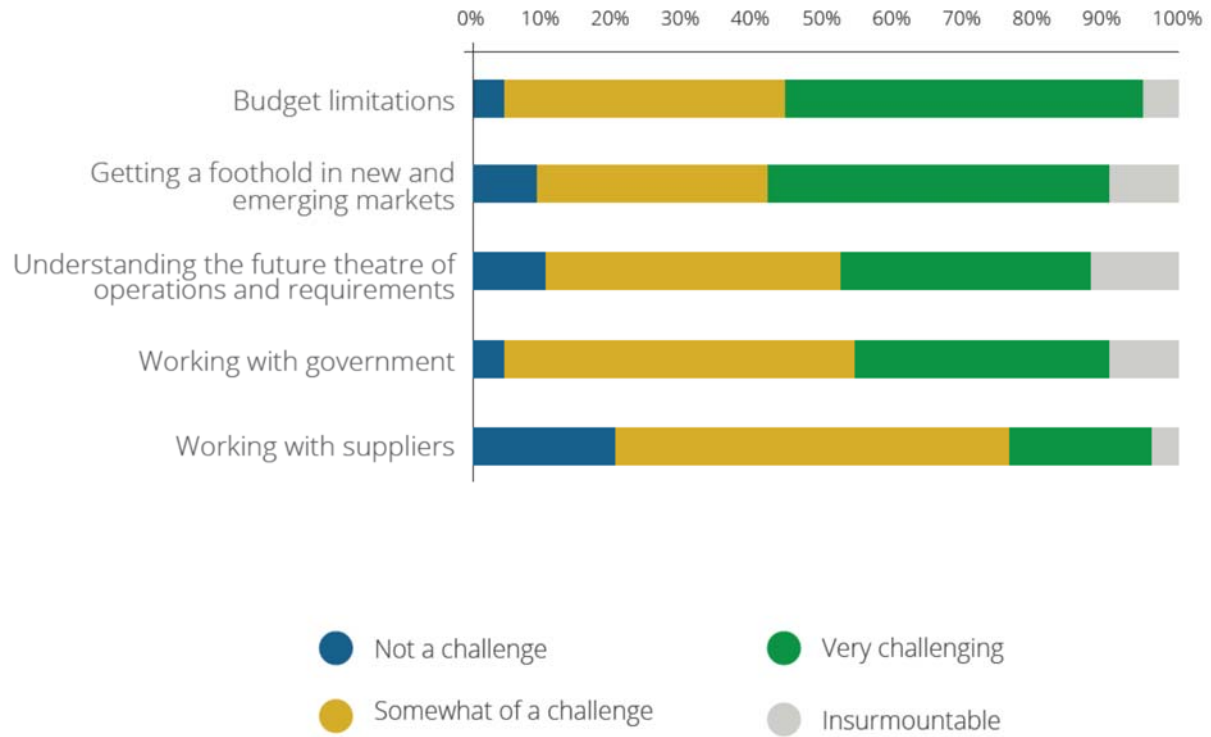


Figure 42. Challenges to Armored Vehicle Market through 2026 Identified by Respondents to Defence iQ Survey

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3. Growing Diversification of Defense Supply

The international arms market has undergone revolutionary changes over the past two decades and is still evolving. These changes have profound implications for the way weapons are developed, produced, and operated. This section begins the discussion of those changes by examining the extent and underlying reasons for the growing diversification of the sources of defense and security products.

A. Purpose of Arms Shows

Predictably, the purpose of arms shows is usually marketing. Domestic firms target their sales efforts at home governments and potential export clients, while foreign firms market to the host government and official representatives from other countries attending the exhibition. There have been exceptions to this rule for shows in Russia and China. The early editions of the Moscow Air Show were as much about networking among domestic Russian firms as they were about exports. That emphasis changed at subsequent Moscow Air Shows. Likewise, Chinese firms at the China International Defense Electronics Exhibition (CIDEX) 2004 seemed almost as (or perhaps more) intent on establishing connections with fellow Chinese companies. We believe this was necessary in the early days because strict security regulations, “need to know” requirements, and stove piping made it difficult for component and subsystem manufacturers to make contact with prime system developers to understand their needs, and for primes to be aware of potential suppliers. The other exceptions were the International Military-Technical Forum (Army 2016) in Moscow and AirShow China 2014. In both cases, the emphasis of the organizers and domestic exhibitors seems to have been primarily on showing the “bosses” what a good job was being done by the defense sector. One indicator of the focus of Army 2016 was that all (or virtually all) of the Main Directorates of the Ministry of Defense had booths at the show – something not seen at a previous Russian international arms show. Emphasis on exports was secondary at AirShow China 2014 and almost non-existent at Army 2016. It is probably significant that AirShow China came at the end of a five-year cycle, when products were beginning to emerge from the planning process.

Recognizing the main emphasis of each arms show is important. Without understanding the underlying context of the show, it is hard for an analyst or observer to identify what is significant and why.

B. International Arms Exhibitions Have Become More Important and Competitive

The international arms exhibitions have become increasingly important and competitive over the past two decades. This is partially illustrated by the emergence of many new defense and

security exhibitions. Over time, new shows have been created and existing arms exhibitions have expanded. Some of the new arms shows created since the collapse of the Soviet Union are: Moscow Air Show (1992), AirShow China (1996), SOFEX (1999), IDEAS (Pakistan in 2000), Russia Arms Expo (2005), International Military-Technical Forum “Army” (Russia in 2015), and Japan International Aerospace Exhibition (2016).

Another measure of the growing importance the international arms market places on shows is the amount of indoor exhibition space at individual shows; it has grown significantly over the years. Table 26 illustrates that growth by examining two exemplar shows. Indoor floor space at Defense Services Asia increased from 6,000 m² in 1988 to 41,500 m² in 2016. Indoor exhibition space at the first edition of International Defense Exhibition (IDEX) held in the United Arab Emirates was 16,000 m² in 1999. That increased to 35,000+ m² in 2015, a figure that does not include 2,384 m² indoor exhibition area at the co-located Unmanned Systems Exhibition and Conference (UMEX) and 3,000 m² at the Naval Exhibition and Conference (NAVDEX).

Table 26. Growth of Indoor Exhibition Floor Space at Defense Services Asia and AirShow China

Show Year	Indoor Floor Space Defense Services Asia	Indoor Floor Space AirShow China*
1988	6,000 m ²	n/a
1990	7,200 m ²	n/a
1992	9,600 m ²	n/a
1994	11,600 m ²	n/a
1996*	22,000 m ²	8,645 m ²
1998	18,000 m ²	9,200 m ²
2000	15,200 m ²	12,436 m ²
2002	21,000 m ²	15,000 m ²
2004	27,000 m ²	16,700 m ²
2006	33,800 m ²	17,000 m ²
2008	42,000 m ²	21,000 m ²
2010	38,000 m ²	23,000 m ²
2012	40,000 m ²	28,200 m ²
2014	41,000 m ²	35,000 m ²
2016	41,500 m ²	82,000 m ²

*AirShow China began in 1996

Individual shows have also expanded their scope. AirShow China began as an overwhelmingly aerospace show with only a few ground force exhibits. It has since expanded its coverage of ground force weapons significantly, even building two new exhibition halls dedicated

specifically to land warfare systems in 2014 and a dynamic test track in 2016. IDEX also expanded the scope of its coverage by adding the separate, but associated, NAVDEX in 2011 and UMEX in 2015.

Data in Table 27 and Table 28 demonstrate that the number of exhibitors at individual international arms shows has generally grown by a factor of two or three, depending on the particular show. The one exception to this trend in Table 28 is the Paris Air Show, which has long been a large, preeminent arms exhibition. But even there, the number of exhibitors increased by about 47% between 1993 and 2015. Increased numbers of exhibitors per show are evident, despite a significant consolidation of defense companies in the West over the past two decades.

Table 27. Number of Exhibitors at Moscow Air Show, IDEX, Paris Air Show and DSEi

Year	Moscow Air Show	IDEX	Paris Air Show	DSEi
1992	200+	n/a	n/a	n/a*
1993	260	350	1,569	n/a
1995	400	566	1,620	n/a
1997	400	752	1,853	n/a
1999	450	862	n/a	n/a**
2001	512	860	1,700+	664
2003	606	698	1,728	1,002
2005	654	730	1,916	1,201
2007	787	862	1,996	1,352
2009	735	897	2,000	1,280
2011	842	1,060	2,113	1,391
2013	1,000	1,112	2,215	1,489
2015	760***	1,200	2,303	1,683
2017	n/a****	1,235	n/a****	n/a****

*First show called Mosaeroshow-92, renamed Moscow Air Show in 1993

**First called DSEi in 1999 when it replaced the combined British Equipment Exhibition and Royal Navy Equipment Exhibition

***The sharp decline in the number of exhibitors at the Moscow Air Show in 2015 was probably due to the impact of international sanctions.

**** Exhibition not held as of the information cut-off date for this report.

Table 28. Number of Exhibitors at AirShow China and Defense Services Asia (DSA)

Year	AirShow China	Defense Services Asia
1998	n/a	394
1990	n/a	419
1992	n/a	483
1994	n/a	520
1996	400	614
1998	500	593
2000	400	420
2002	370	500
2004	500	550
2006	550	590
2008	600	718
2010	600	830
2012	650	850
2014	700	1,057
2016	700+	1,200

The proliferation of exhibitions and costs of attending have caused some vendors to become selective about which shows to attend. Increased regional focus allows vendors to tailor products to interests and requirements of potential regional customers.

BAE Systems, Eurofighter, Northrup Grumman, and Saab chose not to attend the Paris Air Show 2015, instead pursuing a new policy of targeting shows closer to their customers. Northrup Grumman cited cost and a desire to align resources better to markets as being among the reasons for not attending both the Paris Air Show and the Farnborough International Airshow, preferring to concentrate “its international business development activities and resources in country markets.”⁸⁴

Finmeccanica also greatly reduced its footprint at the Paris Air Show 2015. According to a corporate statement, “Finmeccanica’s presence at events of primarily institutional relevance has been greatly reduced so that it can expand its presence at sector-specific shows with more commercial value...” That same statement went on to note that Finmeccanica’s decision was in

⁸⁴ Andrew Chuter, “BAE Will Sit Out Paris Air Show,” *DefenseNews*, April 14, 2015. Accessed 14 September 2016 at <http://www.defensenews.com/story/defense/show-daily/paris-air-show/2015/04/14/bae-not-exhibiting-at-the-paris-air-show/25764581/>.

keeping with “a trend adopted, in various dimensions, by other large international companies operating in aerospace and defense.”⁸⁵

Chinese defense and aerospace industries are following the same path regarding selective participation in international arms exhibitions. The Commercial Aircraft Corporation of China (COMAC) was the only large Chinese stand at the Farnborough Air Show 2016. By contrast, most of the major Chinese state-owned defense companies and export organizations participated in Africa Aerospace and Defense (AAD) 2014. The list of Chinese exhibitors at that show included:

- NORINCO – Producer of armored vehicles, artillery systems, military trucks
- China Shipbuilding Trading Corporation (CSTC)
- China National Aero-Technology Import & Export Corporation (CATIC)
- State Administration for Science, Technology and Industry for National Defense (SASTIND)
- China Electronics Technology Cooperation International (CETCI)
- China Precision Machinery Import-Export Corporation (CPMIEC) – Export representative for the sale of Chinese cruise missiles and air defense systems
- Poly Technologies – Export representative for a wide range of defense and security equipment (e.g., small arms, communications equipment, marine equipment and parts, air defense systems, etc.)

C. Major New Players Emerge

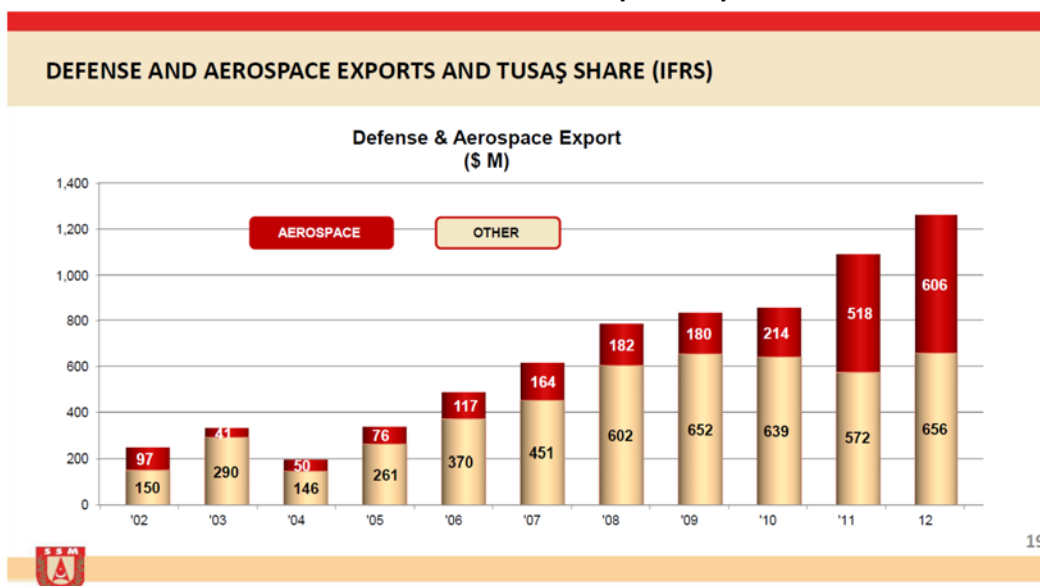
Traditional arms exporters like Europe, China, Russia, Israel, and the U.S. remain the mainstays of arms exhibitions. However, a growing number of other countries are expanding their presence, both geographically and through the range of technologies and systems being offered. This is based in part on technical expertise and intellectual property acquired through prior export arrangements with traditional suppliers of defense goods. It is also the result of governments encouraging local defense industries to spread their wings internationally for both economic and strategic reasons. Emerging exporters are seeking to gain a significant share of regional and global arms markets and become major players in the international and regional arms markets. Such countries include: Brazil, South Korea, Turkey, Japan, and the United Arab Emirates. Turkey and South Korea are making significant strides toward reaching that goal. AVASCENT (a multi-national business strategy and management consulting firm) predicts that, “The maturation and

⁸⁵ Tony Osborne, “Defense Presence Small at Paris Air Show,” *Show News* prepared by *Aviation Week*, June 15, 2015. Accessed 14 September 2016 at <http://aviationweek.com/paris-air-show-2015/defense-presence-smaller-paris-air-show>.

proliferation of these industries in the global defense marketplace will inevitably ‘squeeze’ Western defense manufacturers over the next 10 years.”⁸⁶

Turkish defense industries are becoming major players in the defense export market. Table 29 illustrates the growth of Turkish defense and aerospace exports from 2002 to 2012. These numbers come from a briefing delivered by M. Arif SEZGİN, Director of Sectoral Strategies and Investment Planning of the Under-Secretariat for Defense Industries (Turkish Ministry of Defense). That trend has continued. The Ankara-based Defense and Aerospace Industry Exporters' Association (SSI) reported that Turkish defense exports totaled \$1.4 billion in 2013, a 10% gain over 2012.⁸⁷ The defense exports were \$1.66 billion in 2015 according to Asuman Vangölü, Head of the International Cooperation Department, Under-Secretariat for Defense Industries.⁸⁸ The Turkish Exporters Assembly reported that defense exports for January to February 2016 rose 30%, compared to the same period in 2015.⁸⁹

Table 29. Growth of Turkish Defense and Aerospace Exports from 2002 to 2012⁹⁰



⁸⁶ Daniel Yoon et al. “Dynamics of International Military Modernization 2016,” AVASCENT white paper, May 2016. Accessed on 28 November 2016 at http://www.avascent.com/wp-content/uploads/2016/05/Dynamics_of_International_Military_Modernization_2016_WP_05192016.pdf.

⁸⁷ Grant Turnbull, “Turkey’s formidable defence industry – rising star or NATO’s unruly ally?” *Army-technology.com*, April 2, 2014. Accessed on 2 September 2016 at <http://www.army-technology.com/features/featureturkeys-formidable-defence-industry-rising-star-or-natos-unruly-ally-4207115/>.

⁸⁸ Interview with Asuman Vangölü, “A new Strategic Approach for Export and International Cooperation. Turkish Defense Industry Export Momentum Expected to Accelerate,” *Defence Turkey*, June 27, 2016. Accessed 2 September 2016 at <http://www.defenceturkey.com/?p=article&i=2327#.V8mAafkrLX4>.

⁸⁹ “Turkey’s defence exports rise in first two months of 2016,” *TRTWorld*, March 11, 2016. Accessed on 2 September 2016 at <http://www.trtworld.com/turkey/turkeys-defence-exports-rise-in-first-two-months-of-2016-65562>.

⁹⁰ M. Arif SEZGİN, “Turkish Defense & Aerospace Industry and Acquisition System,” the Under-Secretariat for Defense Industries, Turkish Ministry of Defense, 2012. Accessed on 2 September 2016 at http://accd.vermont.gov/sites/accd/files/TURKISH%20TRADE%20DAYS%20_%20JAN2014_V04.pdf.

The uptick in defense exports beginning in 2011 may be due in part to the Under-Secretariat for Defense Industries creating regional International Cooperation offices that year. These offices provide support to the business development activities of Turkish companies and promote the industry in general. Their goal is enhancing the opportunities for defense exports in their regions.

Turkey has been particularly active (and successful) in Asian and African markets over the past few years. The Head of the International Cooperation Department, Under-Secretariat for Defense Industries ascribes that success to Turkey's cultural and historic ties with Asian and African countries; ties that, according to her, bring multiple advantages.⁹¹ She goes on to note that region-specific approaches to exports are no longer appropriate, and hence her organization is expanding its focus, with special emphasis on South America.

There also has been a convergence between defense and security products and services at international arms exhibitions over the past decade. New actors are emerging from traditionally non-defense markets (e.g., police, internal security, and border control). One of the first shows to recognize this trend explicitly was DSEi, where organizers noted in 2009 that 30% of exhibitors that year focused on security rather than defense technologies and services. Additionally, adjacent industries offering COTS/dual-use technologies (e.g., biometrics, information technology, cyber, new materials, big data analytics, artificial intelligence, and 3D printing) are also becoming regular features at international arms shows.

South Korea has been called "Asia's New Powerhouse Arms Exporter" by *The Diplomat* magazine, with good reason.⁹² Five South Korean companies were named among the Top 100 arms-producing and military service companies by the Stockholm International Peace Research Institute in 2013. Another measure of South Korean impact on the defense market is that exports have grown from \$144 million in 2002 to \$3.6 billion in 2014.⁹³ According to South Korea's Defense Acquisition Program Administration, defense exports have had an average growth rate of 31% between 2009 and 2014.⁹⁴

Over time, South Korea has evolved from a third-tier arms supplier into a global competitor to some of world's largest arms supplying countries. Much of South Korea's success has come in Asia, with Indonesia, Malaysia, and the Philippines being major customers. However, their ambitions are more wide-ranging. Recently, South Korea has made major inroads with Latin American countries, supplying assault rifles, aircraft, anti-ship missiles and warships, and entering

⁹¹ Interview with Asuman Vangölü, "A new Strategic Approach for Export and International Cooperation. Turkish Defense Industry Export Momentum Expected to Accelerate," *Defence Turkey*, op cit.

⁹² Tai-jun Kang, "South Korea: Asia's New Powerhouse Arms Exporter," *The Diplomat*, May 25, 2014. Accessed 14 September 2016 at <http://thediplomat.com/2014/05/south-korea-asias-new-powerhouse-arms-exporter/>.

⁹³ Joyce Lee and Tony Munroe, "South Korea wants to turn its arms industry into an export powerhouse," Reuters and *Business Insider*, April 22, 2015. Accessed 14 September 2016 at <http://www.businessinsider.com/r-south-korea-seeks-bigger-role-in-global-arms-bazaar-2015-4>.

⁹⁴ Jim Burton, "Arms Makers target exports as government weapons buying slows," *Asia Review*, October 1, 2015. Accessed 14 September 2016 at <http://asia.nikkei.com/Business/Companies/Arms-makers-target-exports-as-government-weapons-buying-slows>.

into joint ventures with local shipyards for the design and construction of patrol vessels. South Korean arms exports to Latin American countries come in three forms: (1) outright sale of either weapons or military platforms, such as ships and aircraft, (2) design and co-production joint ventures, and (3) transfers of surplus naval vessels.⁹⁵

In 2014, the Japanese government implemented a new rule on exporting and international joint development of weapons, thereby ending a 70-year-old ban on arms exports. The new rule still places limitations on the export of weapons. However, an editorial in *The Japan Times* warned, “Such conditions for weapons export, however, are so vague and wide in scope that it will be very difficult to the new agency to draw a clear line for allowing or forbidding arms exports.”⁹⁶

In addition to allowing the export of defense products, the Japanese government created the Acquisition, Technology and Logistics Agency as an external bureau of the Defense Ministry. Its responsibilities include helping arms exports through promoting cooperation with the United States and other countries in the field of joint weapons development and procurement.

Just before the creation of the Acquisition, Technology and Logistics Agency, Japan Business Federation (Keidanren) called for the government to make defense exports a “national strategy,” apparently reflecting the views of Japanese companies that such exports offer new business opportunities.⁹⁷ Keidanren went farther, encouraging the Japanese government to gather information that would contribute to arms exporting activities.

Japanese defense companies reacted quickly. A month after the easing of government restrictions on the exporting of defense goods, the Japanese defense industry, represented by 14 companies, exhibited at Eurosatory 2014. Companies were clustered in the first “Japan Pavilion.” This was also the first time Japanese companies had participated in an international all-defense show.

Market penetration by these emerging arms exporters have proven harder than expected for a variety of reasons. Can the supplier be relied upon to provide spare parts (often over the course of decades)? Will the new supplier remain in business long enough to honor maintenance contracts and warranties? Has the weapon been proven in combat? Does the seller’s home country have enough faith in the system that its own military has also acquired it? Does the product contain U.S. systems and components, and hence will be subject to American export control? Even if significant penetration of the export market remains limited, emerging exporters (e.g., Turkey and South Korea) do present a challenge to U.S. third-party sales, since future domestic orders for military equipment that might otherwise have gone to American firms will go to local ones instead.

⁹⁵ Sanjay Badri-Maharaj, “IDSA Comment: South Korean Arms Exports to Latin America,” Institute for Defence Studies and Analyses (India), August 16, 2016 accessed 14 September 2016 at http://www.idsa.in/idsacomments/south-korean-arms-exports-to-latin-america_sbmarahaj_190816.

⁹⁶ Editorial, “Weapons development and exports,” *The Japan Times*, October 19, 2015 accessed 14 September 2016 at http://www.japantimes.co.jp/opinion/2015/10/19/editorials/weapons-development-exports/#.V9IXf_krLX4.

⁹⁷ Editorial, “Weapons development and exports,” *The Japan Times*, October 19, 2015, op. cit.

D. China Strives to Become a Major Player

According to the Stockholm International Peace Research Institute (SIPRI), China's defense exports almost doubled between 2011 and 2016.⁹⁸ The rise in numbers only tells part of the story. Twenty years ago, China marketed mostly poorly made, low-cost products, like small arms and armored vehicles, often on the basis of "friendship prices." Over time, the Chinese defense industry began to offer better-made products.

China aspires to more. The Shenyang Aircraft Corporation developed the J-31/FC-31 stealth fighter exclusively for the export market, with Pakistan rumored to be the possible launch customer. The China Precision Machinery Import-Export Corporation (CPMIEC) was on the verge of getting Turkey to purchase the HQ-9 /FD-2000 strategic air and missile defense system in September 2013. In announcing its selection of the HQ-9/FD-2000, Turkey's Undersecretary for Defense Industries stated that the Chinese offer bested the competition in terms of "price, technology, local work share, technology transfer, and credit financing terms."⁹⁹ Turkey subsequently changed this decision under pressure from NATO allies. Chengdu Aircraft Corporation has sold the FC-1/JF-17 fighter to Pakistan, with other countries including Qatar, Egypt, Algeria, Saudi Arabia, Argentina, and Uruguay expressing some degree of interest. China has also sold Yuan Class submarines to Pakistan and Thailand. It has reportedly sold armed UAVs to a number of Middle Eastern countries: Saudi Arabia, Iraq, Egypt, and the United Arab Emirates. Despite these successes, however, China remains only a bit player in the high-technology defense export market. China is still on the verge of becoming a major player in the international arms market rather than a country that has arrived.

Despite having limited success in the high-end technology export market, China still aggressively markets high-tech, upper-tier systems, including networked systems-of-systems products for a variety of missions. Poly Technologies at IDEX 2013, for instance, presented a national air defense system covering warning and surveillance; command and control; interception; and strike, maintenance, and personnel training for both peacetime and wartime. With a distributed, modularized, and redundant design, the system has enhanced reliability, compatibility, and practicality. Some equipment, such as early warning aircraft, can be added according to the needs of customer. A year later, Poly Technologies offered a coastal defense system at DSA 2014 that included undersea early warning sensors, as well as various fixed and mobile means of surveillance. The coastal defense system also does information sharing and processing and provides the coast management department and coast defense forces with a comprehensive understanding of the coastal situation.

⁹⁸ SIPRI report quoted by Megha Ragagopalan, "China weapons exports surge over past five years: report," Reuters, February 21, 2016. Accessed on 28 November 2016 at <http://www.reuters.com/article/us-china-defence-exports-idUSKCN0VU11Q>.

⁹⁹ Turkish Undersecretary for Defense Industries quoted by Nate Nurkin et al. in "The global implications of China's military modernization," *HIS Markit*, May 19, 2014. Accessed on 29 November 2016 at <http://blog.ihm.com/q12-the-global-implications-of-chinas-military-modernization>.

E. Weapons of Mass Consumption: The “Good Enough” Market Segment

There is a niche in the international arms market that caters to developing countries with limited defense budgets, mostly in Africa and South America, that want to purchase new products that do not aim for perfection or technological sophistication. Vendors working this niche are offering reliable-enough products at low-enough prices to attract and meet the operational needs of mid-level consumers. These systems are good enough to meet less the ambitious operational needs of mid-level customers.

A prime example of “good enough” systems being offered in the arms market are multi-functional light military jet aircraft that perform flight training, reconnaissance, and light attack missions. Examples of such aircraft are: (1) Russian Yak-130, (2) Chinese K-8 and JL-10/L-15, (3) Italian Alenia Aeromacchi M-346, (4) South Korean KA-1, (5) German Mako, and (6) British Hawk.

The Chinese K-8, for example, has been sold to Bangladesh, Bolivia, Egypt, Myanmar, Ghana, Namibia, Pakistan, Sri Lanka, Sudan, Venezuela, Zambia, and Zimbabwe, as well as to the People’s Liberation Army Air Force (PLAAF). Purchase of the K-8 by the PLAAF was crucial to the export success of the K-8, because few countries are willing to purchase aircraft not in service with the producer’s national military, believing the product is somehow substandard and/or fearing that the supply chain may not be reliable.

The Chinese have also sold an armed version of the Wing Loong UAV to several African and Middle Eastern countries since 2011. In the armed version of the Wing Loong, the Chinese are offering a less capable version of the U.S. MQ-9 Reaper, but with two advantages over the Reaper. Wing Loong is much less expensive (estimated to cost \$1 million per unit) than Reaper and is available to a larger number of nations who are excluded from purchasing by U.S. export controls.¹⁰⁰ Wing Loong, therefore, offers “good enough” capability at a price point affordable to most nations.

The co-developed, Pakistani-produced JF-17 fighter is another example of a product targeting the “good enough” market segment. The JF-17 fighter (especially the Block 1 version) offers a basic, single-engine fighter at a low cost. While certainly not capable enough to engage first-line Western, Russian, and Chinese fighters, the JF-17 is adequate for nations that need decent capability that will not break the bank.¹⁰¹

¹⁰⁰ “China’s Weapons of Mass Consumption,” *Foreign Policy*, March 20, 2015. Accessed on 12 January 2017 at <http://foreignpolicy.com/2015/03/20/chinas-weapons-of-mass-consumption/>.

¹⁰¹ “Need a Cheap Fighter Aircraft? The JF-17 Might Work,” *National Interest*, November 13, 2015. Accessed on 12 January 2017 at <http://nationalinterest.org/blog/the-buzz/need-cheap-fighter-aircraft-the-jf-17-might-work-14336>.



Figure 43. Slide from a Presentation by Yang Wei, AVIC of China's Chief Designer of JF-17 During a Briefing at the Dubai Air Show 2011

Despite aggressive Pakistani marketing of the JF-17, there have so far been no export sales, but there have been “lookers.” Morocco, while in the process of seeking a replacement of its F-16C/D fighters, invited Pakistan Aeronautical Complex (producers of the JF-17) and the Chinese Chengdu Aircraft Corporation (co-developers of the JF-17) to showcase the JF-17 at the Marrakesh Air Show 2016. The Malaysian High Commissioner to Pakistan also signaled his country's possible interest in JF-17. He told the Associated Press of Pakistan:

*I think the Malaysians might be genuinely interested because Pakistan has a respectable defense industry, with the products being considerably cheaper compared to the West due to cheap labor,... These products have been amply proven in the hands of very professional armed forces. These are reasons enough for many developing countries to look for defense hardware from Pakistan.*¹⁰²

¹⁰² Remarks by Dr. Hasrul Sani to Associated Press of Pakistan, cited by Benjamin David Baker, “The Sino-Pakistani JF-17 Might Have Another Buyer in Asia,” *Pakistan Defence*, December 23, 2015. Accessed on 12 January 2017 at <http://defence.pk/threads/the-sino-pakistani-jf-17.414843/>.

Some have also described Sweden's JAS 39 Gripen fighter as a competitor based on price and being good enough.¹⁰³

Unfortunately, U.S. companies have few systems designed to compete in the "good enough" segment of the international arms market. One significant exception to this observation is SpaceX – a privately funded initiative to low-cost space launch capability. The U.S. defense industry should be encouraged to develop similar "good enough" systems in areas where there is a reasonable opportunity for economic return. Success, however, would probably also need help from the Department of Defense. Such help would include purchasing a limited number of these products for Aggressor Units or the National Guard to signal the U.S. military's confidence in the product and as an assurance of a reliable supply chain for export customers.

F. Exports Are the Lifeblood of Defense Industries

During the Cold War, Western (with the exception of France) and Soviet defense firms generally concentrated on the domestic market, with exports playing a relatively minor role in a company's bottom lines. The collapse of the Soviet Union and the concomitant decrease in defense budgets changed that calculus. Arms transfer decisions increasingly came to be seen in economic rather than national security terms. Arms have come to be seen as just one more commodity in the perpetual struggle to gain a positive balance of trade, keep defense industries open, and keep people employed.

Exports today are the lifeblood of the global defense industry. The Israeli defense industry is a case in point. Originally, it was created to promote self-sufficiency and reduce reliance on defense imports. In the early days, defense exports were a "secondary interest and a means to counterbalance local demand fluctuations."¹⁰⁴ Now, exports account for a majority of sales by Israeli defense industries.¹⁰⁵ The Israeli defense industry is a "major contributor to Israel's balance of payments."¹⁰⁶ We have been told by one Westerner with contacts in Israel that the export potential of a new system has even become a major criterion for the Israeli Ministry of Defense when deciding whether to go ahead with a new weapons program.

The same is true of French aerospace and defense industries for at least the last 16 years. A press release from the French Land Defense Manufactures Association (GICAT) at Eurosatory 2000 noted the importance of exports, both to the French economy as a whole and to the defense industry specifically. That press release stated that defense exports represented 10% to 12% of the

¹⁰³ James Dunnigan, "Gripen Competes On Price and Being Good Enough" *Strategy Page*, December 16, 2013. Accessed on 12 January 2017 at <https://www.strategypage.com/dls/articles/Gripen-Competes-On-Price-And-Being-Good-Enough-12-16-2013.asp>.

¹⁰⁴ Yaacov Lifshitz, *Strategic and Economic Roles of Defense Industries in Israel*, BESA Center Perspective Paper No. 164, February 23, 2012. Accessed 14 September 2015 at <http://besacenter.org/perspectives-papers/strategic-and-economic-roles-of-defense-industries-in-israel/>.

¹⁰⁵ Ibid.

¹⁰⁶ Ibid.

positive balance of payments, even though they accounted for 1% of exports as a whole. The GICAT press release at Eurosatory 2000 emphasized:

They [exports] are necessary to maintain the jobs in some towns where defense industry represents the biggest employer...They govern the survival of this industry which had to face a great reduction in the [domestic French defense] budget in recent years.

The export market is still essential for the French defense industry. According to the French GICAT, approximately 40% of the annual turnover for these firms came from exports in 2014.¹⁰⁷ The French Aerospace Industry Association (GIFAS) claimed that 82% of revenues generated by its members came from exports in 2015.¹⁰⁸ French officials claim that arms sales created about 30,000 jobs in 2015 alone.¹⁰⁹

Potential export appeal of defense products is probably also an important part of South African Denel's decision-making process about whether to proceed with weapons programs. According to a Denel press release for IDEX 2017, the company earns almost 60% of its revenue from exports.¹¹⁰

The Patria's Nemo Container was introduced at IDEX 2017. Nemo Container is the world's first 120 mm mortar system integrated with a container in a single package. The genesis of the project, according to Kari Reunamäki, Vice President of Patria's weapon systems product line, was when, "One of our customers, the United Arab Emirates Navy, asked us whether Nemo could also be mounted on a transferable platform, not just fixed on a boat or vehicle."¹¹¹ During the development process, developers from Patria were in touch with officials of the United Arab Emirates Navy to ensure that the new system took customer requirements into consideration to the maximum extent. The size of the container, for example, was decided in collaboration with the customer.

Exports are important, even for state-owned corporations. A representative of a Chinese defense firm, for example, told the authors at one international arms exhibition that the People's Liberation Army paid his expenses, but exports generated his profits.

Perhaps nowhere have exports been more important than in Russia. The collapse of the Soviet Union brought "the traumatic disintegration of the formerly integrated Soviet military-industrial

¹⁰⁷ "Key Figures," GICAT website. Accessed 2 August 2016 at <http://www.gicat.com/gicat/key-figures/?lang=en>.

¹⁰⁸ "GIFAS Helps the French Flex Aero Muscles at Singapore," *Show News*, Singapore Airshow 2016, February 16, 2016. Accessed 14 September 2016 at <http://aviationweek.com/singapore-airshow-2016/gifas-helps-french-flex-aero-muscles-singapore>.

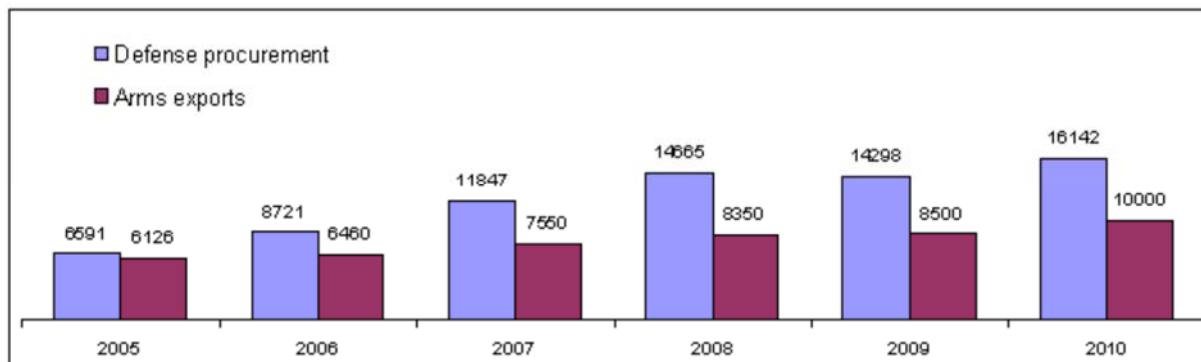
¹⁰⁹ Torie Rose DeGhett, "If the US Won't Sell You Weapons, France Might Still Hook You Up," *Defense & Security*, September 10, 2015. Accessed on 29 November 2016 at <https://news.vice.com/article/if-the-us-wont-sell-you-weapons-france-might-still-hook-you-up>.

¹¹⁰ "Denel to highlight its capabilities at IDEX 2017 defence exhibition." Accessed on 9 February 2017 at <http://defence-blog.com/army/denel-to-highlight-its-capabilities-at-idex-2017-defence-exhibition.html>

¹¹¹ Remarks by Kari Reunamäki quoted by Jukka Nortio in "A heavy mortar system with high mobility." Accessed on 9 February 2017 at <http://www.patriamagazine.fi/en/a-heavy-mortar-system-with-high-mobility/>

complex...coupled with the sharp and sustained slowdown in government defense spending.”¹¹² The economic stability of Russian defense industries in the 1990s fully depended on exports.¹¹³ In the early 2000s, Russian defense spending increased, but exports remained a major share of defense industry revenues through at least 2011, as shown in Table 30.

Table 30. Revenue from Russian Defense Procurement versus Exports from 2005 to 2011 in U.S. Dollars in 2012 prices



Sources: State Duma's Defense Committee, Russian Federal Service for Military and Technical Cooperation, Russian Central Bank, Russian media and Centre for Analysis of Strategies and Technologies¹¹⁴

Even if the massive funding allocated to fulfill the goals of the Russian State Armaments Plan (SAP) 2011-2020, which envisions raising the proportion of “modern” military equipment in the Russian inventory to 70%, is sustained despite current Russian state budgetary difficulties, defense exports will remain important to Russia for other reasons. Russian defense exports account for a disproportionate share of the country’s high-tech exports (e.g., defense products accounted for 60% of total Russian high-tech export volume or an estimated 5% of GDP in 2013, according to Olga B. Koshovets of the Russian Academy of Sciences’ Institute of Economy¹¹⁵). Koshovets also estimated that Russian arms exports would be responsible for 20% of the Russian high-tech growth from 2014 to 2016 and would account for 30% of all Russian high-tech exports in that period.¹¹⁶

Export potential is also important in some countries’ weapons acquisition decision-making processes. In the past European contractors have fitted U.S.-supplied subsystems into their

¹¹² Richard Weitz, “Russian Defense Industry: Breakthrough or Breakdown?” International Relations and Security Network, March 6, 2015. Accessed on 15 September 2016 at <http://www.defense-aerospace.com/articles-view/feature/5/161630/russia-s-defense-industry%3A-breakthrough-or-breakdown%3F.html>.

¹¹³ “Russian defense industry and arms trade: facts and figures,” Centre for Analysis of Strategies and Technologies, 2012. Accessed on 15 September 2016 at http://www.cast.ru/files/book/all-stats_eng_14_02_2012.pdf.

¹¹⁴ Ibid.

¹¹⁵ Olga B. Koshovets, “Financial Performance and Technology Modernization of Russian Hi-Tech Complex and Their Role to Boost Economic Growth,” *Journal of International Scientific Publications*, Vol. 8, 2014. Accessed on 14 September 2016 at <http://www.scientific-publications.net/get/1000007/1409340758352379.pdf>.

¹¹⁶ Ibid.

armored fighting vehicles but, due to ITAR controls, this is also ending. We were told by one long-term observer of the European ground force weapons market that in one joint French/U.K. program, which included U.S. parts, the French insisted these be removed, fearing adverse consequences of U.S. export controls on marketability. We have also been told that the export potential of a new weapons system is a regular part of the Israeli defense acquisition process. If prospects are not good, new systems often do not go forward.

G. Buyer's Market

As military budgets declined after the collapse of the Soviet Union, leading arms producers around the world increasingly looked abroad for new markets to compensate for shrinking domestic demand. Arms exports began to equate with corporate survival for many, especially for Russian firms. This in turn led to a saturated global arms market filled with highly motivated sellers.

As an article in *Asia Times* observed, “it’s a buyer’s market, and the buyers know it.”¹¹⁷ Past supplier restraint has been replaced by a readiness to sell almost all kinds of conventional weapons systems to anyone for the past two decades. Some nations placing non-economic restraints on the sale of certain kinds of systems is seen by other nations as an opportunity. The U.S., for instance, refuses to sell armed UAVs to many countries, so the Chinese defense industry made a decision to fill the void by selling armed UAVs to any nation that wants them.

The increased number of highly motivated vendors offer arms purchasers a great deal of leverage to drive down prices and gain greater access to sophisticated, top-of-the-line systems. India, for example, realizing Dassault Aviation was anxious to make its first foreign sale of Rafale, demanded another 25% discount on the earlier French offer to clinch the deal in the final phase of negotiations.¹¹⁸

The traditional approach of Western suppliers to addressing international opportunities was to offer products for export that were developed for their domestic customers. Often, such products did not meet the budgetary or operational needs of foreign customers. The new buyer’s market has forced companies to move to a market demand-based approach that involves either developing products specifically for the foreign market and/or being willing to modify designs to meet the requirements of individual customers. (This willingness is often stated in marketing brochures.)

¹¹⁷ Richard A. Bitzinger, “Japan’s disappointing entrée into the global arms market,” *Asia Times*, May 20, 2016. Accessed on 16 September 2016 at <http://atimes.com/2016/05/japans-disappointing-entree-into-the-global-arms-market/>.

¹¹⁸ Pranab Dhal Samanta and Manu Pubby, “France offers 25% discount to India on purchase of 36 Rafale Jets,” *The Economic Times*, May 6, 2015. Accessed on 19 September 2016 at <http://economictimes.indiatimes.com/news/defence/france-offers-25-discount-to-india-on-purchase-of-36-rafale-jets/articleshow/47168431.cms>.

H. Diversifying Suppliers

The growing number of countries seeking a major share in the arms market coincides with increasing interest of major arms importers in diversifying their supplier bases. Reasons for diversification are many, including: (1) desire to reduce costs/price, (2) improved access to technology transfers, (3) greater access to technologies embedded in systems, (4) allowing in-country co-production, (5) acquiring more reliable sources of spares, (6) acquiring weapons proscribed by particular sellers, (7) sending a political message and (8) dissatisfaction with post-sale export controls imposed by the seller. Sometimes, nations just feel under appreciated by long-time suppliers and/or wish to avoid dependence on a single vendor. Regardless, the increasing capabilities of homegrown defense industries are undermining the West's traditional competitive advantages in the international arms market and are likely to change the landscape of the global defense market in coming years.

A late December 2015 editorial in *Korea Times* illustrates some of the underlying motivations for diversification.¹¹⁹ The editorial begins by saying that South Korea was the world's ninth largest arms importer between 2010 and 2014 that that 89% of the weapons came from the U.S. According to the writer, heavy dependence on American defense firms was understandable, given the security situation on the peninsula. The opinion piece, however, complains:

The problem is that Korea has been neglected by the U.S. when it comes to technology transfer, although it has been buying a large quantity of American weapons. A case in point is the U.S. administration's refusal to allow Lockheed Martin to hand over four core technologies needed to push Seoul's KF-X project to develop indigenous fighter jets by 2025.

The editorial goes on to note that arms exporters are waging "a fierce battle to explore new markets." Such competition among exporters:

...raises the urgent need for Korea to diversify its arms import sources. It is long overdue for Korea to be obliged to buy expensive U.S. weaponry without putting up any resistance.

The result of taking advantage of increased competition for exports will be "strengthening the bargaining power of our defense procurement agency."

India has long been one of Russia's leading customers for defense equipment. Russia supplied 75% of India's weapons imports from 2009 to 2013 according to the Stockholm International Peace Research Institute (SIPRI).¹²⁰ That situation is changing because of growing Indian frustration over serious delays in delivering products, lack of spares, low quality of some

¹¹⁹ "Diversifying arms imports," *Korea Times*, December 29, 2015. Accessed on 15 September 2016 at http://www.koreatimes.co.kr/www/news/opinion/2015/12/202_194256.html.

¹²⁰ Figures from the Stockholm International Peace Research Institute (SIPRI) cited by Dimtry Gorenburg, *Russian Military Forum*, June 22, 2015. Accessed on 15 September 2016 at <http://mobile.businessinsider.com/why-the-us-arms-competition-with-russia-will-come-down-to-india-2015-6>.

Russian products, and cost overruns on major defense purchases.¹²¹ India's answer to these frustrations was to increase its leverage by purchasing from other countries, pitting different suppliers against each other, and adopting a "Make in India" policy. Although Russia remains India's largest supplier, its market share has declined significantly. Russian sources claim that out of India's current 67 arms contracts with other countries, 18 are with Russia, 13 are with the U.S., and 6 are with France – a far cry from Russia's 75% market share between 2009 and 2013.¹²²

It is not always easy, however, for a nation to diversify its suppliers, especially if it has relied upon the same supplier for a long time. Take the case of Vietnam. The U.S. Government has lifted the decades-old arms embargo, but the Vietnamese military is still closely integrated with Russian military equipment. The country's workforce and logistics networks are geared to uniquely Russian approaches to maintenance and repair processes, which differ significantly from the counterpart Western processes.

I. Domestic Production Playing a Growing Role in Arms Deals

As a growing number of countries compete to sell their wares in the international arms market, importing countries are increasingly being offered (or insisting) that products purchased be assembled in whole or in part in their country rather than that of the exporter, which was the standard practice in the past. Fewer than 10 countries had offset or counter-trade regulations prior to 1979. Now, more than 200 countries have some form offset legislation. Offset agreements have long been a feature of arms deals. Traditionally, offset required the foreign supplier to purchase a certain amount of goods from the purchasing company, usually in non-defense fields. But today purchasing countries are demanding a substantial role in final assembly, supply chain, and product sustainment as a condition of sale for imported defense products. As the head of business development for Lockheed Martin Corp's Mission Systems and Training told a reporter for Reuters at the Farnborough Air Show 2016: "If you want to be successful in any country, you have to have content in that country,... And the ones who move faster ... do better."¹²³

Insistence on the transfer of technology and industrial knowledge has important consequences. Many emerging defense exporters can trace their heritage to key roles played by technology transfer from American, European, and Russian firms as part of earlier arms sales. Growing capabilities of domestic defense industries is limiting market access of Western and Russian suppliers, particularly with regard to after-market spares, services, and upgrades. Locally

¹²¹ Maaïke Verbruggen, "India's arms imports: A holistic overview of India's motivations for choosing arms suppliers," Master's thesis, Universitet I Oslo, Autumn 2015. Accessed on 15 September 2016 at <https://www.duo.uio.no/bitstream/handle/10852/48931/Thesis-Maaïke-Verbruggen.pdf?sequence=1> and Dimtry Gorenburg, *Russian Military Forum*, June 22, 2015, op. cit.

¹²² Viktor Litovkin, "Making Russian arms in India," *Russia & India Report*, 24 March 2016. Accessed on 15 September 2016 at http://in.rbth.com/opinion/2016/03/24/making-russian-arms-in-india_578649.

¹²³ Remarks by Steve O'Bryan, "Tech transfer, domestic production play growing roles in arms deals," Reuters, July 14, 2016. Accessed on 19 September 2016 at <http://www.reuters.com/article/us-airshow-britain-defence-industry-idUSKCN0ZU2D3>.

sourced defense acquisition for South Korean armed forces increased from a little less than 40% in 2010 to more than 50% in 2015.¹²⁴ Additionally, the successful increase in domestic defense industrial capabilities through technology transferred in previous imports reinforces the resolve of governments to impose even more stringent technology-sharing and work-sharing conditions on future import deals.¹²⁵

Saab's JAS 39 Gripen NG fighter sales efforts offer the following insights about offsets or industrial cooperation:¹²⁶

- "...offset is an essential part of doing business, with customers becoming increasingly discriminating as to the form and quality of the economic compensation required for their defense investments."
- "Today almost every major defense acquisition is accompanied by an obligation on the part of the contractor to provide economic compensation."
- "...customers' tender evaluations are attaching a progressively greater significance, over price and product criteria, to real offset benefits and more innovative financing solutions."

The sale of 36 JAS 39 Gripen Next Generation (NG) fighters to Brazil required Saab to set up an assembly line in country, in partnership with Brazilian aircraft manufacturer Embraer SA. A Reuters story reported the contract calls for the production of 15 of the JAS 39 Gripen NGs in Brazil, including a run of eight two-seater planes.¹²⁷ Other aviation news sources, however, have speculated that the number of aircraft to be assembled in Brazil may be as high as 29 units.¹²⁸

In late December 2012, Russian Helicopters offered to open a facility in India as a "critical component" in an effort to win Indian Army Forces' requirement for 197 light multi-role helicopters. Russian Helicopters even went so far as to sign an agreement with Elcom Systems Private Ltd., part of the Indian investment conglomerate SUN Group, to set up an assembly facility in New Delhi. According to a press release from Russian Helicopters, this assembly facility would have "the capacity to produce key helicopter units and carry out final assembly of the machines as

¹²⁴ Daniel Yoon et al. "Dynamics of International Military Modernization 2016," op. cit.

¹²⁵ Ibid.

¹²⁶ "Gripen Industrial Co-Operation," Saab. Accessed on 16 September 2016 at http://saab.com/globalassets/commercial/air/gripen-fighter-system/gripen_industrial_co-operation.pdf.

¹²⁷ "UPDATE 2 –Sweden lowers loan costs in Saab fighter deal for Brazil," Reuters, July 29, 2015. Accessed on 16 September 2016 at <http://www.reuters.com/article/brazil-sweden-saab-idUSL1N1091UT20150729>.

¹²⁸ Gerard O'Dwyer, "Sweden, Brazil Pursue Deeper Cooperation with \$4.7B Gripen NG Deal," *DefenseNews*, October 24, 2015. Accessed on 16 September 2016 at <http://www.defensenews.com/story/defense/2015/10/24/sweden-brazil-pursue-deeper-cooperation-47b-gripen-ng-deal/74415116/>.

well as engage in ground and flight testing.”¹²⁹ This was significant because the company had never assembled any of its helicopters outside the Russian Federation.¹³⁰

Even Lockheed Martin is offering “Exclusive F-16 production” to India.¹³¹ Their sales pitch is “For India. From India.”¹³² The Lockheed Martin website goes on to say:

*Our partnership and joint venture company with Tata Advanced Systems Limited (TASL) has proven that Indian industry can manufacture airframe components for the C-130J airlifter and the S-92 helicopter. We hope to build on that success with the F-16, the world’s most successful, combat-proven multi-role fighter.*¹³³

As a condition for purchasing German Class 214 submarines, South Korea demanded that final assembly be done by Korean manufacturers Hyundai and Daewoo. South Korea also insisted on extensive technology transfers.¹³⁴ The German shipyard Howaldtswerke-Deutsche Werft (HDW) agreed to win the order.

Offset requirements in India were first introduced as part of Defense Procurement Procedure (DPP) 2005 and have undergone several revisions. Offsets are now mandatory for defense purchases from foreign vendors worth more than Rs 2,000 crore. The recent sale of Rafale fighters to India by Dassault Systems, for instance, included a 50% offset deal. This package called for a 30% commitment for military aerospace research and development programs and another 20% offset commitment with domestic Indian firms for making components for Rafale fighters.¹³⁵

Sometimes, however, the desire for in-country production is inconsistent with the realities of domestic industrial capabilities. For example, it took the Indians six years to translate the design documents for Russian T-90 tank production in India. Production difficulties led to a 40% shortfall in deliveries of T-90s by Indian Ordnance Factories. The original target was for Indian factories to produce 300 tanks by 2010, but only 167 tanks were delivered to the Army by 2013.¹³⁶ India was forced to buy 800 barrels for T-72 tanks in 2013 because 200 license-produced Russian barrels

¹²⁹ “Russian Helicopters to Open Helicopter Assembly Plant in India,” December 26, 2012. Accessed on 16 September 2016 at <http://www.russianhelicopters.aero/en/press/news/3935/>.

¹³⁰ Tony Osborne, “Russian Helicopters Looks to Foreign Production,” *Aviation Week & Space Technology*, January 14, 2013. Accessed on 16 September 2016 at <http://aviationweek.com/awin/russian-helicopters-looks-foreign-production>.

¹³¹ “For India. From India.” Lockheed Martin. Accessed on 12 January 2017 at <http://www.lockheedmartin.com/us/who-we-are/global/india.html>.

¹³² Ibid.

¹³³ Ibid.

¹³⁴ Philipp Dienstbier, “Germany: The Economic Perils of More Arms Exports,” *Atlantic-Community.org*, December 22, 2014. Accessed on 19 September 2016 at <http://www.atlantic-community.org/-/germany-the-economic-perils-of-more-arms-exports>.

¹³⁵ Vivek Raghuvanshi, “France Imposes New Conditions on Rafale Deal With India,” *DefenseNews*, July 6, 2016. Accessed on 16 September 2016 at <http://www.defensenews.com/story/defense/international/2016/07/06/rafale-jet-france-india/86752998/>.

¹³⁶ “T-90 tank induction short by 40%,” *The Tribune*, December 22, 2014. Accessed on 19 September 2016 at <http://www.tribuneindia.com/news/nation/t-90-tank-induction-short-by-40/21041.html>.

burst when the main gun was fired.¹³⁷ A similar problem was encountered around 2000. T-72 tank barrels made in India either cracked or burst because Indian factories heated the barrels below the specifications provided by the Russians (i.e., at 430°C rather than 520°C to 570°C).¹³⁸

J. Technology Transfer and Industrial Know-How

Technology transfer and industrial know-how are becoming key determinants of which companies win contracts in the global arms market. Brazil's purchase of Swedish JAS 39 Gripen NG fighters and Chinese negotiations for Su-35 fighters from Russia exemplify this trend.

Saab's deal with Brazil for the JAS 39 Gripen NG included both the exchange of sensitive proprietary intellectual property and transfer of industrial know-how. Saab provided the source code for the system to allow Brazil to upgrade the aircraft in the future and to integrate non-Swedish systems.¹³⁹ Other countries have demanded access to the source codes of aircraft, but this is the first instance of a seller agreeing. Doing so will ratchet up the pressure on other aircraft firms in future.

A Saab press release announcing the signing of the contract with Brazil for JAS 39 Gripen NG emphasized that the contract provided, "substantial technology transfer" from Saab to Brazilian industry.¹⁴⁰ The technology transfer package included approximately 50 projects. This was important, since the technology transfer program was one of the top reasons for the selection of Gripen, according to Mikael Franzén, Program Manager for Gripen Brazil.¹⁴¹

Saab's transfer of technology to Brazil included production know-how. Saab has agreed to provide courses and on-the-job training to 350 Brazilian professionals as part of the technology transfer agreements associated with the JAS 39 Gripen NG sale. Most of the training will take place in Sweden. Saab describes this training as follows:

During this period, each person will have a different program schedule and will receive theoretical and practical training according to the role they will play on the program. This first phase will include many systems engineers and software

¹³⁷ "India to replace bursting T-72 barrels under Rs1,500 cr deal with Russia," *The Economic Times*, August 28, 2013. Accessed on 19 September 2016 at http://articles.economictimes.indiatimes.com/2013-08-28/news/41538730_1_t-72-tanks-tank-ammunition-t-90-tanks.

¹³⁸ Ch Sushil Rao, "Defects boom out T-72 barrels," *The Times of India*, November 16, 2001. Accessed on 19 September 2016 at <http://timesofindia.indiatimes.com/city/hyderabad/Defects-boom-out-of-T-72-barrels/articleshow/1904981562.cms>.

¹³⁹ "Technology That Won Brazil Over," Official Blog for Gripen, Saab, January 3, 2014. Accessed on 19 September 2016 at <http://www.gripenblogs.com/Lists/Posts/Post.aspx?ID=809>.

¹⁴⁰ Saab Press Release, "Saab and Brazil Sign Contract for Gripen NG," Saab Group, October 27, 2014. Accessed on 19 September 2016 at <http://saabgroup.com/media/news-press/news/2014-10/saab-and-brazil-sign-contract-for-gripen-ng/>.

¹⁴¹ Remarks by Mikael Franzén, Program Manager for Gripen Brazil cited in "Saab Gears Up to Provide Technology Transfer to Brazil," Official Blog for Gripen, Saab, October 28, 2015. Accessed on 19 September 2016 at <http://www.gripenblogs.com/Lists/Posts/Post.aspx?ID=1298>.

*developers. Pilots, flight test engineers, production engineers, and so on will be arriving a bit further down the line.*¹⁴²

K. “No ITAR”

Over the last few years, there has been a growing dissatisfaction and restiveness among potential buyers of U.S. military equipment over the provisions of International Traffic in Arms Regulations (ITAR). Dissatisfaction is related to limitations on the resale of items produced in the buyer’s country, but having some content subject to ITAR. Buyers also object to ITAR restrictions on operational employment of equipment purchased from U.S. vendors or on locally produced military systems with U.S. components. Past purchasers of U.S. defense products are taking steps to deal with the problem.

As part of the announcement of an agreement between Italy, France, and Germany to develop a medium-altitude long-endurance UAV, the German Defense Minister reportedly commented: “The goal of the Euro-drone is that we can decide by ourselves in Europe on what we use it, where we deploy the Euro-drone and how we use it... This makes us, the Europeans, independent.” The inference is clear. Europeans do not want their use of UAVs subject to advance approval from the U.S., as required by ITAR. It is also rumored in the international arms market circuit that one of the unstated reasons for the Egyptians’ recent purchase of French Rafale fighters was the government’s displeasure at having to get prior U.S. approval for bombing raids against Libyan targets when using U.S.-built aircraft.

This same issue was touched upon by Thomas Linden the Head of Saab Malaysia at DSA 2016 when talking about Saab’s offer to lease newly built JAS 39 Gripen C/D fighters to Malaysia:

*“Our basic offer is a lease solution using examples where we have leased the Gripen to the Czech Republic and Hungary. The lease solution for Malaysia would work very similar to a purchase. **There is no limit in the operation, you can use any weapons or systems,** and we will build a local support solution here in Malaysia with our local partners. **This program is fully endorsed by the Swedish government.**”*¹⁴³ (Emphasis added)

We have also been told by representatives of several European firms that European governments have implemented a “de-ITARing” process. It requires that defense products made by European firms be entirely free of systems, components, and even small parts that would make the European product subject to ITAR restrictions. On one occasion, a longtime observer of European ground force industries and programs said, the French threatened to withdraw from a joint program with the United Kingdom unless all proposed U.S. content was eliminated. The

¹⁴² “Transfer of Technology,” Saab. Accessed on 19 September 2016 at <http://saab.com/id/air/gripen-fighter-system/gripen/gripen/proud-to-be-brazilian/gripen-for-brazil---the-perfect-match/transfer-of-technology/>.

¹⁴³ Thomas Linden, quoted in “Saab Outlines A Gripen Lease Proposal for Malaysia,” *gripenblogs.com*, April 26, 2016. Accessed on 16 November 2016 at <http://www.gripenblogs.com/Lists/Posts/Post.aspx?ID=1420>.

French feared that ITAR restrictions would have an adverse effect on the marketability of the system.

Freedom from ITAR requirements is now a selling point emphasized by some vendors. Some brochures and placards at international arms shows now contain the message: “No ITAR.”

L. Gaps in U.S. Defense Export Portfolio

In some sectors, the U.S. defense industry has no products to offer. Major firms in the U.S. shipbuilding industry, for example, have specialized in building larger surface naval combatants (e.g., cruisers and destroyers) but ignored smaller surface combatants, such as corvettes, which are in demand today in the international arms market for coastal defense, enforcement of economic exclusion zones, and combating illegal immigration and smuggling. Consequently, the small surface combatant market has been ceded to European, Russian, and Chinese shipbuilders who have offerings at virtually all multi-service arms shows. The same situation exists with conventionally powered submarines, for which the demand is also growing. This may potentially have significant consequences for the U.S.:

Avascent projects that demand for maritime capabilities will grow sharply in the coming 10 years, driven mainly by Middle Eastern and Asian customers. In the Middle East, this represents a cyclical shift from an aviation-led modernization phase to one focused on naval systems. This dynamic has the potential to cause a notable shift in global market share relationships in the coming decade, with U.S. suppliers set to lose out.¹⁴⁴

U.S. firms have also ignored the emerging medium-size transport aircraft market, whereas several foreign vendors are rolling out new products. This may be due, in part, to the fact that the major U.S. commercial aircraft firms do not have a strong position in the marketplace for medium-size commercial airliners that might be converted to transports or tankers. U.S. airlines tend to buy such aircraft from Brazil (Embraer) and Canada (Bombardier) or repurpose larger Boeing aircraft for this purpose. Embraer has made its new KC-390 multi-mission, medium-sized transport a point of emphasis at both the Paris Air Show 2015 and at the Farnborough Air Show 2016. Kawasaki has also recently begun marketing its C-2 mid-size, twin-turbofan engine transport at international arms shows.

The range of U.S. defense exports is also limited by a strategic decision by the U.S. Government to limit the sale of some types of defense products for policy reasons (e.g., desire to restrict the proliferation of defense capabilities that might disturb the strategic military balance in a region). The decision to avoid certain types of weapons risks ceding the market in certain areas to others. The U.S. decision not to sell F-35 fighters in the Middle East leaves a gap in a market that is estimated to be worth \$30.5 billion through 2020 to France’s Rafale, Eurofighter’s Typhoon, and Sweden’s Gripen.¹⁴⁵ China also is trying to get a share of this market. Additionally, the F-22

¹⁴⁴ Daniel Yoon et al. “Dynamics of International Military Modernization 2016,” op. cit.

¹⁴⁵ Ibid.

is on the “no sales” list (Congress is not willing to approve sale to such partners as Japan (Obey amendment)).

Likewise, the American decision not to sell armed UAVs has led to Israeli and Chinese companies moving into the field. Even though Chinese offerings are not as technologically advanced as U.S. analogs, they are “good enough” and sometimes the purchase of even small quantities of such products from China is enough to get the U.S. to make an exception about to whom it is willing to sell such products.

M. “Combat Proven”: A Major Selling Point

Price is an important factor in weapons purchases, but non-economic factors frequently come into play. Offering battle tested, “combat proven” equipment is an important marketing point. As Professor Valery Polovinkin, Honored Scientist of the Russian Federation, explained to reporters from TASS interviewing him about his book entitled *Russian Weapons in Syrian Conflict*, “We realize full well that combat-proven weapons enjoy a higher demand on the international arms market than the ones lacking a combat record do. Everybody wants reliable hardware tested in battle, because they usually pay a lot of money for it.”¹⁴⁶ In a similar vein, the head of the Rosoboronexport delegation to DSA 2016 told reporters from TASS that Russian arms export prospects in the Asia-Pacific region were high because, “Today, it is boosted by the successful use of Russian weapons on large-scale counterterrorist operations. When customers need weapons for something more serious than parades, they turn to us.”¹⁴⁷ *Sputnik News* even went so far as to say that Russia’s air campaign in Syria “has become an advertisement for some of the best weapons in its arsenal.”¹⁴⁸ Russia’s Deputy Defense Minister Yuri Borisov, for example, told TV reporters for channel Russia-24 that foreign states were “are already lining up” to purchase Su-34 and Su-35 aircraft because they had demonstrated their capabilities during military operations in Syria.¹⁴⁹ Another article in *Sputnik News* trumpeted the Gaz-2330 *Tigr* (Tiger) armored all-terrain vehicles as “Well-Proven in Syrian Conflict.”¹⁵⁰

MBDA produces a marketing video entitled “MBDA’s Future Attack Helicopter Weapon builds on the combat proven Brimstone missile” about the Future Attack Helicopter Weapon (FAHW). The lead-in to the video on MBDA’s website says: “MBDA’s proposed FAHW solution

¹⁴⁶ Valery Polovinkin, quoted in “Russia publishes book on role of Russian-made weapons in Syrian Conflict,” TASS, July 11, 2016. Accessed on 14 November 2016 at <http://tass.com/defense/887510>.

¹⁴⁷ Vladimir Yereschenko, quoted in “Russia’s positions on Asia-Pacific arms market,” TASS, April 19, 2016. Accessed on 30 November 2016 at <http://tass.com/defense/870932>.

¹⁴⁸ “Russia Calling the Shots in the Middle Eastern Arms Market,” *Sputnik News*, July 30, 2016. Accessed on 30 November 2016 at <https://sputniknews.com/politics/201607301043792883-russia-syria-arms-middle-east/>.

¹⁴⁹ “Customers ‘Lining Up’ to Buy Russian Su-34, Su-35 Aircraft,” *Sputnik News*, July 12, 2016. Accessed on 14 November 2016 at <https://sputniknews.com/russia/201512071031384963-customers-lining-up-buy-russia-aircraft/>.

¹⁵⁰ “Desert Tiger: Russian-Made Armored Vehicle Well-Proven in Syrian Conflict,” *Sputnik News*, July 13, 2016. Accessed on 14 November 2016 at <https://sputniknews.com/military/201606131041257462-russia-combat-vehicle-syria/>.

builds on the highly acclaimed Brimstone missile (98.7% effectiveness achieved during in-theatre operations) to specifically meet Attack Helicopter requirements by providing the operator with the ability to reliably and simply engage, in both direct and indirect fire modes, a wide range of target types with its multi-effect warhead.”¹⁵¹

Dassault’s successful marketing of the Rafale fighter to India was done under the banner of “Combat Proven.” Dassault advertising emphasized;

*Since 2006, French Air Force and French Navy RAFALE fighters have logged thousands of flying hours in combat in Afghanistan, Libya, Mali, the Central African Republic and Iraq where they have demonstrated a very high level of proficiency and a tangible military value... More recently, French Air Force and French Navy RAFALE fighters have been engaged in the coalition operations over Iraq where they have closely cooperated with allied assets, including US Air Force and US Navy fighters.*¹⁵²

Pierre Bayle, spokesperson for the French Defense Ministry, organized efforts at the Paris Air Show 2015 to introduce the public to French forces and their equipment. Part of his message was that performance of Rafale fighters, Tiger, and NH90 military helicopters, and all the sensors and communications gear, had been proven in real operations. To emphasize this point, he handed out “Combat Proven” stickers.”¹⁵³



Figure 44. Stickers Distributed at Paris Air Show 2015¹⁵⁴

¹⁵¹ “MBDA’s FAWH Builds on the Combat Proven Brimstone Missile,” MBDA Systems website. Accessed on 14 November 2016 at <http://www.mbda-systems.com/fahw-builds-on-the-combat-proven-brimstone-missile/>.

¹⁵² “Combat Proven,” Rafale International. Accessed on 14 November 2016 at <http://rafale.co.in/air-power-unlimited/combat-proven.php>.

¹⁵³ Colin Clark, “France, Eager to Boost Exports, Touts ‘Combat Proven’ Gear,” *Breaking Defense*, June 18, 2015. Accessed on 14 November 2016 at <http://breakingdefense.com/2015/06/france-eager-to-boost-exports-touts-combat-proven-gear/>.

¹⁵⁴ Ibid.

N. Convergence and Intersection of Defense and Security Industries

The international arms market is also growing because global defense and security industry products are converging as the distinction between defense and security products becomes blurred. It is no longer possible to distinguish between the defense and security roles of products in cyber/information domain, new materials, wearable/ flexible electronics, unmanned systems, artificial intelligence, big data analytics, and navigation and communication technologies. Convergence is generating more frequent and intense intersections of these two traditionally distinct and separate industries.

Homeland security and police products are now featured prominently at what were once arms-only exhibitions. Organizers of DSEi 2009, for example, noted that 30% of the exhibitors attending that year focused on security rather than defense technology products and services. Eurosatory 2016 featured six “technology clusters,” one of which was devoted to civil security and emergency response. Civilian security products displayed included armored riot control vehicles, non-lethal systems, sensors, and access control and monitoring devices. The emergence of homeland security products has two important implications. First, nominally civil products can spin onto defense applications (e.g., armored riot control vehicles for military armored personnel carriers). But, more importantly, increased market demand for dual-use technologies (e.g., sensors) creates economies of scale, which in turn drive down unit costs, thereby making products affordable to a wider variety of countries.

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4. Technology and Regional Concerns

The following tables display major defense industrial base end-use sectors reflecting both domestic and export markets. The tables represent sectors where products are sold to both domestic and export markets, as well as to both non-state actors and non-producing defense trade states. The judgements about the selected categories are based on the authors' assessments from attending 90 major international arms exhibitions since 1992. These judgements were equally applied to each region and the criteria were based on what has been observed in production for domestic use and what is offered for export.

Below are some caveats and explanations for the accompanying charts:

- For some categories (UAS for example), the only constraints are policy decisions (which countries are allowed to be customers) and competition – there are many potential suppliers. If they can make it, they are, in principle, exporters.
- Our notion of “exports” uses an industrial age term. Current understanding lags developments in ways; in some sectors (large aircraft, satellites, space launch), the players are consortia, not individual states. For some sectors, services are the high-value-added/high-margin portion of the business. Finally, particularly for expensive major platforms, much of the revenue involves the aftermarket (post-sale servicing, supplies, and upgrades) as opposed to the headline initial sales prices.
- In determining where a product was produced or exported within a consortium, we selected the prime manufacturer, with supporting countries as sub-assemblers (for example, the Airbus 400M military transport, Airbus Helicopters, and European-based MBDA missile products).
- “Exports” include market-related economic activities that are the focus in U.S. discussion of the topic, plus other kinds of transfers by non-market states. In some instances, terms are concessionary. At the limit, some “exports” involve donations in support of foreign policy objectives or what others might characterize as smuggling.

Software is increasingly important (and a larger fraction of total cost). Some of the most significant challenges for both U.S. and foreign 5th generation fighter development have involved software. Software sometimes has an elusive character, comprising a mix of products and services that is difficult to disentangle. Traditional thinking about exports tends to focus on finished large military systems, not services.

Some specific country insights noted in the charts include:

- Canada’s defense firms (and industry, generally) are linked to those of the U.S. in unique and complex ways. A number of U.S. export controls are automatically waived for Canada. In some instances, Canadian firms are integral to what might be perceived as “American” supply chains.
- Japanese defense products were cleared by the Japanese government for export only two years ago.
- Russia has demonstrated a willingness to co-produce with other countries (for example, the Chiron MANPADS using 9K338 Igla-S (SA-24 Grinch) technologies coproduced by South Korea and the Bazalt designed RPG-32, which is coproduced in Jordan).
- Iran is banned from exporting military equipment, per UN Security Council Resolution (UNSCR) but does export to those it wishes to support (i.e., Sudan, Hezbollah in Lebanon, Hamas in Gaza, and Houthis in Yemen).

The key for the accompanying tables, following major defense industrial base end-use sectors broken out by similar regions of the world and covering the major arms producers and exporters in selected categories, is below:

KEY	
On-going Programs / Export Presences	
Domestic R&D Program Effort / Some Export Presence	
No Programs / No Export Presences	
Among world leaders in this area	
Licensed production or in-country division/subsidiary of a multi-national conglomerate	

Table 31. Major Defense Industrial Base End-use Sectors for Canada and Brazil

Major Defense Industrial Base End-Use Sectors	Canada 		Brazil 	
Information Systems	Domestic	Export	Domestic	Export
Command and Control Systems				
Electronic Warfare				
Cybersecurity				
Space	Domestic	Export	Domestic	Export
Satellite Launch Vehicles				
Military Satellites				
Commercial Space				
High-speed/Hypersonic Technologies				
Aerospace Weapon Systems	Domestic	Export	Domestic	Export
Fighter Aircraft				
Training Aircraft				
Airborne Early Warning Aircraft				
Tanker Aircraft				
Maritime Patrol Aircraft (MPA)				
Transport Aircraft				
Military Aircraft Engines				
Military Attack Helicopters				
Military Transport Helicopters				
Military Helicopter Engines				
Radars and Sensors				
Avionics				
Aerospace Low Observability Technology				
Cruise Missiles				
Long-Range Air-to-Air Missiles (0-100 miles)				
Short-Range Air-to-Air Missiles (0-22 miles)				
Precision Guided Munitions (PGM)				
Simulation for Aviation Systems				

Naval Weapon Systems	Domestic	Export	Domestic	Export
Aircraft Carriers				
Landing Helicopter Dock Platforms				
Resupply Ships				
Destroyers-class Ships				
Frigate-class Ships				
Corvette-class Ships				
Patrol Craft and Mine Countermeasures Vessels				
Landing Ships				
Arctic Patrol Vessels				
Nuclear Attack Submarines (SSN)				
Diesel Attack Submarines (SSK)				
Maritime Air Defense				
Maritime Radars				
Maritime Propulsion				
Maritime Low Observability Technology				
Simulation for Naval Systems				
Ground Force Weapon Systems	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)				
Infantry/Armored Fighting Vehicles (Tracked)				
Infantry/Armored Fighting Vehicles (Wheeled)				
Engines/Powerpacks for Ground Combat Systems				
Multiple Launch Rocket Systems (MLRS)				
Self-propelled Artillery				
Towed Artillery				
Ground Vehicle Low Observability Technology				
Anti-tank Guided Missiles (ATGM)				
Future Soldier Systems				
Simulation for Ground Systems				

Air Defense	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)				
Medium-Range Air Defense (3-40 miles)				
Short-Range Air Defense (0-3 miles)				
Military Unmanned Systems	Domestic	Export	Domestic	Export
Autonomous Systems				
Robotic Systems				
Unmanned Aerial Systems (UAS)				
Unmanned Combat Aerial Vehicle (UCAV)				
Unmanned Surface Vehicles (USV)				
Unmanned Submersible Vehicles (USV)				
EOD Unmanned Ground Vehicles (UGV)				
Reconnaissance UGVs				
Combat UGVs				
Engineering UGVs				
Logistics UGVs				
Simulation for Unmanned Systems				
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities				

Table 32. Major Defense Industrial Base End-use Sectors for United Kingdom, France, Germany, and Spain

Major Defense Industrial Base End-Use Sectors	United Kingdom		France		Germany		Spain	
	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Information Systems								
Command and Control Systems	★		★		★			
Electronic Warfare								
Cybersecurity								
Space								
Satellite Launch Vehicles			★					
Military Satellites			★					
Commercial Space			★					
High-speed/Hypersonic Technologies			★					
Aerospace Weapon Systems								
Fighter Aircraft	★		★					
Training Aircraft	★							
Airborne Early Warning Aircraft								
Tanker Aircraft			★					
Maritime Patrol Aircraft (MPA)								
Transport Aircraft			★					
Military Aircraft Engines			★					
Military Attack Helicopters			★					
Military Transport Helicopters			★					
Military Helicopter Engines			★					
Radars and Sensors	★		★					
Avionics			★					
Aerospace Low Observability Technology			★					
Cruise Missiles			★		★			
Long-Range Air-to-Air Missiles (0-100 miles)	★		★					
Short-Range Air-to-Air Missiles (0-22 miles)	★		★		★			
Precision Guided Munitions (PGM)	★		★					
Simulation for Aviation Systems								
Naval Weapon Systems								
Aircraft Carriers	★		★					
Landing Helicopter Dock Platforms	★		★				★	
Resupply Ships								
Destroyers-class Ships	★		★					
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels	★				★			
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)	★		★					
Diesel Attack Submarines (SSK)			★					
Maritime Air Defense			★					
Maritime Radars			★					
Maritime Propulsion	★				★			
Maritime Low Observability Technology	★		★					
Simulation for Naval Systems	★		★		★			

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)	★		★		★			
Infantry/Armored Fighting Vehicles (Tracked)	★				★			
Infantry/Armored Fighting Vehicles (Wheeled)			★		★			
Engines/Powerpacks for Ground Combat Systems	★		★		★			
Multiple Launch Rocket Systems (MLRS)								
Self-propelled Artillery					★			
Towed Artillery	★		★					
Ground Vehicle Low Observability Technology	★							
Anti-tank Guided Missiles (ATGM)			★		★			
Future Soldier Systems			★		★			
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)			★		★			
Medium-Range Air Defense (3-40 miles)	★		★					
Short-Range Air Defense (0-3 miles)	★		★					
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems	★		★					
Robotic Systems	★		★					
Unmanned Aerial Systems (UAS)			★					
Unmanned Combat Aerial Vehicle (UCAV)			★					
Unmanned Surface Vehicles (USV)	★							
Unmanned Submersible Vehicles (USV)	★							
EOD Unmanned Ground Vehicles (UGV)	★							
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities	★				★			

Table 33. Major Defense Industrial Base End-use Sectors for Italy, Sweden, and Switzerland

Major Defense Industrial Base End-Use Sectors	Italy 		Netherlands 		Sweden 		Switzerland 	
	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Information Systems								
Command and Control Systems	★		★		★			
Electronic Warfare	★				★			
Cybersecurity	★						★	
Space								
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems								
Fighter Aircraft					★			
Training Aircraft	★							
Airborne Early Warning Aircraft					★			
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)					★			
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters	★							
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors	★				★			
Avionics					★			
Aerospace Low Observability Technology					★			
Cruise Missiles					★			
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems					★			
Naval Weapon Systems								
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships	★		★					
Corvette-class Ships					★			
Patrol Craft and Mine Countermeasures Vessels			★		★			
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology					★			
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)								
Infantry/Armored Fighting Vehicles (Tracked)								
Infantry/Armored Fighting Vehicles (Wheeled)								
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)								
Self-propelled Artillery								
Towed Artillery								
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)								
Future Soldier Systems								
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)								
Medium-Range Air Defense (3-40 miles)								
Short-Range Air Defense (0-3 miles)								
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems								
Robotic Systems								
Unmanned Aerial Systems (UAS)								
Unmanned Combat Aerial Vehicle (UCAV)								
Unmanned Surface Vehicles (USV)								
Unmanned Submersible Vehicles (USV)								
EOD Unmanned Ground Vehicles (UGV)								
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities								

Table 34. Major Defense Industrial Base End-use Sectors for Turkey, Poland, Czech Republic, and Bulgaria

Major Defense Industrial Base End-Use Sectors	Turkey 		Poland 		Czech Republic 		Bulgaria 	
Information Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems								
Electronic Warfare								
Cybersecurity								
Space								
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems								
Fighter Aircraft								
Training Aircraft								
Airborne Early Warning Aircraft								
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)								
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters								
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors								
Avionics								
Aerospace Low Observability Technology								
Cruise Missiles								
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems								
Naval Weapon Systems								
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels								
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology								
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)								
Infantry/Armored Fighting Vehicles (Tracked)								
Infantry/Armored Fighting Vehicles (Wheeled)								
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)								
Self-propelled Artillery								
Towed Artillery								
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)								
Future Soldier Systems								
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)								
Medium-Range Air Defense (3-40 miles)								
Short-Range Air Defense (0-3 miles)								
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems								
Robotic Systems								
Unmanned Aerial Systems (UAS)								
Unmanned Combat Aerial Vehicle (UCAV)								
Unmanned Surface Vehicles (USV)								
Unmanned Submersible Vehicles (USV)								
EOD Unmanned Ground Vehicles (UGV)								
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities								

Table 35. Major Defense Industrial Base End-use Sectors for Norway, Finland, Greece, and Serbia

Major Defense Industrial Base End-Use Sectors	Norway 		Finland 		Greece 		Serbia 	
Information Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems								
Electronic Warfare								
Cybersecurity								
Space	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Fighter Aircraft								
Training Aircraft								
Airborne Early Warning Aircraft								
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)								
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters								
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors								
Avionics								
Aerospace Low Observability Technology								
Cruise Missiles								
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems								
Naval Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels								
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology								
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)								
Infantry/Armored Fighting Vehicles (Tracked)								
Infantry/Armored Fighting Vehicles (Wheeled)								
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)								
Self-propelled Artillery								
Towed Artillery								
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)								
Future Soldier Systems								
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)								
Medium-Range Air Defense (3-40 miles)								
Short-Range Air Defense (0-3 miles)								
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems								
Robotic Systems								
Unmanned Aerial Systems (UAS)								
Unmanned Combat Aerial Vehicle (UCAV)								
Unmanned Surface Vehicles (USV)								
Unmanned Submersible Vehicles (USV)								
EOD Unmanned Ground Vehicles (UGV)								
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities								

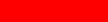
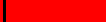
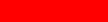
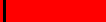
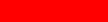
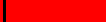
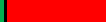
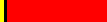
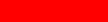
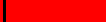
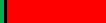
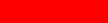
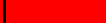
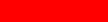
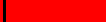
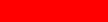
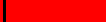
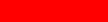
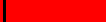
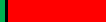
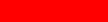
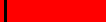
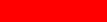
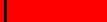
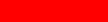
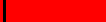
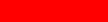
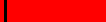
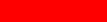
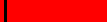
Table 36. Major Defense Industrial Base End-use Sectors for Russia, Ukraine, and Belarus

Major Defense Industrial Base End-Use Sectors		Russia 		Ukraine 		Belarus 	
Information Systems		Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems		★		★		★	
Electronic Warfare		★				★	
Cybersecurity							
Space		Domestic	Export	Domestic	Export	Domestic	Export
Satellite Launch Vehicles		★		★			
Military Satellites		★					
Commercial Space		★					
High-speed/Hypersonic Technologies		★					
Aerospace Weapon Systems		Domestic	Export	Domestic	Export	Domestic	Export
Fighter Aircraft		★					
Training Aircraft							
Airborne Early Warning Aircraft		★					
Tanker Aircraft							
Maritime Patrol Aircraft (MPA)				★			
Transport Aircraft				★			
Military Aircraft Engines		★		★			
Military Attack Helicopters		★					
Military Transport Helicopters		★					
Military Helicopter Engines				★			
Radars and Sensors		★					
Avionics							
Aerospace Low Observability Technology		★					
Cruise Missiles		★					
Long-Range Air-to-Air Missiles (0-100 miles)		★					
Short-Range Air-to-Air Missiles (0-22 miles)		★		★			
Precision Guided Munitions (PGM)							
Simulation for Aviation Systems		★					

Naval Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export
Aircraft Carriers						
Landing Helicopter Dock Platforms						
Resupply Ships						
Destroyers-class Ships						
Frigate-class Ships	★					
Corvette-class Ships	★					
Patrol Craft and Mine Countermeasures Vessels						
Landing Ships						
Arctic Patrol Vessels	★					
Nuclear Attack Submarines (SSN)	★					
Diesel Attack Submarines (SSK)	★					
Maritime Air Defense	★					
Maritime Radars	★					
Maritime Propulsion			★			
Maritime Low Observability Technology						
Simulation for Naval Systems	★					
Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)	★		★			
Infantry/Armored Fighting Vehicles (Tracked)	★		★			
Infantry/Armored Fighting Vehicles (Wheeled)	★		★			
Engines/Powerpacks for Ground Combat Systems	★		★			
Multiple Launch Rocket Systems (MLRS)	★					
Self-propelled Artillery	★					
Towed Artillery	★					
Ground Vehicle Low Observability Technology	★					
Anti-tank Guided Missiles (ATGM)	★		★			
Future Soldier Systems						
Simulation for Ground Systems					★	
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)	★					
Medium-Range Air Defense (3-40 miles)	★					
Short-Range Air Defense (0-3 miles)	★					

Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems						
Robotic Systems						
Unmanned Aerial Systems (UAS)						
Unmanned Combat Aerial Vehicle (UCAV)						
Unmanned Surface Vehicles (USV)						
Unmanned Submersible Vehicles (USV)						
EOD Unmanned Ground Vehicles (UGV)						
Reconnaissance UGVs						
Combat UGVs						
Engineering UGVs						
Logistics UGVs						
Simulation for Unmanned Systems						
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities						

Table 37. Major Defense Industrial Base End-use Sectors for China, Japan, South Korea, and Australia

Major Defense Industrial Base End-Use Sectors	China 		Japan* 		South Korea 		Australia 	
Information Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems								
Electronic Warfare								
Cybersecurity								
Space	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Fighter Aircraft								
Training Aircraft								
Airborne Early Warning Aircraft								
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)								
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters								
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors								
Avionics								
Aerospace Low Observability Technology								
Cruise Missiles								
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems								
Naval Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels								
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology								
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)	★				★			
Infantry/Armored Fighting Vehicles (Tracked)								
Infantry/Armored Fighting Vehicles (Wheeled)								
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)	★				★			
Self-propelled Artillery	★				★			
Towed Artillery								
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)	★							
Future Soldier Systems								
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)								
Medium-Range Air Defense (3-40 miles)	★							
Short-Range Air Defense (0-3 miles)	★							
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems			★		★			
Robotic Systems			★		★			
Unmanned Aerial Systems (UAS)								
Unmanned Combat Aerial Vehicle (UCAV)			Due to policy and acquisition decisions-if Japan wanted to enter these markets, it could and would be a formidable competitor					
Unmanned Surface Vehicles (USV)								
Unmanned Submersible Vehicles (USV)								
EOD Unmanned Ground Vehicles (UGV)								
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities								

Table 38. Major Defense Industrial Base End-use Sectors for Thailand, Indonesia, Singapore, and Malaysia

Major Defense Industrial Base End-Use Sectors	Thailand 		Indonesia 		Singapore 		Malaysia 	
Information Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems								
Electronic Warfare								
Cybersecurity								
Space	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Fighter Aircraft								
Training Aircraft								
Airborne Early Warning Aircraft								
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)								
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters								
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors								
Avionics								
Aerospace Low Observability Technology								
Cruise Missiles								
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems								
Naval Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels								
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology								
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)								
Infantry/Armored Fighting Vehicles (Tracked)						*		
Infantry/Armored Fighting Vehicles (Wheeled)						*		
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)								
Self-propelled Artillery						*		
Towed Artillery						*		
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)								
Future Soldier Systems						*		
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)								
Medium-Range Air Defense (3-40 miles)								
Short-Range Air Defense (0-3 miles)								
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems								
Robotic Systems								
Unmanned Aerial Systems (UAS)								
Unmanned Combat Aerial Vehicle (UCAV)								
Unmanned Surface Vehicles (USV)								
Unmanned Submersible Vehicles (USV)								
EOD Unmanned Ground Vehicles (UGV)								
Reconnaissance UGVs								
Combat UGVs								
Engineering UGVs								
Logistics UGVs								
Simulation for Unmanned Systems								
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities								

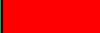
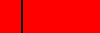
Table 39. Major Defense Industrial Base End-use Sectors for India and Pakistan

Major Defense Industrial Base End-Use Sectors 		India 		Pakistan 	
Information Systems		Domestic	Export	Domestic	Export
Command and Control Systems					
Electronic Warfare					
Cybersecurity					
Space		Domestic	Export	Domestic	Export
Satellite Launch Vehicles					
Military Satellites					
Commercial Space					
High-speed/Hypersonic Technologies					
Aerospace Weapon Systems		Domestic	Export	Domestic	Export
Fighter Aircraft					
Training Aircraft					
Airborne Early Warning Aircraft					
Tanker Aircraft					
Maritime Patrol Aircraft (MPA)					
Transport Aircraft					
Military Aircraft Engines					
Military Attack Helicopters					
Military Transport Helicopters					
Military Helicopter Engines					
Radars and Sensors					
Avionics					
Aerospace Low Observability Technology					
Cruise Missiles					
Long-Range Air-to-Air Missiles (0-100 miles)					
Short-Range Air-to-Air Missiles (0-22 miles)					
Precision Guided Munitions (PGM)					
Simulation for Aviation Systems					

Naval Weapon Systems	Domestic	Export	Domestic	Export
Aircraft Carriers				
Landing Helicopter Dock Platforms				
Resupply Ships				
Destroyers-class Ships				
Frigate-class Ships				
Corvette-class Ships				
Patrol Craft and Mine Countermeasures Vessels				
Landing Ships				
Arctic Patrol Vessels				
Nuclear Attack Submarines (SSN)				
Diesel Attack Submarines (SSK)				
Maritime Air Defense				
Maritime Radars				
Maritime Propulsion				
Maritime Low Observability Technology				
Simulation for Naval Systems				
Ground Force Weapon Systems	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)				
Infantry/Armored Fighting Vehicles (Tracked)				
Infantry/Armored Fighting Vehicles (Wheeled)				
Engines/Powerpacks for Ground Combat Systems				
Multiple Launch Rocket Systems (MLRS)				
Self-propelled Artillery				
Towed Artillery				
Ground Vehicle Low Observability Technology				
Anti-tank Guided Missiles (ATGM)				
Future Soldier Systems				
Simulation for Ground Systems				

Air Defense	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)				
Medium-Range Air Defense (3-40 miles)				
Short-Range Air Defense (0-3 miles)				
Military Unmanned Systems	Domestic	Export	Domestic	Export
Autonomous Systems				
Robotic Systems				
Unmanned Aerial Systems (UAS)				
Unmanned Combat Aerial Vehicle (UCAV)				
Unmanned Surface Vehicles (USV)				
Unmanned Submersible Vehicles (USV)				
EOD Unmanned Ground Vehicles (UGV)				
Reconnaissance UGVs				
Combat UGVs				
Engineering UGVs				
Logistics UGVs				
Simulation for Unmanned Systems				
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities				

Table 40. Major Defense Industrial Base End-use Sectors for Israel, Saudi Arabia, United Arab Emirates, and Iran

Major Defense Industrial Base End-Use Sectors	Israel 		Saudi Arabia 		United Arab Emirates 		Iran* 	
Information Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Command and Control Systems								
Electronic Warfare								
Cybersecurity								
Space	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Satellite Launch Vehicles								
Military Satellites								
Commercial Space								
High-speed/Hypersonic Technologies								
Aerospace Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Fighter Aircraft								
Training Aircraft								
Airborne Early Warning Aircraft								
Tanker Aircraft								
Maritime Patrol Aircraft (MPA)								
Transport Aircraft								
Military Aircraft Engines								
Military Attack Helicopters								
Military Transport Helicopters								
Military Helicopter Engines								
Radars and Sensors								
Avionics								
Aerospace Low Observability Technology								
Cruise Missiles								
Long-Range Air-to-Air Missiles (0-100 miles)								
Short-Range Air-to-Air Missiles (0-22 miles)								
Precision Guided Munitions (PGM)								
Simulation for Aviation Systems								
Naval Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Aircraft Carriers								
Landing Helicopter Dock Platforms								
Resupply Ships								
Destroyers-class Ships								
Frigate-class Ships								
Corvette-class Ships								
Patrol Craft and Mine Countermeasures Vessels								
Landing Ships								
Arctic Patrol Vessels								
Nuclear Attack Submarines (SSN)								
Diesel Attack Submarines (SSK)								
Maritime Air Defense								
Maritime Radars								
Maritime Propulsion								
Maritime Low Observability Technology								
Simulation for Naval Systems								

Ground Force Weapon Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)	★							
Infantry/Armored Fighting Vehicles (Tracked)	★							
Infantry/Armored Fighting Vehicles (Wheeled)								
Engines/Powerpacks for Ground Combat Systems								
Multiple Launch Rocket Systems (MLRS)	★							
Self-propelled Artillery								
Towed Artillery	★							
Ground Vehicle Low Observability Technology								
Anti-tank Guided Missiles (ATGM)	★							
Future Soldier Systems	★							
Simulation for Ground Systems								
Air Defense	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)	★							
Medium-Range Air Defense (3-40 miles)								
Short-Range Air Defense (0-3 miles)								
Military Unmanned Systems	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
Autonomous Systems	★							
Robotic Systems	★							
Unmanned Aerial Systems (UAS)	★							
Unmanned Combat Aerial Vehicle (UCAV)	★							
Unmanned Surface Vehicles (USV)	★							
Unmanned Submersible Vehicles (USV)	★							
EOD Unmanned Ground Vehicles (UGV)	★							
Reconnaissance UGVs	★							
Combat UGVs	★							
Engineering UGVs	★							
Logistics UGVs	★							
Simulation for Unmanned Systems	★							
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities	★							

Table 41. Major Defense Industrial Base End-use Sectors for South Africa and Sudan

Major Defense Industrial Base End-Use Sectors 	South Africa 		Sudan 	
Information Systems	Domestic	Export	Domestic	Export
Command and Control Systems				
Electronic Warfare				
Cybersecurity				
Space	Domestic	Export	Domestic	Export
Satellite Launch Vehicles				
Military Satellites				
Commercial Space				
High-speed/Hypersonic Technologies				
Aerospace Weapon Systems	Domestic	Export	Domestic	Export
Fighter Aircraft				
Training Aircraft				
Airborne Early Warning Aircraft				
Tanker Aircraft				
Maritime Patrol Aircraft (MPA)				
Transport Aircraft				
Military Aircraft Engines				
Military Attack Helicopters				
Military Transport Helicopters				
Military Helicopter Engines				
Radars and Sensors				
Avionics				
Aerospace Low Observability Technology				
Cruise Missiles				
Long-Range Air-to-Air Missiles (0-100 miles)				
Short-Range Air-to-Air Missiles (0-22 miles)				
Precision Guided Munitions (PGM)				
Simulation for Aviation Systems				

Naval Weapon Systems	Domestic	Export	Domestic	Export
Aircraft Carriers				
Landing Helicopter Dock Platforms				
Resupply Ships				
Destroyers-class Ships				
Frigate-class Ships				
Corvette-class Ships				
Patrol Craft and Mine Countermeasures Vessels				
Landing Ships				
Arctic Patrol Vessels				
Nuclear Attack Submarines (SSN)				
Diesel Attack Submarines (SSK)				
Maritime Air Defense				
Maritime Radars				
Maritime Propulsion				
Maritime Low Observability Technology				
Simulation for Naval Systems				
Ground Force Weapon Systems	Domestic	Export	Domestic	Export
Main Battle Tanks (MBT)				
Infantry/Armored Fighting Vehicles (Tracked)				
Infantry/Armored Fighting Vehicles (Wheeled)	★			
Engines/Powerpacks for Ground Combat Systems				
Multiple Launch Rocket Systems (MLRS)				
Self-propelled Artillery	★			
Towed Artillery	★			
Ground Vehicle Low Observability Technology				
Anti-tank Guided Missiles (ATGM)	★			
Future Soldier Systems				
Simulation for Ground Systems				

Air Defense	Domestic	Export	Domestic	Export
Long-Range Air Defense (40-250 miles)				
Medium-Range Air Defense (3-40 miles)				
Short-Range Air Defense (0-3 miles)				
Military Unmanned Systems	Domestic	Export	Domestic	Export
Autonomous Systems				
Robotic Systems				
Unmanned Aerial Systems (UAS)				
Unmanned Combat Aerial Vehicle (UCAV)				
Unmanned Surface Vehicles (USV)				
Unmanned Submersible Vehicles (USV)				
EOD Unmanned Ground Vehicles (UGV)				
Reconnaissance UGVs				
Combat UGVs				
Engineering UGVs				
Logistics UGVs				
Simulation for Unmanned Systems				
Chemical, Biological, Nuclear and Radiological (CBRN) Countermeasures	Domestic	Export	Domestic	Export
CBRN Countermeasures Capabilities				

5. Observed Arms Market Trends

The following discussion takes a look at several major technology themes associated with the radical changes that have reshaped the international conventional arms market over the past 20 years. Each technology trend is identified, described, and in many cases illustrated with specific examples drawn from the international arms market.

A. The Main Battle Tank Is Not Dead Yet

Are MBTs obsolete? This question has waxed and waned over the last 40 years. Arguments against the continuing utility of tanks include their vulnerability to ATGMs, difficulty in operating in urban environments, and inappropriateness as tools in peacekeeping and/or counter-insurgent operations. Some European militaries believed that the possibility of major land battles in Europe was a thing of the past, so large numbers of MBTs were no longer required. The German *Bundeswehr* fielded over 2,100 Leopard 2 MTBs in various versions, but sold off many of them following German reunification in 1990 and the subsequent collapse of the Soviet Union. The *Bundeswehr* sold off 298 of its Leopard 2A4 MBTs to Turkey in November 2005 and another 140 Leopard 2A4s to Chile in March 2006. Greece also purchased 333 used MBTs from *Bundeswehr* reserves in 2005: 183 Leopard 2A4s and 150 Leopard 1A5s.

MBT development at the platform level was virtually non-existent since the collapse of the Soviet Union. The only new MBT to enter service during that period was the French Leclerc in 1992. Other marquee name brands like Leopard, Challenger, Abrams, Russian T-series, and even the Israel Merkava saw only evolutionary improvement at the platform level and/or improvements via add-on (e.g., active protection systems). However, what constitutes “evolutionary” versus “fundamental” may be in the eye of the beholder; some would argue, for instance, that the Abrams modifications through the M1A2 SEP v.3 have been significant in terms of improved military capabilities.

That situation has changed. French, German, and Russian tank builders are now engaged in developing next generation MBTs with characteristics that go well beyond product upgrades, even major capability upgrades. The situation with respect to U.S. tanks and armored combat vehicles is quite different. Lieutenant General H.R. McMaster Jr. (Director, Army Capabilities Integration Center and Deputy Commanding General, Futures, U.S. Army Training and Doctrine Command) noted in a recent speech before The Association of the United States Army’s Institute of Land Warfare that the U.S. Army does not have a new ground combat vehicle under development for the first time since World War I. He went on to say that at “at current funding levels, the Bradley and Abrams will remain in the inventory for 50 to 70 more years.”¹⁵⁵ Furthermore, Lt. Gen.

¹⁵⁵ Remarks by Lt. Gen. H.R. McMaster, Jr., quoted by David Vergun, in “4 Myths about combat vehicles, debunked by Lt. Gen. McMaster,” Army News Service, November 2, 2016. Accessed on 25 January 2017 at https://www.army.mil/article/177652/4_myths_about_combat_vehicles_debunked_by_lt_gen_mcmaster.

McMaster observed, “our enemies, and even our friends and allies, have not remained static.”¹⁵⁶ He specifically called out the German Puma infantry fighting vehicle, Swedish Combat Vehicle 90 (CV-90), the six-variant British Ajax family of future armored fighting vehicles, and the new technologies being integrated into the Russian Armata family of armored vehicles as examples of this trend.

A January 2017 study from the Congressional Research Service makes similar observations at the component level:

*In terms of fire control systems, while once a U.S. comparative advantage, most tanks now employ some form of Forward Looking Infrared Radar (FLIR) as well as Global Positioning Systems (GPS) and thermal and night vision technology, thereby, to a certain extent, “leveling the playing field” with the U.S. M-1A2 Abrams tank.”*¹⁵⁷

Some observers disagree. They argue that the Abrams M1A2 SEP v.3 offers significantly improved capabilities that make this model a virtual next generation vehicle. The question is, will potential buyers perceive these upgrades as equivalent to emerging foreign next generation MBTs?

A life size model of the Leclerc XLR Main Battle Tank (a.k.a.: Renovated Leclerc) was shown at Eurosatory 2016. Leclerc XLR is modernized variation of the Leclerc Main Battle Tank. The project with Nexter Systems has three main objectives: (1) integrate and network Leclerc into “Scorpion” joint tactical groups by virtue of the new CONTACT tactical radio and SCORPION information and command system, (2) adapt it for operations in urban environments with upgraded protection against rocket-propelled grenades and IEDs, and (3) improve its attack capabilities with the new Nexter Munitions high-explosive round currently under development. The first two prototypes will be delivered in 2018 and will be directly followed by the notification of production tranches. Current plans call for delivery of 200 Leclerc XLR MBTs between 2020 and 2028. The intention is to give French land forces “first entry” capability as part of an international coalition to 2040 and beyond.

Rheinmetall now has a marketing briefing that outlines its medium-term and long-term concepts for significant MBT modernization. Medium-term upgrades include: (1) a new high-pressure 120mm main gun and ammunitions that Rheinmetall claims will result in a 20% increase in performance, (2) active defense system, and (3) digital turret core system. Long-term improvements include a new 130mm caliber main gun, which is expected to increase performance (penetration, effectiveness) by 50%. Rheinmetall displayed its MBT Advanced Technology Demonstrator at Eurosatory 2016. It is a test bed for exploring the many ways of enhancing the combat performance and operational effectiveness of main battle tanks.

¹⁵⁶ Ibid.

¹⁵⁷ Andrew Feickert, “Selected Foreign Counterparts of the U.S. Army Ground Combat Systems and Implications for Combat Operations and Modernization,” Congressional Research Service, January 18, 2017. Accessed on 25 January 2017 at http://www.stripes.com/polopoly_fs/1.450622.1485284337!/menu/standard/file/R44741.pdf.

Russia is developing its new next generation T-14 MBT based on the modular Armata Universal Combat Platform, which is also being used as a base for other types of armored vehicles. The Armata T-14 has been described as a groundbreaking design for the Russians because it has a remote-controlled turret and an internal capsule for the crew that is isolated from ammunition and fuel, a layout that could significantly increase the chances for the crew survival if the tank is hit. According to a pre-Russian Arms Expo 2015 release by TASS, the new Armata T-14 tanks:

*“have received unmanned turrets, all digital control and isolated armored crew capsules. The key armament of Armata is a 125mm gun, but the use of a 152mm gun is not ruled out in the future.”*¹⁵⁸

Likewise, an article in *Sputnik News* claimed: “Uralvagonzavod engineers intend to outfit the Armata platform with a 152mm cannon to create a new heavy assault armored vehicle dubbed “the Tank Killer.”¹⁵⁹ Other features of the Armata T-14 tank include: (1) multiple high-resolution cameras that function as gun sights and viewing slits for the crew, (2) a 65-ton chassis, and (3) an engine, that according to the General Director of Uralvagonzavod, increases power by 300 horsepower. The silhouette of the Armata T-14 is also noticeably higher than the current generation T-90 main battle tank. Andrei Leonidovich Terlikov, Chief Designer of the Armata T-14, claims that the tank is a “decisive step towards more advanced unmanned machines, including those that can operate autonomously in combat – a new technology built into Armata can make it possible in future to build fully robotic vehicles.”¹⁶⁰ A prototype of the T-14 has already been displayed during Russia’s World War II Victory Parade and at Russian Arms Expo 2015.

The U.S. and China, the other two major battle tank-building nations, have so far shown no indications of having next generation tank programs directed at international markets. They instead emphasize incremental improvements to existing designs. China is aggressively marketing those incrementally improved models at arms exhibitions, whereas the U.S. efforts at arms shows have practically ceased in recent years (e.g., no Abrams tank has been exhibited at the past two IDEX or Eurosatory shows (places where it frequently appeared in the past)).

¹⁵⁸ “Russia’s newest Armata tank to be on display at RAE-2015 expo in Nizhny Tagil,” TASS, July 27, 2015. Accessed on 20 January 2016 at <http://tass.ru/en/russia/810910>.

¹⁵⁹ “Tank Killer: New Armata Gets Really Big Gun,” *Sputnik News*, November 17, 2015. Accessed on 20 January 2016 at <http://sputniknews.com/military/20151117/1030258753/prototype-armata-gun.html>.

¹⁶⁰ Chief Designer Andrei Leonidovich Terlikov, as quoted by Richard O. Lindstrom, “T-14 Armata MBT,” September 28, 2015. Accessed on 20 January 2016 at http://www.ointres.se/t-14_armata_mbt.htm.



Figure 45. Russia's Uralvagonzavod Prototype T-14 Armata Main Battle Tank on Display at RAE 2015

B. Heavy Urban Combat Vehicles – A Market That Never Materialized

Lessons drawn from the experiences of Israeli armored forces in Lebanon in 1982 and from Russia's 1995 heavy loss of tanks and armored vehicles in Grozny led some to see a need for heavy tracked armored vehicles that could operate in urban environments heavily infested with anti-tank weapons. The resultant responses had some common characteristics. They were generally based on modified main battle tank chassis, mounted the engine in the front to increase protection for personnel inside the vehicle from against frontal attack, moved the turret assembly or remote weapon station rearward, and housed troops in the rear of the vehicle with rearward access/egress for protection from enemy fire.

Firms in several countries responded to the perceived market opportunity but enjoyed little success. A few heavy urban combat vehicles were sold to domestic armed forces and virtually none were exported. The lack of export was despite the fact that some of the vehicles were displayed at international arms exhibitions.

Israel responded by developing the *Merkava* family of main battle tanks, *Namer* armored personnel carrier, and *Achzarit* infantry fighting vehicle. Both *Namer* and *Achzarit* designs were modified versions of the *Merkava* main battle tank. *Namer* entered service with the Israel Defense Force (IDF) in limited numbers. Additional vehicles are now being produced at the Joint Systems Manufacturing Center in Lima, Ohio. *Achzarit* was based on Soviet-built T-55 tanks captured during the Arab-Israeli wars. It too was purchased in limited number by the IDF. None of these three vehicles has been successfully exported.

Jordan's King Abdullah Design and Development Bureau has also developed and tried to market heavy tracked urban combat vehicles. The Design Bureau produced the AB14 *Temsah* experimental technology demonstrator heavy armored personnel carrier. It was designed and fabricated to accommodate components from surplus-to-requirements main battle tanks. The front and rear of *Temsah* was reversed, putting the engine in front and troop compartment in the rear. The turret was also removed and rear hatches added. The concept was marketed at IDEX 2001 and DSEi 2003 but never found a buyer. The Multi-Purpose Armored Platform (MAP) and its upgrade the MAP II is a conversion of the Tariq main battle tank, which is an upgraded version of the British Centurion, and the Jordan Armed Forces acquired four of these vehicles in 2014. It has also been displayed at IDEX but so far has not found an export client.

Russia's Uralvagonzavod designed and has extensively marketed the BMPT Terminator at arms exhibitions in Russia and abroad. The BMPT is designed to support tanks and other armored vehicles in urban areas. It is built on a T-72 tank chassis and is armed with four 9M120 Ataka-T ATGMs, two 30mm 2A42 automatic cannons, one PKTM 7.62mm machinegun and two AG-17D 30mm grenade launchers. A small number of BMPT Terminators were delivered to the Russian Army in 2005 but the Russian Army now appears more interested in procuring the T-15 infantry fighting vehicle, which is based on the Armata Universal Combat Chassis. The only known export success of the BMPT Terminator was Kazakhstan.

The Ukraine's Morozov Machine-Building Design Bureau developed the BMP-55 in a private venture and called it a heavy infantry fighting vehicle. Development commenced in 2000 and the vehicle was revealed publicly in 2007. Two years later, Morozov claimed it was ready for production, but received no orders. The BMP-55 is based on refurbished T-55 tank hulls, which have the turrets removed and replaced by a remote weapon station armed with a 12.7 mm machine gun.

Subsequently, another Ukrainian heavy urban combat vehicle called the BMPV-64 was developed as a private venture. The first prototype, completed in 2005, is a conversion of the T-64 main battle tank into a heavy armored personnel carrier. The tank's turret was removed and replaced with a remote weapon station fitted with a 30mm automatic cannon, coaxial 7.62 mm machine gun, and 12.7 mm remote-controlled machine gun. The BMPV-64 was also fitted with Ukrainian *Nozh* explosive reactive armor. As with other heavy urban combat vehicles, the engine is in the front and the troop compartment and exit doors are in the rear. There are no known operators of the BMPV-64.



Figure 46. Russia's Uralvagonzavod BMPT Terminator at the Mobility Display at RAE 2015

C. Shift to Wheeled Armored Vehicles

There has been a transition from tracked to wheeled armored fighting vehicles in the global market since the 1990s.¹⁶¹ A story in *DefenseUpdate* entitled “The Big Wheels are Rolling Again at Eurosatory 2012” emphasized that the trend toward wheeled armored fighting vehicles was continuing, despite them becoming heavier.¹⁶² We have observed the trend continuing at the arms exhibitions we have attended since 2012.

Wheeled armored fighting vehicles offer a number of advantages:

- **Operational Costs:** Wheeled armored vehicles have lower operational costs than tracked vehicles (e.g., a wheeled armored vehicle can go farther on the same amount of fuel).
- **Maintenance Costs:** One of the big advantages of wheeled armored vehicles is they cost less to maintain. Tracks are complex, get caught on things, pins joining track links break, hard use will stretch steel track links slightly, and they are hard to repair and replace. Wheels, on the other hand, have fewer parts to go bad and are easier to replace.
- **Production Costs:** Wheeled vehicles are also less expensive to produce, so vendors can afford to self-finance prototypes targeted at perceived market niches.

¹⁶¹ “Multi role armored vehicle,” GICAT. Accessed on 25 October 2016 at http://www.gicat.com/wp-content/uploads/2015/10/Mrav_GICAT-2016.pdf.

¹⁶² Tamir Eshel, “The Big Wheels are Rolling Again at Eurosatory 2012,” *DefenseUpdate*, June 10, 2012. Accessed on 25 October 2016 at http://defense-update.com/20120610_wheeled_armored_vehicles_eurosatory-2012.html.

- **Operational Advantages:** They perform more freely in urban and “civilized areas” – places where tracked vehicles would heavily damage and destroy the road network. This has become an important consideration as the emphasis on urban and peace support operations has increased over time.¹⁶³ Another advantage is that wheeled armored vehicles are more flexible for ad-hoc reconfiguration, e.g., Nexter’s EVASAN armored medical evacuation vehicle is a variant of its VBCI infantry fighting vehicle. According to Nexter, a standard VBCI can be reconfigured for casualty evacuation or armored ambulance in less than four hours.¹⁶⁴
- **Market Opportunity/Demands:** Other factors also drive increasing demand for wheeled armored platforms. One of those is “large scale modernization initiatives being undertaken by key defense spenders across the world” which market analysts expect “will drive the demand in the 8x8 armored vehicle market over the coming years.”¹⁶⁵ Another factor is the growing internal security market. Wheeled armored vehicles can be used for armored police vehicles, anti-riot, security special forces, and anti-terrorism vehicles, as well as traditional military armored personnel carriers. The second factor may explain why the Chinese in particular are marketing several dozen wheeled armored vehicle products at international arms and police/security equipment exhibitions.



Figure 47. France’s Nexter VBCI Troop Carrier (left) and IFV Version (right) on Display at Eurosatory 2014

¹⁶³ “Tracks or Wheels: Which is Better for Armored Fighting Vehicles?” *U.S. Patriot Tactical*. Accessed on 10 October 2016 at <http://blog.uspatriottactical.com/tracks-or-wheels-which-is-better-for-armored-fighting-vehicles/>.

¹⁶⁴ Tamir Eshel, “The Big Wheels are Rolling Again at Eurosatory 2012,” op. cit.

¹⁶⁵ “The 8x8 Armored Vehicle Market 2016 – Key Drivers, Trends and New Developments – Research and Markets,” *BusinessWire*, August 16, 2016. Accessed on 25 October 2016 at <http://www.businesswire.com/news/home/20160816005584/en/8x8-Armored-Vehicle-Market-2016---Key>.

D. Mine-Resistant Ambush Protected (MRAP) Vehicles

MRAPs are vehicles that usually have V-shaped hulls, raised chassis, and armored bodies with blast resistant underbodies. MRAPs are designed to protect crews from landmines and improvised explosive devices (IEDs) by directing the force of the blast away from the underside of the vehicle. Some are also equipped with signal jammers to block the detonation signals from cellphones and other electronic devices.

The MRAP design was originally developed during the Rhodesian Bush War to counter landmines. Subsequently, the design matured in South Africa's Casspir armored fighting vehicle. For many years, South Africa marketed Casspir as a counter-mine vehicle at international arms shows, even during dynamic demonstrations at several early IDEX exhibitions of a wheel being blown off a Casspir by a landmine and the passengers surviving to replace the damaged wheel in the field. The South Africans had only modest success selling Casspirs as counter-landmine vehicles.

The aggressive IED campaign by insurgents, first in Iraq and later in Afghanistan, led to extensive market demand for MRAP vehicles beginning in the 2004 to 2007 timeframe. Marketing emphasis changed from mine-resistant to IED-resistant. MRAP vehicles have become a prominent feature at international arms exhibitions since 2010. They are offered by companies from Australia, China, France, Germany, Italy, Russia, South Africa, South Korea, Thailand, Turkey, United Kingdom, and U.S.

The sudden appearance and growth of MRAP vehicles demonstrates the ability and willingness of the arms market to respond quickly to urgent niche opportunities that spring up. Profits from the sale of products in short-term opportunity niche markets have provided the capital for entry into or expanded presence in other more traditional markets. An example of this is the Streit Group's sales of MRAPs, which seem to have underwritten the expansion of the Group's portfolio in wheeled armored vehicles. What is not clear, however, is whether the MRAP market (or other short-term opportunity niche markets) can survive beyond the end of the particular circumstances/conflict that led to market demand.



Figure 48. International Constium's Streit Group KrAZ-Hurricane 8 x 8 MRAP at the Mobility Display at IDEX 2017

E. Truck-Mounted Self-Propelled Artillery Systems

Until the early 2000s, artillery systems offered in the international arms market were either towed or mounted on tracked vehicles. That changed in 2003 when the first CAESAR truck-mounted 155mm artillery systems from GIAT were fielded. The first version of CAESAR (*“Camion equipe d’in systeme d’artillerie”* in French, “Truck Equipped with Artillery System” in English) was mounted on a Sherpa 5 6x6 five-ton truck chassis. An 8x8 version appeared at Eurosatory 2014.

The appearance of CAESAR sparked the development of other truck-mounted artillery systems, including: (1) Swedish Archer, (2) South African G6 Rhino, (3) Slovakian Zuzana, (4) Serbian NORA B-52, (5) Israeli ATMOS (Autonomous Truck MOUNTed howitzer System), (6) Chinese 155 mm SH-1, 122 mm SH-2, and lightweight 122 mm SH-4 (7) Czech DANA, and (8) Russian A-222 “Bereg” 130 mm coastal defense gun and Koalition-2 155 mm howitzer concept.



Figure 49. France's Nexter 8 x 8 CAESAR 155 mm Self-Propelled Howitzer on Display at DSEi 2015

F. Tactical Precision for Ballistic Munitions and Countermeasures

Precision-guided munitions appeared in the 1960s, improved in the 1970s, and grabbed the world's attention in the first Gulf War in 1991. Interest in precision-guided munitions continued to grow, with most of the attention being focused on large systems such as bombs, air-to-surface missiles, and cruise missiles.

Over the last decade, however, precision-guidance technologies began to be applied to tactical ballistic munitions like artillery rounds, artillery rockets, and even mortar rounds. Precision-guided tactical ballistic munitions being marketed include:

- **Ukreksport Karasuk 122 mm Semi-Active Laser Guided Artillery Round (Ukraine):** This system was displayed on a placard at Eurosatory 2010, the Karasuk, a semi-active laser-guided artillery round is intended for use either from 122 mm howitzers or as the payload for 122 mm MLRS, such as the BM-21.

- **KBP Design Bureau KM-8 “Gran” Laser Guided Mortar (Russia):** KBP is offering the KM-8 “Gran” laser-guided mortar, which uses a mobile or dismounted fire-control system that supports target illumination and orientation of the firing position.

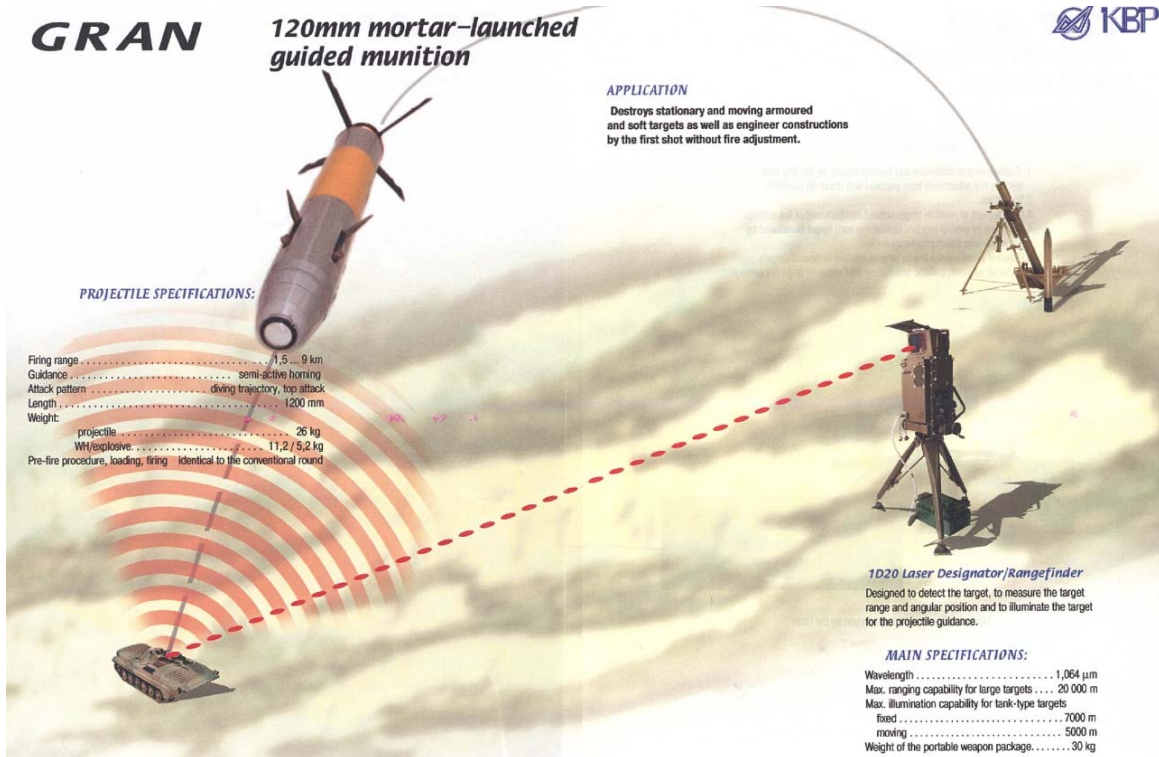


Figure 50. Russia's KBP KM-8 “Gran” Laser-Guided Mortar Operations
Brochure at DSA 2016

- **Israel Military Industries (IMI) ACCULAR Guided MLRS (Israel):** IMI is offering the ACCULAR autonomously guided 160 mm artillery rocket system, which uses an internal GPS Trajectory Correction system and a thruster steering kit to achieve a 10 meter circular error probability (CEP).
- **IMI GMM 120 Guided Mortar Munition (Israel):** IMI is offering the GMM 120 guided mortar in either GPS or laser-guided options. It is equipped with GPS/inertial measurement unit (IMU) and flight control computer (FCC) guidance and navigation system, a canard servo and control mechanism, and a computerized setter. It claims an accuracy of 10 meter CEP.



Figure 51. Israel's IMI GMM 120 Guided Mortar Mmunition Brochure at DSEi 2015

- **NORINCO Laser-Guided Artillery Projectiles (China):** China has marketed two semi-active laser-guided artillery projectiles the GP5 122 mm and the GP6 155 mm, as well as the GP4 120 mm terminally corrected mortar projectile at international arms shows.



Figure 52. China's NORINCO GP5 122mm (left) and GP6 155mm Laser-Home Artillery Weapon Systems Brochures Distributed at Eurosatory 2014

Precision fire now extends down to personal weapons of individual soldiers. According to TASS, Russia's Advanced Research Foundation (ARF) has started testing a "smart bullet" in a guided flight regime that is designed to hit targets up to 10 kilometers away.¹⁶⁶ According to Andrei Ivanovich Grigoriev, General Director of the Foundation:

¹⁶⁶ "Russia launches 'smart bullet' testing in guided flight regime," TASS, July 19, 2016. Accessed on 16 November 2016 at <http://kitup.military.com/2016/07/russians-launch-smart-bullet-effort-in-the-wake-of-u-s-program.html>.

*We are creating in principle a brand new family of bullets, for example, made from two or more metals (in alloy), having special armor-penetrating qualities, as well as long flight. Our scientists are working on intelligent rifle sights, and a whole new sniper's reactive complex, along with smart-guided bullets and lots of other things.*¹⁶⁷

TrackingPoint (U.S. company) also now offers the M1400 rifle with the RapidLok fire control system: (1) connects the tracking optic with a guided trigger, (2) shooter designates an exact target impact point, and (3) tracking system then guides the trigger release.

Inevitably, proliferation of precision-guided tactical ballistic munitions has spawned a market for counter rockets, artillery, and mortar (C-RAM) systems. C-RAM systems are designed to detect and/or destroy incoming artillery, rockets, and mortar rounds in the air before they hit ground targets. Examples C-RAM systems include:

- **ELTA ELM-2138T “Green Rock” (Israel):** “Green Rock” includes dual-band radar, which acquires and tracks trajectories of ballistic munitions. The system then calculates the launching point and predicts impact location. This data is then sent to precision weapons systems for quick response to the threat.
- **Rafael Iron Dome Anti-Rocket System (Israel):** System was designed in 2007 to engage incoming rockets up to 70 kilometers away using truck-mounted EL/M-2084 mobile phased array radar for target identification, engagement tracking, and engagement assessment; a truck-mounted command; a control shelter; and 20 Tamir launch cells and a generator.

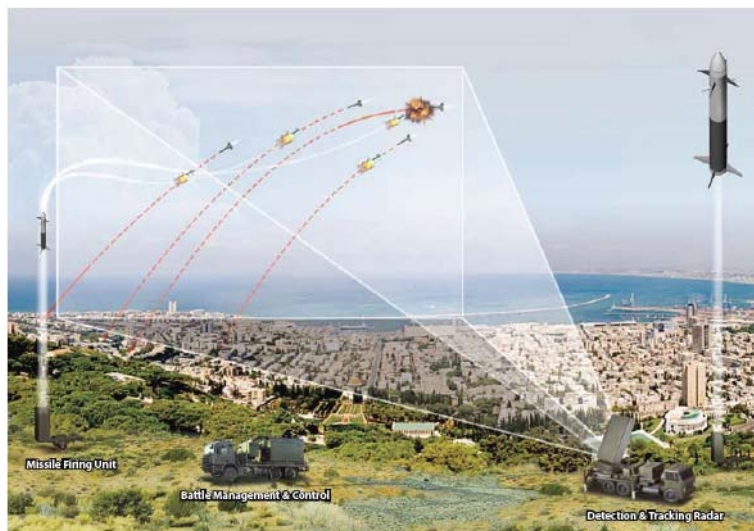
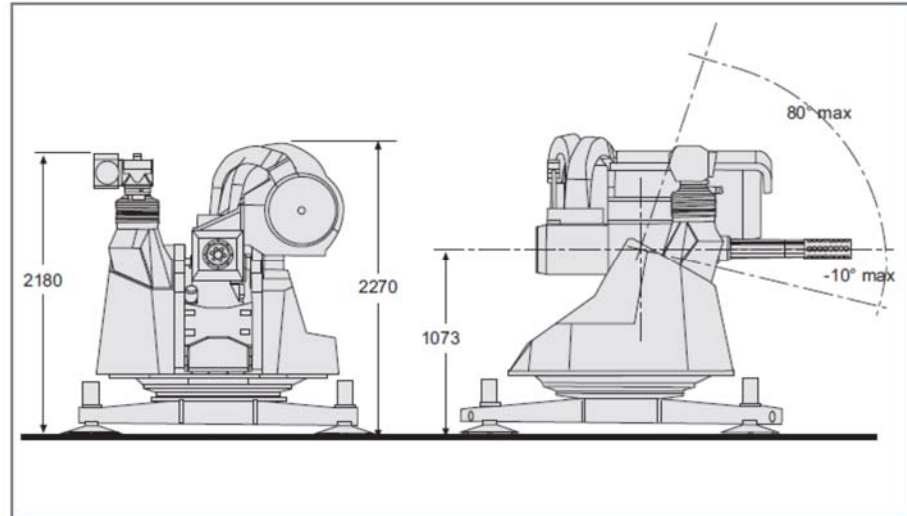


Figure 53. Israel's Rafael Advanced Defense Systems Illustrating Iron Dome in Action Brochure at DSEi 2015

¹⁶⁷ Andrei Ivanovich Grigoriev quoted in “Russian Military Working On ‘Smart Bullet’ for Snipers,” July 19, 2016. Accessed on 16 November 2016 at <https://awfulavalanche.wordpress.com/2016/07/19/russian-military-working-on-smart-bullet-for-snipers/>.

- **OTO Melara PORCUPINE C-RAM (Italy):** The system, consists of four firing units, one central control post for target designation and weapon control, and 3D radar. Each remote firing unit consists of one 20 mm M61A1 Gatling cannon, its ammunition handling system, and a stabilized optronic IR tracking system.



PORCUPINE C-RAM

Main Characteristics:

Weapon	M61A1 20mm Gatling 6 barrels
Rate of fire	3000-6000 rds/min
Ammunition	20mm x 120 MP-T-SD M-940 Multi Purpose Tracer with self-destruction
Sensor	High resolution MWIR 3rd Generation Infrared E.O. IFF
Radar System	Net of 2D Radars for surveillance, detection and Multiple Targets Tracking contemporary to the surveillance
Type	LPI, Solid State, TWS Doppler Radars
Range	up to 10 Km depending on the RAM threat
System capability	· Independent line of fire for each weapon · Multiple engagement capability (one target for each weapon at the same time) · Continuous 360° surveillance during engagement · Minimization of costs and logistic through capability of the system to adapt to the size of protected area and intensity of conflict

Figure 54. Italy's OTO Melara PORCUPINE C-RAM
Brochure at Eurosatory 2014

- **Thales’ RAPIDFire C-RAM gun system (France):** This system from Thales, is a mobile, multi-role weapon system that consists of a 40 mm anti-aircraft gun, 3D GROUNDMaster radar and C2 module.

G. Cued Man-Portable Air Defense Systems (MANPADS)

Man-portable air defense missile systems have been available for a long time. However, around 2007, cued MANPADS began appearing in the international arms market. Portable radars and other sensors provide visual target cues to guide the MANPADS operator to the designated target, thereby improving the probability of kill. The sensors can be linked to one or more MANPADS. The extension of integrated air defense systems (IADS) down to the level of MANPADS is a “headline” development. This changes the challenges – the U.S. and its allies now may have to start worrying about proliferated, dense IADS, national level through small unit. Cueing isn’t full IADS integration, but it is an important first step.

Examples of cued MANPADS include:

- **Rheinmetall Canada Advanced Man-Portable Air Defense System (AMADS) (Canada):** This system consists of the command post Battle Management Software (BMS) and MANPADS cueing system. The BMS allows the commander to forward real-time situation awareness data and control orders to MANPADS teams. The MANPADS cueing system is an easy-to-learn, easy-to-use, cue-to-target aid for operators.



Figure 55. Canada’s Advanced Man-Portable Air Defense System (AMADS) from Rheinmetall Canada’s Website¹⁶⁸

¹⁶⁸ Image taken from Rheinmetall Canada website. Accessed on 17 October 2016 at https://www.rheinmetall.ca/en/rheinmetall_canada/systemsandproducts/airdefence/air-defence.php.

- **Rheinmetall Defence Oerlikon MANPADS Cueing System (Germany):** This system gives MANPADS systems a command and control capability that provides control capability and situational awareness for MANPADS teams to produce shorter reaction time. The local sensor can be integrated in network.



Figure 566. Germany's Oerlikon MANPADS Cueing System from Rheinmetall Website¹⁶⁹

- **China Precision Machinery Import-Export Corporation (CPMIEC) QW-1A MANPADS (China):** This system links a small ground-based radar to multiple linked missile launchers, thereby increasing the probability of kill.



Figure 57. China's CPMIEC QW-1A MANPADS System Elements
Brochure at AirShow China 2014

¹⁶⁹ Image taken from Rheinmetall website. Accessed on 17 October 2016 at https://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/air_defence_systems/stationary_air_defence/index.php.

- Tian He Defense Technology Company from Xi'an TH-S711 Smart Hunter (China):** This system is being marketed by both CPMEIC and Poly Technologies. It includes small forward-alert radar on a light truck that is radio linked to the MANPADS or anti-aircraft guns to provide directional information as well as target assignment. TH-S711 has been displayed at IDEX 2013 and IDEX 2015, where it included a dummy fitted with the MANPADS along with the associated radio and cueing system. Radar detects targets and then selects and alerts the MANPADS teams about the target bearing via a radio set deployed with the MANPADS team. The system includes various options, including a small display that can be fitted to the gripstock to enable the command post to provide visual aiming instructions.



Figure 58. China's Tian He Defense Technology THS711 Smart Hunter Cued MANPADS System Brochure at AirShow China 2010

- OJSC Agat SHLEM MANPADS (Belarus):** This system's unit control complex from was marketed at IDEX 2013. Radar develops the air situation ("air tracks" that are provided to the commander's workstation. The air defense missile launchers: (1) receive control commands and target designations from the commander's workstation, (2) calculate and indicate the direction for launching tube correction relative to the target, (3) do automatic position finding and (4) transmit launcher status information and coordinates to the commander's workstation. Agat claims that *SHLEM* doubles the efficiency of MANPADS.

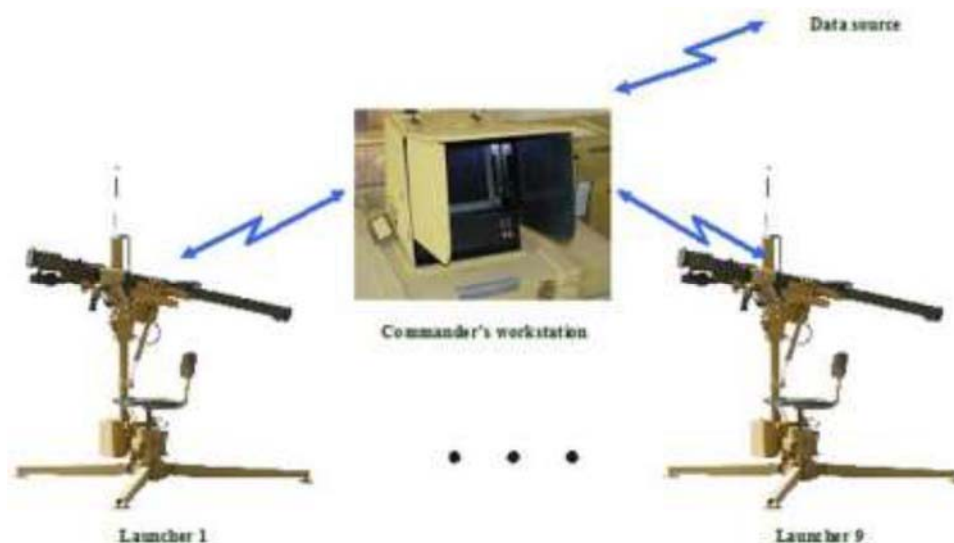


Figure 59. Belarus' OJSC Agat SHLEM MANPADS Unit Control Complex
Brochure at IDEX 2013

H. Enhanced Individual Soldier Capabilities

At the end of the last century and the beginning of the new one, views regarding the role of individual infantrymen and their place in the battlespace began changing. Infantrymen came to be seen as nodes in a larger networked system of systems. This led to a rethinking of how the individual soldier should be equipped, which in turn spawned soldier modernization programs.

Soldiers came to be viewed as a “battlefield system” or “human platform” capable of executing a full range of dismounted combat operations by enhancing command and control/situational awareness, lethality, survivability, sustainability, and mobility capabilities of individual soldiers or small units (e.g., squads). This system-of-systems approach to soldier modernization focused on optimizing individual soldier effectiveness through subsystem integration across a diverse spectrum of operations. The soldier system was also seen as contributing to the larger, network enabled environment, in which each soldier platform became a key component within the network-centric battlefield. The resultant soldier system consists of modular, integrated, reconfigurable, and fully upgradeable pieces.

Most countries pursuing an integrated soldier system modernization program develop components that fall into the following seven basic categories:¹⁷⁰

- **Command, Control, Communications, Computing and Intelligence (C4I)** – Ability to direct, coordinate, and control personnel, weapons, equipment, information, and procedures necessary to accomplish the mission. This also includes acquiring and maintaining situational and context awareness of one’s own position

¹⁷⁰ For a good discussion of the basic ideas underlying the soldier as system concept, see “Soldier,” 1998 Army Science and Technology Master Plan. Accessed on 19 April 2007 at <http://www.fas.org/man/dod-101/army/docs/astmp98/sec3i.htm>.

and the positions of other members of his small unit *vis a vis* the location of enemy assets and terrain features.

- **Lethality** – A soldier’s ability to detect, recognize and destroy the enemy targets.
- **Survivability** – Protection of the soldier against weapon impacts and environmental conditions.
- **Sustainability** – Ability to maintain a soldier in the field, to include rations, nutritional tailoring to enhance physical and mental performance, a capability to eat on the move, individual purification of all water sources, and improvements in field feeding and field services.
- **Clothing** – There is some overlap between this area and the preceding one, since clothing covers not only uniforms but also load-carrying vests, which might be considered an element of sustainability as well.
- **Mobility** – Ability to move about the battlefield with accompanying load to execute assigned missions. This category includes both load-carrying devices and navigation aids.
- **Power Supply** – Future soldier equipment consumes large amounts of electrical energy, so power sources (e.g., batteries, fuel cells, etc.) are one of the two main drivers of future soldier capabilities.

The French Army’s future infantry requirements are being pursued under the name of *Fantassin à Équipements et Liaisons Intégrés*, or Infantry with Integrated Communication and Equipment (FELIN). FELIN is built around a modular, multi-mission system of systems concept to enhance the skills of infantrymen in the areas of mobility, fighting, communications, survivability, ISR, and logistics support. Other objectives include making the infantry kit easier to use and maintain, providing an urban warfare-capable system, interoperability, reliability, and growth potential. The French Army also sees FELIN as one element of the French Army’s larger *bulle opérationnelle aéroterrestre* (the air land operational bubble) net-centric land warfare system.

Russia also has a future soldier program, called Ratnik (Warrior). According to Andrei Ivanovich Grigoriev, General Director of the Russia’s Advanced Research Foundation, Warrior is a “single systematic approach” to outfitting and arming individual soldiers.¹⁷¹ Warrior has up to 10 different interacting subsystems.

Vendors have responded to this new view of enhanced individual soldier capabilities in two ways. Some firms offer complete future soldier programs, whereas other concentrate on individual pieces of kit. Like vendors, some countries (e.g., France, Germany, Russia, and China) are

¹⁷¹ Remarks by Andrei Ivanovich Grigoriev cited in “Defender of the Future: A Look at 2030,” *PIR Center*, May 14, 2015. Accessed on 16 November 2016 at <http://www.pircenter.org/news/6748-the-future-defender-looking-forward-to-2030>.

pursuing a full spread of future soldier capabilities whereas others (e.g., South Africa and Thailand) are pursuing capabilities in only one or two of the functional capability areas described above.



Figure 60. Russia's Ratnik Future Soldier Program Uniforms and Gear Display at Army 2016

I. Radical Changes in the Unmanned Platforms Market

Unmanned platforms have proliferated significantly in the last two decades. The nature of the unmanned platform market is changing in many ways. The customer base has broadened significantly. Unmanned platforms being marketed are no longer just aerial platforms, as they were 20 years ago. There are now major markets for unmanned ground, sea, and undersea platforms as well. The mission sets have evolved from essentially passive ones (e.g., reconnaissance, surveillance, explosive ordnance disposal) to armed combat roles.

At one time, only the militaries of major nations had unmanned aerial platforms. The drop in the price of intelligence, reconnaissance, and surveillance UAVs coupled with the proliferation of

suppliers has made them available to almost all militaries. Even some non-state actors are using drones. Hezbollah, for example, has been flying reconnaissance UAVs into Israel air space since November 2004. Hezbollah has also employed UAVs to photograph Israeli military operations in the Golan Heights. Small privately owned UAVs overflew French Sainte-Assise naval communications center, used for command and control of submarines, in March 2015.¹⁷² Similarly, a small private UAV overflew the U.S. submarine base in Bangor in February 2016. The reason for the overflights of sensitive French and U.S. naval facilities is unknown, but it is significant that the flights in both cases occurred in prohibited air space.



Figure 61. Hezbollah Video Animation of a UAV Over Israel Territory¹⁷³

A large segment of the unmanned platform market is now devoted to police and homeland security missions. Law enforcement agencies are using aerial, ground, and water-borne drones for surveillance, crowd control, explosive ordnance detection, and maritime security. The interest in unmanned platforms for police and security missions is demonstrated by products displayed at Milpol 2015. That worldwide event for police and homeland security featured 16 UAVs for law

¹⁷² David Chazan, "Drone spotted over French military site," *The Telegraph*, March 8, 2015. Accessed on 24 October 2016 at <http://www.telegraph.co.uk/news/worldnews/europe/france/11458116/Drone-spotted-over-French-military-site.html>.

¹⁷³ Roi Kais, "Hezbollah has fleet of 200 Iranian-made UAVs." Accessed on 17 October 2016 at <http://www.ynetnews.com/articles/0%2C7340%2CL-4457653%2C00.html>.

enforcement and homeland security missions, 9 unmanned ground vehicles, 4 unmanned surface vessels, and 2 mini remotely operating undersea vehicles.

A large commercial market for unmanned platforms is emerging as well. Companies like Amazon Prime, Wal-Mart, and Google X all have plans or have experimented with using UAVs to transport packages directly to individual customers. A California-based start-up, Matternet, is already delivering medical supplies and specimens in countries around the world (e.g., Switzerland, Haiti, and Dominican Republic).¹⁷⁴ Private individuals are now purchasing small UAVs in large numbers. Members of the U.S. Consumer Technology Association (CTA) reported purchasing 700,000 UAVs in the 2015 holiday season. CTA research estimates sales of drones in the U.S. alone are expected to approach 2.8 million units in 2016, up 149% over 2015.¹⁷⁵ Several automotive companies are also developing autonomous/self-driving cars, and European Commission's Seventh Framework Program is developing an autonomous merchant ship with a consortium of companies.

The emerging commercial market for unmanned platforms has implications for defense. Many "commercial" systems have dual-use application and improvements from the commercial sector will flow over into defense products. Also, the investment in R&D for commercial unmanned platforms is likely to be large and that, in turn, should spur technological advances that are likely to be spun into products for military and homeland security customers. Additionally, commercial advancements mean that more unmanned platforms will be available to non-state actors based on price and the generally unregulated nature of the export market for unmanned systems.

Things are changing even within the military segment of the international market. Armed unmanned systems are appearing in greater numbers. The U.S., U.K., and Israel are the main users of unmanned combat aerial vehicles (UCAVs), but other countries such as Russia, China, Iran, India, and South Korea have begun developing increasingly sophisticated UCAVs.¹⁷⁶ The China Aerospace Science and Industry Corporation (CASIC), for example, displayed the WJ-600A/D, which can be equipped with small air-to-surface missiles, at AirShow China 2014. Examples of next generation, low observable demonstrator UCAVs include the British Taranis, French nEUROn, and Russian Skat.

¹⁷⁴ "Drone delivery is already here – and it works," *MarketWatch* December 15, 2015. Accessed on 24 October 2016 at <http://www.marketwatch.com/story/drone-delivery-is-already-here-and-it-works-2015-11-30>.

¹⁷⁵ *CES 2016 Press Release*, January 2016 at CES 2016 exhibition.

¹⁷⁶ *Use of unmanned air, maritime and land platforms by the Australian Defence Force*, op. cit.



Figure 62. China's CASIC WJ-600A/D High Altitude and High Speed UAV Model at AirShow China 2014



Figure 63. Russia's MiG Skat UCAV on Display in a Closed Hanger at MAKS 2007

Many countries are also marketing UGVs armed with machine guns, ATGMs, and automatic grenade launchers. Examples from the Army 2016 show in Moscow include the Russian Uran-9 Attack Robot armed with 30 mm automatic cannon, 7.62 mm machine gun and 4 ATGMs, and the BAS-01G *Sorotnik* (“Comrade-in-Arms”) Robot with 7.62 mm machine gun, 12.7 mm machine gun, and 30 mm or 40 mm automatic grenade launches or ATGMs. There is also a small number of armed unmanned surface vessels like the Israeli Protector Unmanned Naval Combat System, which is equipped with the Mini-Typhoon Stabilized Weapon Station and high-pressure water cannon.



Figure 64. Russia's Uran-9 Attack Robot on Display at Army 2016

Vendors in the international arms market are beginning to offer hybrid unmanned systems that combine multiple UGVs or UGVs and UAVs into a single integrated system. Thales' R-TROOPER UGV, for instance, consists of a large wheeled UGV that can launch multiple small UGVs housed inside the mother vehicle. Oto Melara has shown a UGV capable of launching a quad-rotor UAV at Eurosatory 2008.



Figure 65. France's Thales Trooper R Unmanned Ground Vehicle Disgorgeing Smaller UGVs on Display at Eurosatory 2008



Figure 66. Italy's Oto Melara's UGV and UAV Combination on Display at Eurosatory 2008

Another major change in the unmanned platform market is the growing autonomy of unmanned platforms. Originally, unmanned platforms were controlled entirely by a human operator, either through radio signals or a wire link. Next, semi-autonomous platforms could self-navigate via waypoints but permitted human intervention. Some ground and aerial platforms now operate on a “follow me” principle, where the platform automatically follows a person with human direction. A press release from Israel Aerospace Industries (IAI) issued at the Seoul International Aerospace and Defense Exhibition 2009 described this concept as embodied in its REX Cargo Transporting UGV:

The robotic vehicle follows the lead soldier from a given distance, utilizing technology developed and patented by IAI. Using simple commands, including 'stop', 'fetch', and 'heel', the lead soldier controls the robot without being distracted from the mission at hand. Controlling the robot in this way allows for intuitive interaction and rapid integration of the product on the field within a short time frame...



**Figure 67. Israel's IAI REX UGV Following a Squad of Infantrymen
Brochure at Seoul International Aerospace and Defense Exhibition 2009**

Next on the horizon are fully autonomous unmanned platforms. The commercial sector is leading the way by investing heavily in “driverless” cars right now. Developers are working on cooperative autonomy, where two or more fully autonomous systems interact in a cooperative fashion. Research is currently underway on cooperatively autonomous cars and trucks operating in convoys and autonomous UAVs operating in coordinated teams or swarms. The Chinese National Center of Intelligence Transport Systems Engineering and Technology, for example, is working on a Cooperative Vehicle Infrastructure System. The defense sector is also working on autonomous unmanned platforms. Japan's Technology Research and Development Institute (TRDI) is developing a medium size UAV, which is launched from F-15, flies, and lands autonomously.

J. Disrupting and Destroying Unmanned Aerial Systems

In the arms market, as in nature, each action produces a counteraction. Predictably, the vast increase in the scope of missions for UAVs, as well as the sheer number now in service with militaries around the world, has led to increasing demand from military forces and homeland security organizations for: (1) the creation of new systems to destroy and defeat UAVs and (2) upgraded capabilities of existing systems that already have counter-UAV capabilities. Technical solutions being offered include: (1) destroying the UAV, (2) disrupting, deceiving, or evading on-board sensors, (3) disrupting/jamming navigation systems, (4) cutting or jamming data links and

(5) third parties taking control of the UAVs. Countermeasures range from high-tech solutions, like lasers and hacking, down to low-tech products, such as nets to ensnare small UAVs.

Examples of systems marketed recently at international arms exhibitions specifically to counter-UAVs include:

- **Shipovnik-AERO Electronic Warfare (EW) System (Russia):** Mounted on KAMAZ truck, the system suppresses control signals and can “cut off” a UAV from the original signal and replace it with one generated by Shipovnik-Aero EW System. It also creates a false navigation field by changing dynamic coordinates, so a UAV can be driven away and landed in another site, and hacks onboard systems.
- **Blighter Anti-UAV Defense System (AUDS) (United Kingdom):** It is designed to disrupt and neutralize UAVs, remotely piloted aircraft systems (RPAS), or unmanned aircraft systems (UAS) engaged in hostile airborne surveillance and potentially malicious activity. The Blighter AUDS combines electronic-scanning radar target detection, electro-optical (EO) tracking/classification, and directional RF inhibition capability.



Figure 68. United Kingdom's Blighter Anti-UAV Defense System
Brochure at DSEi 2015

- **Drone Guard (Israel):** It uses adaptive jamming systems against low-level, low-speed hostile aerial targets. The jamming disrupts the drone's flight and can either cause it to return to its point-of-origin (“Return Home” function) or to shut down and crash.
- **EAGLE 108 Drone Jammer (Israel):** The EAGLE 108 tactical jammer was designed by Phantom Technologies Ltd. to neutralize unauthorized drones/quadcopters from entering secured fields and campuses. Once a threat is

detected, the system sends an automatic command to the jamming unit and starts to block all radio communication channels, including GPS signals and video link. At this point, the drone will drift away and lose communication with its operator.



Figure 69. Israel's EAGLE 108 Drone Jammer Brochure at Milpol 2015

- **Rafael Iron Beam High Energy Laser (Israel):** Iron Beam is a technology demonstrator from Rafael Advanced Defense Systems that is designed to perform counter-UAV and C-RAM functions. Truck-mounted Iron Beam employs two separately located high-power fiber-optic lasers



Figure 70. Artist's Conception of Israel's Rafael Iron Beam's Twin Lasers¹⁷⁷

¹⁷⁷ Gareth Jennings, "Singapore Airshow: Rafael launches Iron Beam." Accessed on 13 March 2016 at <http://www.janes.com/article/33647/singapore-airshow-rafael-launches-iron-beam>. See also David Donald,

- **M.A.L.O.U. Tech Drone Interceptor MPI 200 (France):** The MPI 200 neutralizes an intruder UAV weighing up to six kilograms with a net.



Figure 71. France's M.A.L.O.U. Tech Drone Interceptor MPI 200 on Display at Milipol Paris 2015

- **New Microwave Cannon to Kill UAVs (Russia):** Russia showed a microwave cannon to military specialists at ARMY 2015, a show held in June 2015 outside Moscow. Reportedly, it can disable drones and warheads at a distance of up to six miles.
- **Silent Hunter Anti-UAV Laser (China):** Developers claim that the laser destroyed more than 30 drones with a 100% success rate during testing.

“Rafael Lifts Lid on Laser Defense.” Accessed on 13 March 2016 at <http://www.ainonline.com/aviation-news/singapore-air-show/2014-02-12/rafael-lifts-lid-laser-defense>.



Figure 72. China's Silent Hunter Anti-UAV (upper) and Small UAV Destroyed by the System (lower)¹⁷⁸

- **Institute of Metal Science AHM-100 Anti-UAV/Anti-Helicopter Mine Units (Bulgaria):** At DSEi 2013, the Institute of Metal Science, Equipment and Technologies along with the Hydroaerodynamics Center of Bulgaria displayed a placard of a ground-based explosively formed projectile (EFP) mine complex designed to engage UAVs and helicopters. This anti-UAV/anti-helicopter mine complex is composed of four EFP mines, a central communication arming unit, and a portable control unit.

¹⁷⁸ "China develops anti-drone laser," DefenceBlog, November 3, 2014. Accessed on 8 December 2016 at <http://defence-blog.com/?p=2017>.



Figure 73. Bulgaria's Institute of Metal Science AHM-100 Anti-UAV/Anti-Helicopter Mine Units Placard at DSEi 2013

- **ZBL09 8x8 Self-Propelled Anti-Aircraft Gun System (China):** The ZBL09 is fitted with a 30 mm six-barrel Gatling gun and four FN-6 MANPADS surface-to-air missiles. It is advertised for use against a number of targets, including UAVs.
- **BAE Systems Taranis UCAV Technology Demonstrator (United Kingdom):** Taranis was designed by BAE Systems to defend itself against manned and other unmanned enemy aircraft with air-to-air missiles.

K. Quest for Autonomous Systems

Developers are trying to move beyond simple unmanned systems to autonomous systems for military applications. While there is considerable disagreement about the definition of what constitutes an autonomous system, autonomy is being widely pursued. The ultimate goal appears to be systems that require no human intervention to perform their designed activities and that can work in consort if necessary. The desire for autonomous systems encompasses ground vehicles, sea surface vehicles, undersea vehicles, air vehicles, and weapon systems. The last category is the most contentious, given the legal requirements for a “man-in-the-loop” to make decisions about firing a weapon. This final qualification may be most restrictive for the United States and some allied countries.

Concerns about man-in-the-loop control over firing decisions by autonomous weapons are now being observed in a few cases. In the case of active protection systems, for example, the decision may be on/off, as opposed to a person looking at targets and potential collateral effects prior to approving a shot. Also, loitering anti-radiation munitions do not always have man-in-the-loop control over the decision to attack an emitter once the target is acquired.

A number of products have appeared in the international arms market claiming to be autonomous. The Crew Task Support Unmanned Ground Vehicle, for instance, is advertised by the China South Industries Group as operating in four modes: (1) manned drive, (2) remote control, (3) semi-autonomous, and (4) full autonomous. China’s CETC showed a video at AirShow China 2016 of a couple dozen UAVs flying in formation and doing improvised, network-generated flight patterns marked by inter-UAV communications and coordination to reach their destination.¹⁷⁹

¹⁷⁹ Jeffrey Lin and P.W. Singer, “China’s New Fleet of Drones: Airshow Displays the Future of Chinese Warbots and Swarms,” *Fortuna’s Corner*, November 4, 2016. Accessed on 8 November 2016 at <http://fortunascorner.com/2016/11/08/chinas-new-fleet-of-drones-airshow-displays-the-future-of-chinese-warbots-and-swarms/>.



**Figure 74. China's CETC Video Showing a Couple Dozen UAVs Flying in Formation
Video Screen Capture at AirShow China 2016**

There are also grand challenges and competitions promoting the development of autonomous vehicles. The 3rd Autonomous Surface Vehicle Competition (Iran) aimed to enhance cooperation between universities and government agencies on autonomous sea surface vessels. The Naval Commander of The Islamic Revolution Guards Corps (IRGC), Rear-Admiral Ali Fadavi, spoke at that competition.

L. Directed Energy Weapons

The last decade has seen the appearance of directed energy weapons (i.e.; weapons that use high power microwave, millimeter wave, pulsed energy, radio frequency energy, and lasers to jam or disrupt electrical and electro-optical equipment). Some are designed for use against people rather than equipment. Many of these directed energy weapons appear to be concept projects or prototypes, not ready-for-sale products.

IDEX 2015 was a sort of coming-out party for directed energy weapons, since there were several directed energy weapons systems prominently featured and actively marketed. Rheinmetall had a large 30 kW high-energy laser weapon on display. This was a combination of Rheinmetall's high-energy laser (HEL) research integrated with the Oerlikon Skyguard air defense system. Nearby, Rheinmetall also had the Oerlikon Skyguard-3 30 mm turret with the conventional gun armament. The HEL effector consisted of an Oerlikon Skyguard 3 fire control unit for target acquisition and weapon control and a high-energy laser gun using a revolver gun turret equipped with laser weapon modules. Each module consists of one 10 kW fiber laser and a beam-forming unit. Commercial-off-the-shelf (COTS) fiber lasers were modified for air defense applications.

The beam-forming unit provided diffraction-limited beam focusing, target imaging, and fine tracking of the target. By using beam superimposing technology, Rheinmetall combined the power of single lasers into one multiplied laser beam. This technology not only allowed superimposition of multiple lasers on a single gun platform, but also superimposition of multiple gun platforms. Another HEL system on display was the Boxer Mobile HEL Effector, a joint venture of Rheinmetall and KMW, that placed a 10 kW HEL on the Boxer IFV. This was intended to serve as a multi-role weapon, including the engagement of UAVs, defeating optronics on enemy aircraft, neutralizing ammunition, disposing of unexploded ordnance, and clearing battlefield obstacles. The third HEL system on display was far less conspicuous. MBDA had a small-scale model of a Laser Effector. This was based on work being undertaken by MBDA Germany based on contracts from the Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw), as well as private MBDA funding. MBDA Germany's efforts focused on the design of an autonomous C-RAM capable and transportable laser effector with more than 100 kW of power that can be connected to existing command and weapon control systems. The program was being tested at MBDA Germany's Schrobenehausen site that includes three test ranges for firing and tracking trials, a test laboratory, and a roof laboratory with a laser demonstrator.



**Figure 75. Germany's Rheinmetall HEL Technology
Brochure at DSEi 2015**

Other countries have demonstrated an interest in using directed energy weapons for air defense. Scientific Production Organization Almaz of Russia experimented with the MLTK-50 Mobile Laser demonstrator, which mounts a high energy laser on a MAZ-7910 truck chassis for air defense and metal cutting. India's Defense Research and Development Organization (DRDO) website also advertised an air defense long-range laser dazzler for use against rogue airplanes venturing in no-fly zones protecting critical infrastructure locations.

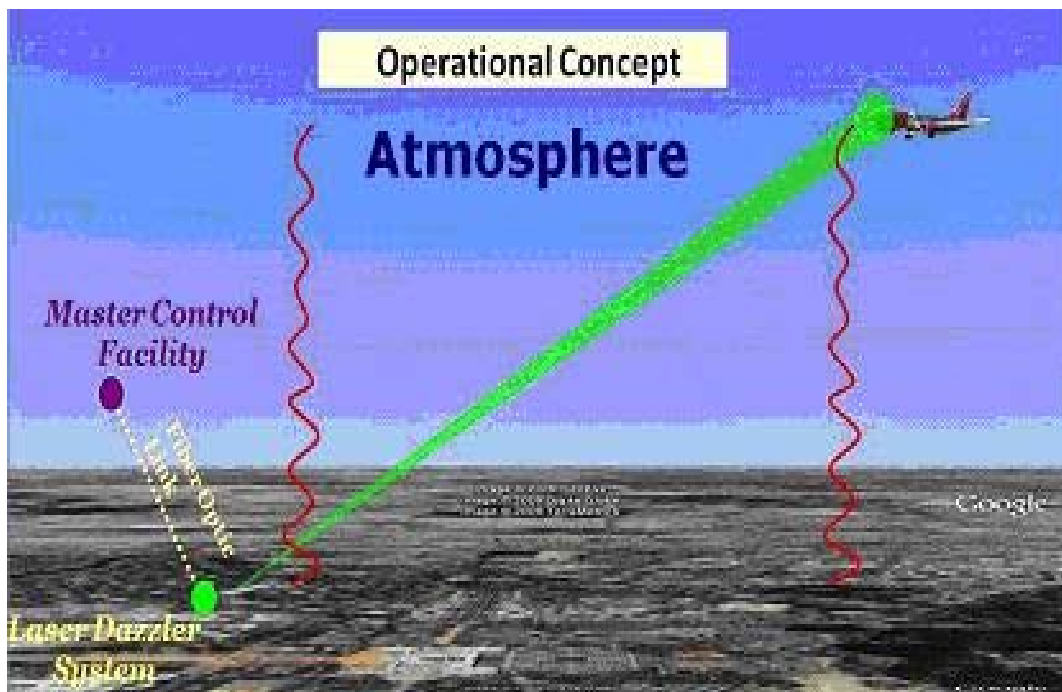


Figure 76. India's Air Defense Long Range Laser Dazzler from DRDO Website

Directed energy systems designed for use against people include:

- **BAE Systems Prototype Anti-Pirate Laser Distracter (United Kingdom):** The custom-made neodymium yttrium aluminum garnet laser provides a visual warning to pirates at distances over 2 km and disorients attackers at less than 2 km. The prototype was tested at Pershore Trails Range
- **Defense Research and Development Organization (DRDO) Vehicle Mounted Laser Dazzler System (India):** DRDO advertised a vehicle-mounted laser dazzler system in the DRDO catalog distributed at Africa Aerospace and Defense (AAD) 2014 show held in Pretoria, South Africa, in September 2014. This vehicle-mounted laser dazzler system was integrated with a two-axis gimbal assembly to produce a very green laser beam for flooding a large section of an unruly crowd with the help of a joystick controlling the gimbal mount.
- **Jetlasers Portable Laser Dazzler/Disruptor (China):** This system is designed for temporary visual disorientation or flash blindness.

- **JG-2002 Laser Rifle (China):** This system is a shoulder-aimed laser-dazzling weapon for riot control. It can disrupt vision at 50 meters and is effective out to 100 meters.
- **Defense Research and Development Organization (DRDO) Short-range Portable Laser Dazzler (PLD) (India):** DRDO's short-range portable laser dazzlers are especially suited for counter-insurgency operations. There are two hand-held and one squad weapon-mounted versions of PLD have maximum operation ranges of 50 to 500 meters. Produces randomly flickering green laser output sufficient to cause a temporary dazzling effect.
- **Desert Wolf Skunk Riot Control Drone (South Africa):** This riot control drone is capable of firing 400 rounds of pepper spray and paint balls from several guns mounted under the drone, as well as employing "blinding lasers" and loudspeakers to deter protesters. Reports indicate that an undisclosed mining company in South Africa has purchased 25 of the "Skunk riot control copter" devices developed by military surveillance and communications contractor Desert Wolf.



Figure 77. South Africa's Desert Wolf Skunk Riot Control Drone with Blinding Lasers Display at IFSEC International 2014

M. Platform and Weapons Training Systems

Platform and weapons training simulators have been around for a long time. But over the last 10 to 15 years, the importance, complexity, and sophistication of products offered in the international arms market has grown. Once training systems and simulators were considered an afterthought or something used only by major nations. That has changed. A representative from Rheinmetall told the authors that it is now impossible to sell major platforms without including

training packages. Rheinmetall training and simulation products are used by 35 customers worldwide. At DSEi 2015, Airbus Defence and Space showcased its products, technologies, and services using virtual reality. A first for both the company and DSEi 2015, the entire stand was designed around customized virtual reality cockpits and transported visitors into a virtual world using Oculus Rift headsets. This allowed them to convey the breadth of their current portfolio across defense, space, military, and civil aircraft in a unique way. At Eurosatory 2016, simulation and training was one of five points of emphasis (i.e., “technology clusters”).

The quality of tactical training systems and simulators has improved. The Appended Tank Crew Trainer from Elbit Systems, for example, allows the training to be conducted on the actual platform. Likewise, Elbit Systems’ Embedded Training Solution for Gunnery offers a “complete, autonomous, on-board training and simulation suite” for tanks and armored combat vehicles.¹⁸⁰



Figure 78. Israel's Elbit Systems Appended Tank Crew Trainer Brochure at Eurosatory 2016

Patria’s Nemo Training Simulator provides a realistic, virtual training environment for all kinds of fire missions that can be performed with the Patria Nemo mortar system. The simulator combines virtual training with actual Nemo hardware and software that is installed in a cabin simulating the Nemo commander’s or gunner’s position in the vehicle. The Anti-Aircraft Air Defense and MANPADS Simulator from Zen Technologies (India) is designed to train air defense operators on laying procedures in both simulated and field conditions, as well as psychophysiological training experienced at the time of launch. The psychological and physiological aspects of the training are imparted to operators with setback force/jerks, sound, and flash/light.

¹⁸⁰ “Elbit Systems: ‘Train Like You Fight’ Solutions Offer Unpatrolled Realism and Global Deploy ability for Training Land Forces,” Brochure from Elbit Systems.



**Figure 79. India's Zen Technologies MANPADS Simulator
Placard at DSA 2016**

The growing momentum of platform and weapons simulator products in the international arms market is likely to continue in coming years, since simulators offer a way of cutting operations and maintenance costs (i.e., simulators are less expensive to operate than vehicles in live field exercises and the reduction of field exercises reduces wear on equipment). A study by Frost & Sullivan, for example, estimated that the period for return on investment from helicopter simulators was three to five years.¹⁸¹ Additionally, platform and weapons simulators offer a way of coping with the increasing complexity of military equipment, an especially important consideration for many nations relying on poorly educated conscripts.

The growing emphasis on platform and weapons simulators at international arms shows has security implications for the U.S. Simulators offer an effective and low-cost way of improving the weapons proficiency of conscript soldiers of potential future adversaries, thereby reducing the qualitative edge enjoyed by U.S. soldiers since Operations Desert Storm. This is important because the qualitative edge of its soldiers is generally acknowledged as one of the U.S. military's main combat advantages. Also, as the performance levels of individual soldiers increase, so does their lethality – an important consideration as the size of U.S. forces shrinks. Also, weapons simulators allow foreign armies and non-state actors to conduct training in secret inside buildings, thereby potentially denying the U.S. knowledge that it is even taking place. This is a very serious potential intelligence shortfall in the case of some types of weapons, like man-portable air defense missiles.

N. Complex Simulation

Over the years, there has been a dramatic rise in the capabilities of modeling and simulation technologies offered at international arms exhibitions. They are designed to reduce training time, improve proficiency/skill levels, design future forces' tactics, techniques, and procedures (TTPs), design concepts of operation (CONOPS), and permit program managers to define and evaluate capabilities of systems prior to fielding.

The French Battle Laboratory (officially *laboratoire technico-opérationnel* in French or technical and operational laboratory in English) has been operational since 2006 and was highlighted at Eurosatory 2010. The laboratory technical-operational (LTO) was started by the *Délégation générale de l'armement* (DGA) to conduct experiments. LTO provides a structure that permits program managers, technical experts, industrialists, and testing teams to define and evaluate capabilities in a collegial manner. LTO provides a set of methods, services, and tools enabling shared and interdisciplinary discussion of doctrines, concepts, architectures, or organizations through simulations (virtual experiments) and man-in-the loop experiments with real people and real hardware. Using concept imaging and modeling tools, a multi-cultural team can share a common interpretation of concepts and scenarios uses.

Led by the French Joint Staff and DGA, the French Battle Laboratory is operated by the Center for Technical and Operational Analysis (CATOD) in Arcueil (near Paris). LTO is

¹⁸¹ Frost & Sullivan *Market Insight on Military Training & Simulation Market – 2013*, January 23, 2013. Accessed on 29 November 2016 at <http://www.slideshare.net/FrostandSullivan/fs-mi-trainingsimulation2013>.

connected to various agencies of the DGA (centers of expertise and testing), but also forces (command centers and training and simulation, etc.). As mentioned, industrial partners are involved regularly in the experiments.

LTO provides assistance in finding technical solutions, through:

- Ability to materialize operational situations through simulations or experiments
- Simulations of LTO that can quickly explore different technology routes and identify the most appropriate operational needs
- Simulations of global-level technical and operational concepts for the illustration
- Technical means for organizing distributed experiments: network infrastructure, videoconferencing, supervision
- A capacity for openness to foreign and industrial resources (network gateway to NATO) with the network EXAC

The LTO process also offers the following services through cooperation with the armed forces, DGA, and industry:

- Access to lessons learned and reference databases
- Interconnection with battle labs of industry and allied nations
- Collaborative and multi-disciplinary analysis of concepts
- Architecture and organizational modeling
- Situation gaming
- Simulations with simplified models
- Constructive simulations
- Experimentation with concepts with real system

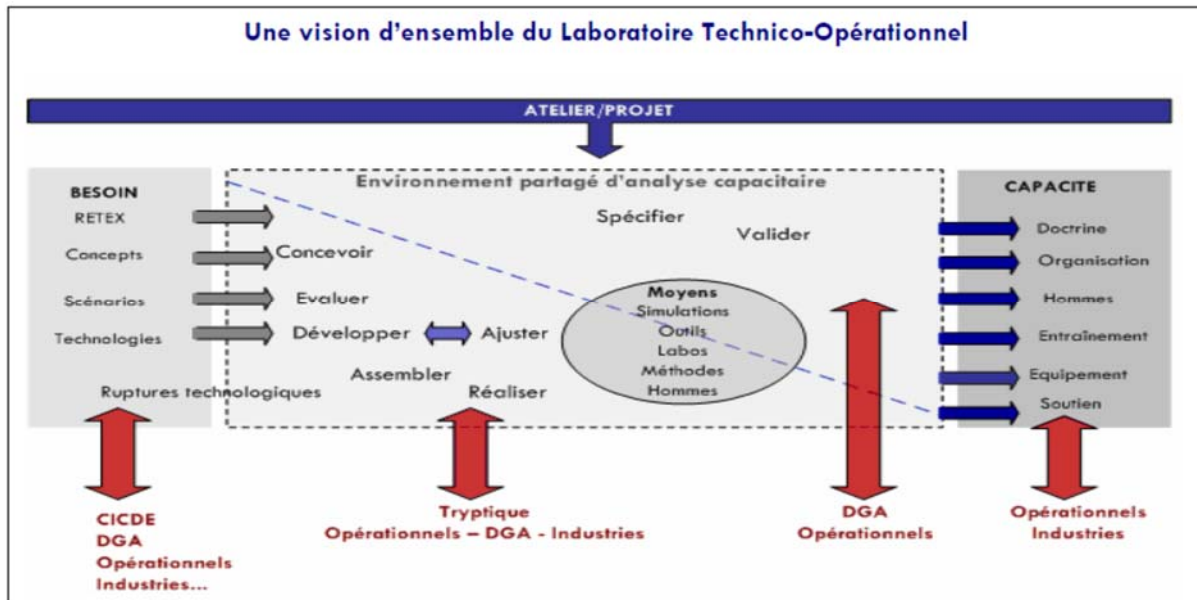


Figure 80. France's DGA Original Operational Vision for the LTO (Circa 2006)
Brochure at Eurosatory 2010

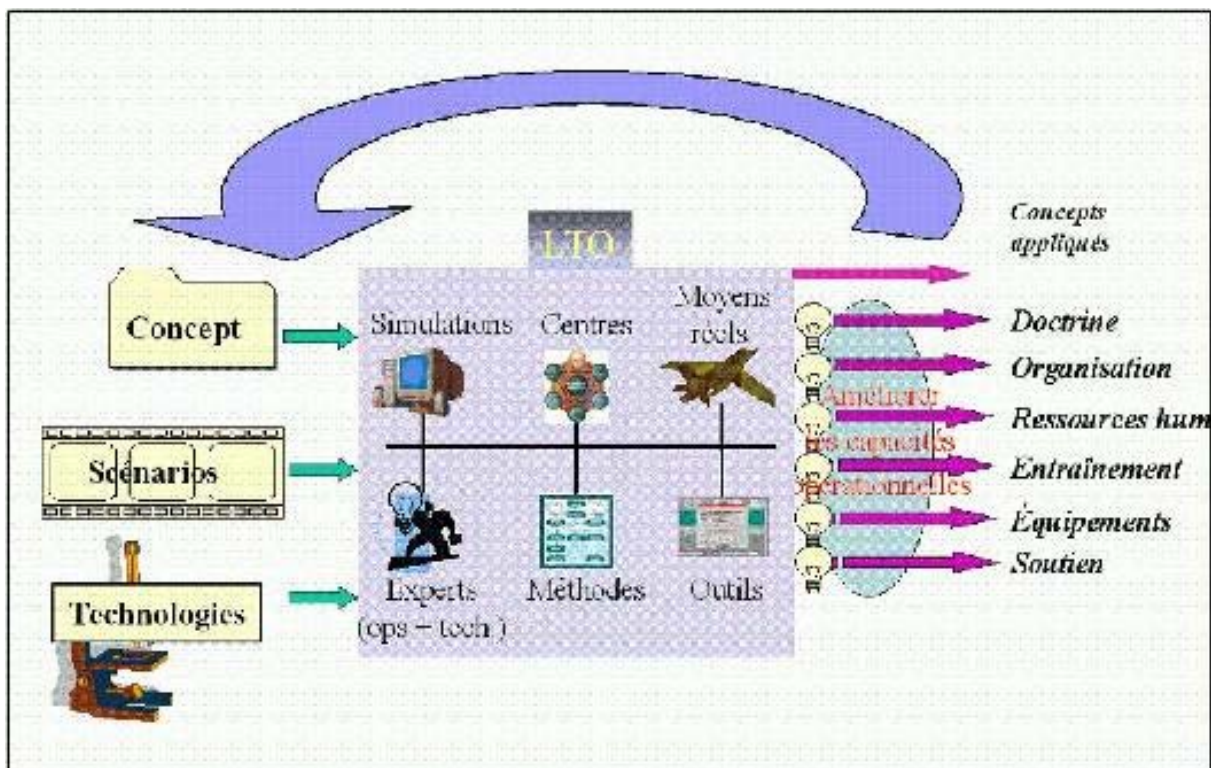


Figure 81. France's DGA Operational Concept for LTO (Circa 2010)
Brochure at Eurosatory 2010



Figure 82. France's DGA Experiment/Simulation Being in Progress Brochure at Eurosat 2010



Figure 83. France's DGA LTO MoD Battle Lab on Display at Eurosat 2010

Network Centric Operations Simulation (NetCOS) is a distributed simulation 3D environment developed by EADS to design, evaluate, and demonstrate Network Centric Operations concepts and systems. It combines and links models, simulations, man-in-the-loop, and real systems in a synthetic environment. The innovative quality of this tool lies in its ability to reproduce a realistic virtual battlefield encompassing the entire “sensor” to “shooter” chain, including the command, control, and information networks. With its modeling, simulating, and experimentation capabilities, NetCOS is a powerful intuitive tool that helps customers in the design and engineering of their large and complex Defense and Security systems. NetCOS users are thus able to generate interactive scenarios to evaluate the performance and interoperability of existing and future capabilities (UAVs, combat aircraft, ships, missiles, etc.) in a network centric architecture.

Israel Aircraft Industries IAI-Magnet’s Net-Centric Simulation Technology and Enterprise for Joint Operations provides comprehensive network centric operation and simulation solutions based on the creation of a network of information sharing and implementation of collaborative C4ISR systems. It provides a test bed for operational ideas in a comprehensive synthetic environment, which is then followed by evaluation and validation of CONOPS in an advanced hybrid Joint Battle Laboratory.

Some simulation tools even employ 3D and virtual reality. Logon d.o.o. (Slovenia) developed the Crisis Response Operations Simulator (CROS) to represent the environment and tasks faced by the ISAF mission in Afghanistan. The CROS system provides an education and training tool that enables appropriate preparation in a 3D environment for the tasks and environment the participants of crisis response operations will face in real missions. Training with the CROS system and its computer assisted exercises enables the trainees to get familiar with their mission environment through general information about the country or region, geographical characteristics, history, language characteristics and communication, ethnic groups, regional culture, customs, traditions and religion, information about the mission, threats from the insurgents and weapons they are using, and tasks they will perform during the mission. The knowledge that trainees gain through the education process is checked with interactive tests and a testing scenario, after which they train with prepared scenarios of the tasks that await them in the crisis response missions. The CROS system allows training using computer assisted exercises and is based on the sophisticated 3D real time CROS graphic engine, an open-source relational database, an education and supervision management system, a data exchange system, dynamic learning contents, and 3D models of assets and virtual training locations.

O. Tethered Aerostats

Aerostats and airships are old ideas that are in vogue again in military and homeland security applications. Interest in aerostats reemerged in the 2006-2008 timeframe, but in the past five to six years, they have become a much more common feature at international arms shows. The two main reasons for their reemergence are their unmatched persistence on station, and relative cost versus of types of platforms performing the same roles. Missions advertised for aerostats include

unmanned aerial surveillance, reconnaissance, target acquisition, communications relay, border and coastal surveillance, intelligence, VIP Protection, search and rescue, and even riot control.

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TAR-SA 100

A mini balloon for close surveillance and reconnaissance provides field's commander with real time "over the hill" reconnaissance capability. The stabilized Electro Optical payload is operational both in day and night time, man-pack transportable, easily assembled and launched in 15 minutes, 1000 meter surveillance range, the payload is easily controlled from handheld PGCS, with a user friendly and intuitive interface.

TAR-SA 180

A tactical aerostat system enables continuous day and night ISR operations at 600 feet. It enables high quality information gathering and accurate target allocation, utilizing gyro stabilized payloads and GPS/ INS navigation. The downlink video and interactive digital map are displayed in real-time via the system's ground control station. The system is highly mobile and rapidly deployed.

TAR-SA 300

A tactical aerostat system enables continuous day and night ISR operations at 1,000 feet. The system is highly mobile and rapidly deployed. It provides high quality information gathering and accurate target allocation utilizing tri-sensor gyro stabilized payloads and GPS/INS navigation. The downlink video and interactive digital map are displayed in real time at the ground control station.

APPLICATIONS

- Unmanned Aerial Surveillance Reconnaissance
- Target Acquisition
- Border and Coastal Surveillance
- Intelligence
- VIP Protection
- Search and Rescue
- Riot Control
- Battle Proven





www.tarideal.com

Figure 84. Israel's TAR Ideal Surveillance Aerostats
Brochure at Milpol 2015

Aerostats are sometimes used as stand-alone systems and sometimes as part of integrated security systems. Rheinmetall's Persistent Surveillance Systems consists of Persistent Surveillance Aerostat and the Persistent Surveillance Tower. The SISDOM border protection suite from Rafael Advanced Defense Systems includes UAVs and aerostats.

P. Evolution and Predicted Replacement of Space-Based Navigation

The last 20 years has witnessed a growing use of space-based navigation aids like American global positioning satellite (GPS) and Russian Global Navigation Satellite (GLONASS) for vehicles and precision-guided weapons. GPS became the gold standard and was adopted by many nations. But over time, competitors arose, like the BeiDou from China and Galileo from Europe, and Regional Navigation Satellite System (IRNSS) from India. The underlying rationale for the development of alternatives to GPS was that precision-guidance of weapons and navigation of vehicles was becoming too important to trust to a system controlled by the U.S.



Figure 85. China's NORINCO BeiDou Applications Placard at IDEX 2017

Multi-constellation Global Navigation Satellite Systems (GNSS) became widely available around 2010-2011 but were capable of accepting inputs from only two constellations, GPS and GLONASS. In 2013, the Teseo-3 from STMicroelectronics (U.S.) appeared, accepting simultaneous inputs from GPS, Galileo, and BeiDou. Another American firm, Trimble, now offers

multi-constellation and multi-frequency satellite positioning receivers capable of accepting inputs from GPS, GLONASS, Galileo and BeiDou. Chinese and Russian vendors now offer multi-constellation and multi-frequency satellite positioning receivers at international arms exhibitions.

Despite these advances, some defense vendors predict the coming replacement of space-based only navigation. New Zealand's Advanced Navigation, for example, now offers a GPS-aided inertial navigation system that can be used on-board UAVs and robotic systems. Navigation technology being offered in the arms market seems to be moving away from space-based navigation alone. As explained in an article by a Western author appearing in the *Chinese Journal of Aeronautics*, the uncertainty of continuous availability of GPS due to jamming is leading to the development of lower-cost inertial navigation (INS) sensors with improved accuracy and low noise levels.¹⁸² Some vendors are now marketing INS and chip-scale miniature atomic clocks because they cannot be jammed. A representative from an Israeli defense firm at Eurosatory 2014 predicted that INS plus atomic clock based on cold atom interferometry would become the predominant navigation technology by 2020. He also predicted that such systems would become smaller, eventually being chip sized.

Q. Preparing for Arctic Military Operations

Far-reaching climate changes in the Arctic are affecting the security situation in the region. Global warming and the prospect of new access to mineral and energy resources is fueling heightened competition among nations to control the exploitation of those resources. (The U.S. Department of Energy, for example, estimates that the Arctic holds 30% of the world's undiscovered natural gas and 13% of the world's undiscovered oil.) Additionally, many countries will make greater use of trans-Arctic shipping routes to reduce transit times dramatically as arctic ice diminishes. Eight countries (the U.S., Canada, Russia, Norway, Finland, Sweden, Iceland, and Denmark via Greenland) hold vast territories in the Arctic. All of them plan to defend their competing territorial claims and develop the natural resources of the region.

The Russian government is emphatically staking a claim to those resources and is preparing to back its claim through military operations if necessary. President Vladimir Putin instructed his military leadership to pay special attention to the Arctic, saying Russia needed "every lever for protection of its security and national interests."¹⁸³ Steps taken include: (1) establishing new military bases in the region, (2) conducting large-scale military exercises in the region, (3) reorganization of the military district structure to establish a new strategic military command in the Arctic (the Northern Fleet-Unified Strategic Command) and (4) designing purpose-built specialized equipment to operate in harsh Arctic conditions. The Russians recognize that the Arctic

¹⁸² George T. Schmidt, "Navigation sensors and systems in GNSS degraded and denied environments," *Chinese Journal of Aeronautics*, Vol. 28, Issue 1, February 2015. Accessed on 15 November 2016 at <http://www.sciencedirect.com/science/article/pii/S1000936114002003>.

¹⁸³ Vladimir Putin as quoted by Jeremy Bender and Michael B. Kelley in "Military Knows That The Arctic Is Melting – Here's How They Are Taking Advantage," *Business Insider*, June 3, 2014. Accessed on 15 November 2016 at <http://www.businessinsider.com/the-competition-for-arctic-resources-2014-6>.

is a harsh operational environment that places special demands on equipment. This recognition has led to the development and fielding of new military systems especially designed for Arctic conditions (e.g., Takhion and Eleron-3 UAVs, Mi-8AMTSh-VA helicopters) and a SOSUS-type sonar system to protect territorial waters in the Arctic.

The Russian military recently released a video of a military version of the TTM-4902 amphibious tracked vehicle being field tested by the Arctic Brigade of the Russian Northern Fleet. The vehicle can carry up to 16 people and operate at temperatures down to -50°C. The TTM-4902 was originally a COTS product developed to service Arctic pipelines, which was militarized with the addition of light armor plating.¹⁸⁴

Russian purpose-built systems for arctic military operations are beginning to appear at international arms exhibitions. The capabilities of the TM-140A amphibious all terrain tracked cargo personnel carrier arctic vehicle were demonstrated at the Russian Arms Expo (RAE) 2013. The TM-140A appears to be a militarized version of the civil TM-140. Two years later, at RAE 2015, RTI Systems and Tiber LLC held a press conference where they announced their collaboration on a project to create a 1.7-ton drone to monitor the Arctic shelf. This UAV will have a continuous operating endurance of 35 hours and a range of up to 4,000 km. Developers claim that the UAV will have a fully automated operating system. Plans call for the first flight to take place in 2017.



**Figure 86. Russia's TM-140A Tracked All-Terrain Vehicle
During a Dynamic Demonstration at RAE 2013¹⁸⁵**

¹⁸⁴ “-50°C no problem: Arctic brigade test-drives 2-unit all-terrain vehicles (VIDEO),” RT, 22 January 2016. Accessed on 15 November 2016 at <https://www.rt.com/news/329811-arctic-tracked-vehicle-russia/>.

¹⁸⁵ “TM-140A amphibious all terrain tracked cargo personnel carrier arctic vehicle Russia Russian army,” YouTube video, *DefenseWebTV*. Accessed on 15 November 2016 at <https://www.youtube.com/watch?v=W2WfxSwnhVQ>.

The first two Russian Ministry of Defense-sponsored International Military-Technical Army expos featured Arctic equipment. Army 2015 displayed a number of specialized Arctic military vehicles, including the “Toros” fire-support engineering vehicle based on the TM-LBU chassis and the TM-140A. Advertising literature from organizers of Army 2016 emphasized that Arctic was a point of emphasis at the show. That exhibition had 10 stands and one entire section specifically dedicated to arctic military equipment, including weapons, vehicles, heating systems, and clothing.



Figure 87. Russia’s “Toros” Fire Support Engineering Vehicle on Display at Army 2015¹⁸⁶

The last two Canadian Prime Ministers have emphasized the need to protect and strengthen Canada’s “Arctic sovereignty.” This has included promises to fund upgraded military capabilities, such as new patrol ships, polar satellites, upgraded transport, new winter apparel, snowshoes, skis, and toboggans. In keeping with the desire to upgrade Arctic military operational capabilities, the Canadian military recently tested a UAV capable of operating in temperatures of up to -30°F.

¹⁸⁶ “Declassified “Toros” Arctic brigades: warm, it will pave the way and will cover fire,” *Vestnik-RM*. Accessed on 15 November 2016 at <http://vestnik-rm.ru/news-4-12781.htm>.

Perhaps predictably, Canada's global defense and security trade show CANSEC 2015 featured several offerings by Canadian firms specifically designed for operating in the Arctic.¹⁸⁷ Ontario-based ARGO, for example, marketed its ARGO-XT extreme-terrain vehicle, which is designed to navigate tundra/snow and to operate in temperatures as low as -40°C. ARGO emphasized that this vehicle is deployable by air and can be fitted with a helicopter sling for air drop. It also offers optional track ice cleats. ARKTOS Developments Ltd now offers a military version of its ARKTOS amphibious craft. An article entitled "Canadian amphibious craft hopes to conquer defence market" noted that ARKTOS was developing a smaller version of its amphibious craft that would fit aboard a transport aircraft, like the C-130 Hercules used by the Canadian military.¹⁸⁸

R. Coastal Monitoring and Defense

Perhaps because of the emphasis (and concern) placed on anti-access/area denial concepts in defense thinking over the past decade, there is now a robust market for coastal defense and monitoring systems. Sometimes the products are individual coastal defense missiles such as: (1) the British Common Anti-surface Modular Missile (CAsMM), (2) Russian Club-M Coastal Defense Missile System, (3) Norwegian Naval Strike Missile (NSM), and (4) the Russian *Bereg* 130 mm coastal defense gun. Vendors also advertise long-range and over-the-horizon radars for coastal monitoring roles.



Figure 88. Norway's Kongsberg Naval Strike Missile (NSM) Mounted on a Truck for a Polish Coastal Defense System Variant on Display at MSPO 2014

¹⁸⁷ Evelyn Brotherston, "Setting Sights on the Defense Industry: Top 20 Gadgets and Innovations on display at CANSEC," July 2015. Accessed on 14 November 2016 at <http://www.arktoscraft.com/wp-content/uploads/2016/02/22-6-CANSEC-2015-Top-20-Gadgets-July-2015-MR.pdf>.

¹⁸⁸ Levon Sevunts, "Canadian amphibious craft hopes to conquer defence market," Radio Canada International, 27 May 2016. Accessed on 14 November 2016 at <http://www.rcinet.ca/en/2016/05/27/arktos-canadian-amphibious-craft-hopes-to-conquer-defence-market/>.



CLUB-M

COASTAL MISSILE SYSTEM



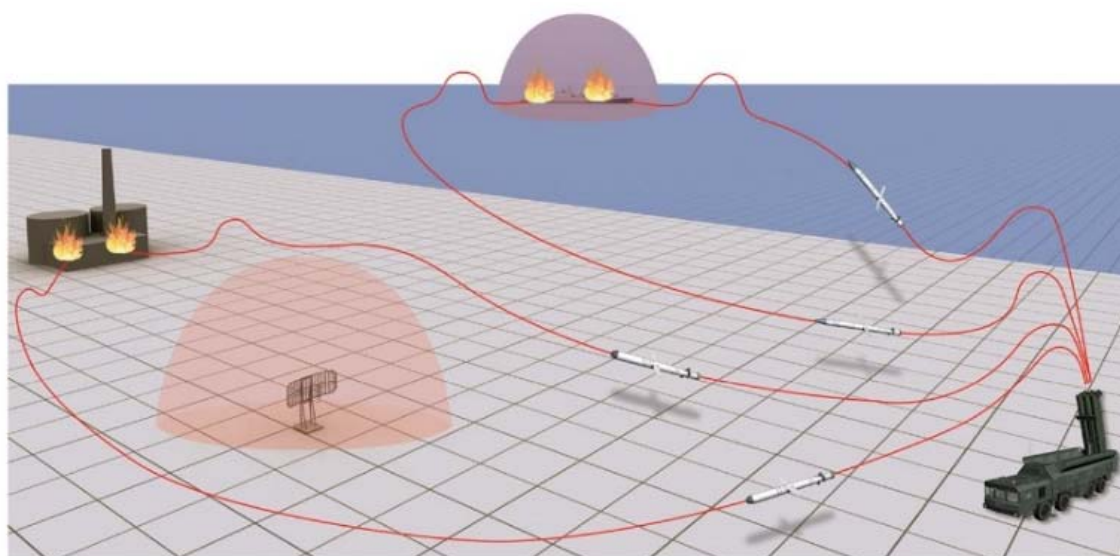
Self-propelled Launcher



Communication and Control Vehicle



Transporter-Launcher



CRUISE MISSILES

3M-54KE



Warhead type
 Penetrating
 high-explosive

Flight altitude
 during midcourse phase, m
 20

Cruising speed,
 mps
 180...700

Flight altitude
 during terminal phase, m
 5...10

Firing range, km
 12,5...220



3M-54KE1



Warhead type
 Penetrating
 high-explosive

20

180...240

5...10

12,5...275



3M-14KE



Warhead type
 High-explosive

20...50

180...240

50...150

UP TO 275



Figure 89. Russia's Club-M Coastal Missile System
 Brochure at Moscow Air Show 2013

At other times, vendors market coastal monitoring and surveillance systems alone. Several Chinese companies, for instance, gave out brochures for such systems at Eurosatory 2014.

- **NORINCO Longview Integrated Coast Surveillance (China):** The company describes the system as an integrated coast surveillance and defense solution focused mainly on 200-nautical-mile exclusive economic zone (EEZ) protection. It is integrated with sensors (airborne/coast/shipborne radars, electro-optic (EO) equipment and sonar equipment), command centers (national sector or observation and communications posts), and wired/wireless communications systems. Longview is capable of detecting surface and low-altitude targets, such as ships, low-flying aircraft, helicopters, and UAVs. It also provides firing data for coast defense artillery in wartime.
- **China Aerospace Long-March International (ALIT) Coastal Monitoring and Control System (China):** ALIT's characterized this system as "an integrated information system" for sea and coast surveillance, protection, and defense. Its main features are: (1) multi-means and customized reconnaissance and sensor subsystem, (2) multi-level, open and modularized information processing subsystem, (3) integrated reconnaissance and detection subsystem linking surveillance, patrol, and strike and (4) support modification, upgrading and integration of existing systems.

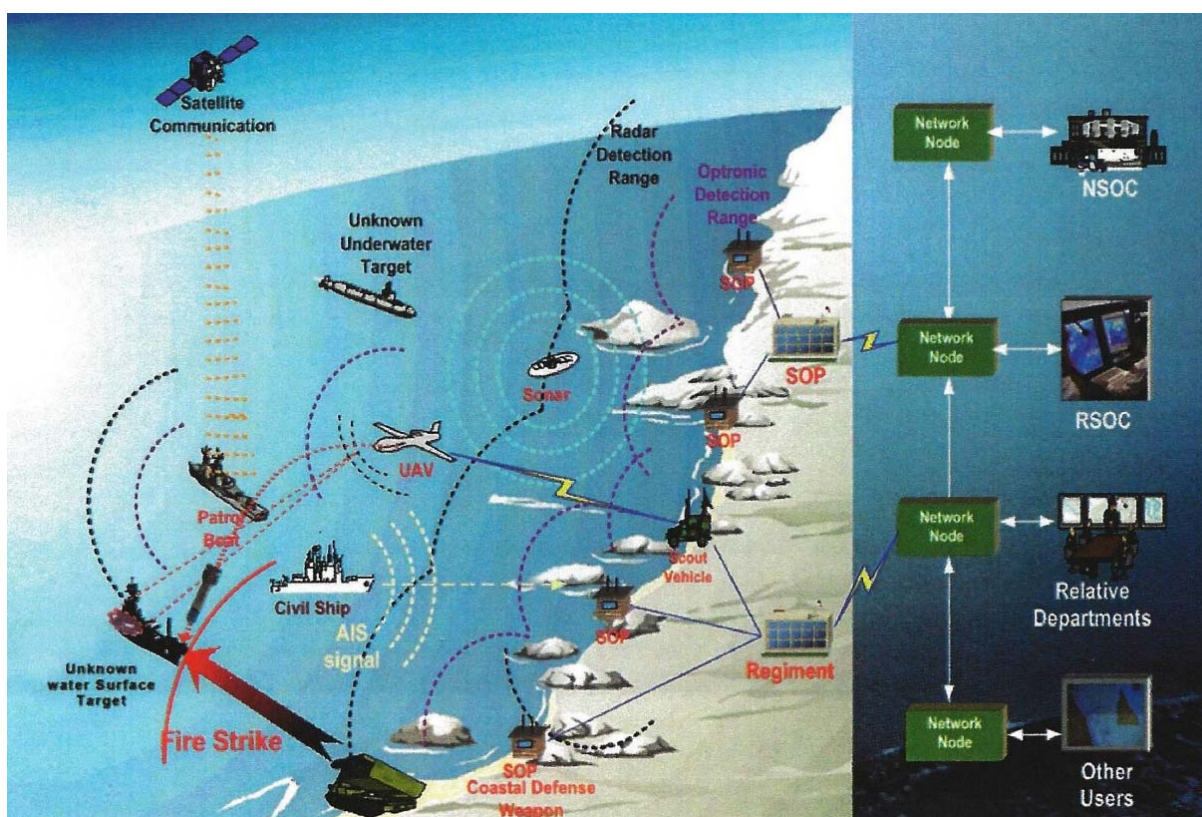


Figure 90. China's ALIT Coastal Monitoring and Control System
Brochure at Eurosatory 2014

A year later, Bharat Electronics Limited marketed a coastal surveillance system at DSEi 2015 to provide maritime security to vulnerable ports and installations and help the Coast Guard thwart terrorists' attempts to sneak into the country via sea route. The offering by Bharat Electronics is designed to monitor an entire coastline as the system presents the complete scenario at a centralized command center on a digital map.

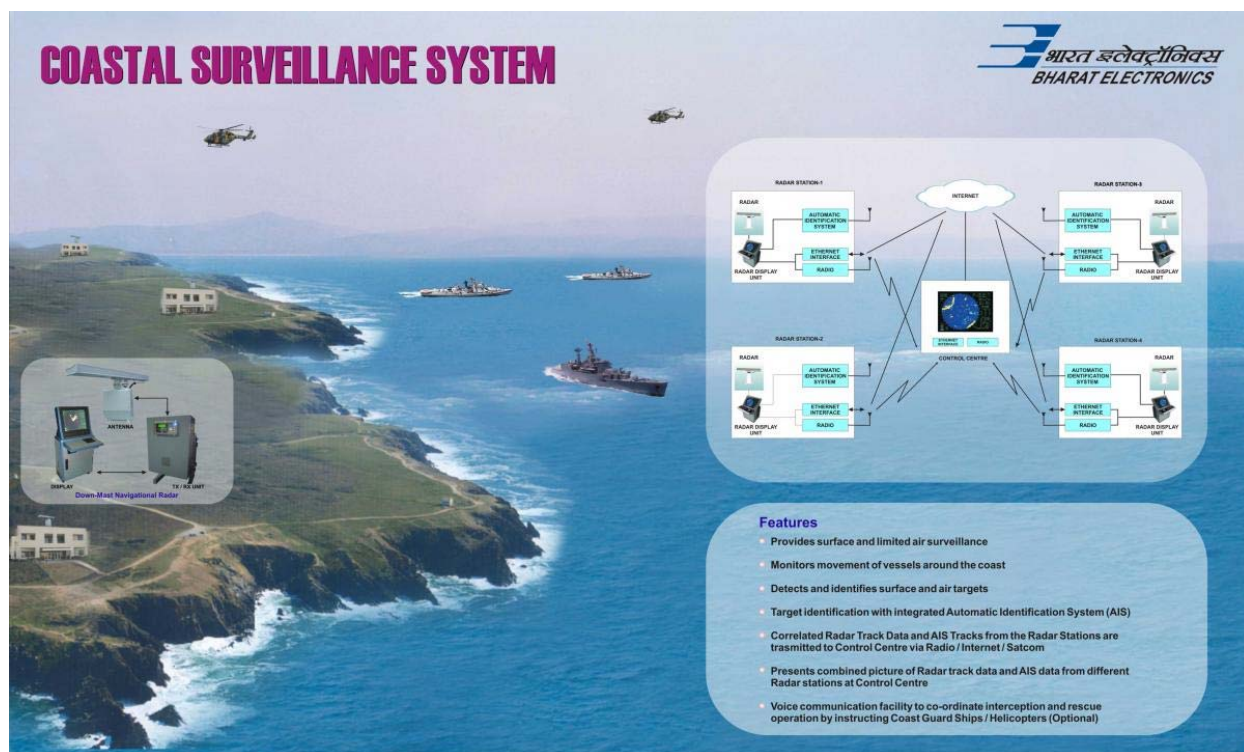


Figure 91. India's Bharat Electronics Coastal Surveillance System Illustrated on Bharat Electronics' Website

Others go farther, marketing systems combining both surveillance capabilities and weapons.

- **NORINCO 155 mm Coastal Defense System (China):** At Eurosatory 2014, NORINCO marketed this system as a “complete structure” that includes a reconnaissance subsystem, fire direction and control subsystem, logistic and support subsystem, and simulation and training subsystem.



**Figure 92. China's NORINCO 155mm Coast Defense Weapon System
Brochure at Eurosatory 2014**

- IMI Coast and Islands Defense System (CIDS) (Israel):** At both Eurosatory 2014 and the Singapore Air Show 2014, IMI advertised CIDS as an advanced system for protecting critical infrastructure and key assets in sea and coastal areas. CIDS consists of single/multiple coastal defense radars, which are backed by an optional suite of sensors that includes maritime surveillance manned or unmanned platforms for detecting and tracking possible threats. Other components include the LYNX self-propelled multiple rocket launcher and IMI's newly developed Remote Controlled Fixed Launchers, as well as a variety of GPS-guided missiles with ranges of 10 to 150 km with accuracy up to 10 m.



**Figure 93. Israel's IMI Coast and Islands Defense System (CIDS)
Brochure at Eurosatory 2016**

S. Access Control

A corollary development is the plethora of access-control products that have recently appeared at international arms and police shows. We first encountered a single device being presented at two shows in 2005. Biometric devices were such an insignificant part of arms shows in the next decade that we seldom noted them in our trip reports. But in the last two years, biometric identification and verification systems have appeared at Eurosatory 2014, DSEi 2015, Paris Air Show 2015, and IDEX 2015 arms shows. Fifteen different biometric-based (e.g., fingerprint, voice) entry control devices appeared at the MILPOL 2015 police and security exhibition alone.

The wider use of biometric identification devices at border entry points will make it more difficult to insert individuals under one or more false identities into countries. This problem will become more serious, since 24 countries now maintain government-run centralized biometric databases. Some of these are (or soon will be) supplemented by regional and international ones. The European Commission has proposed the Smart Borders Initiative, which would share data regarding European and third-party nationals crossing borders into member countries. Since 2003, the European Commission has also maintained The European Data Protection Supervisor (EURODAC), a centralized fingerprint database of asylum seekers. Originally, EURODAC could be used only for asylum purposes, but it has recently been opened for use by national police forces and the European Police Office (EUROPOL) in criminal investigations.¹⁸⁹

Several companies are also offering intruder detection systems designed to counter clandestine entry by individuals into protected areas. This poses potentially serious problems for Special Forces personnel attempting to penetrate/operate undetected across borders or behind enemy lines. Examples of intruder detection systems available in the international arms market include:

- **SAES Multi-Sensor Underwater Intruder Detection System (Spain):** This company has offered two multi-sensor underwater intruder detection systems at DSEi 2015.
- **Atermes BARIER (*Balises Autonomes de Reconnaissance, d'Identification et d'Evaluation de la Riposte*) (France):** This system is a sentry beacon system from which is composed of eight autonomous sentry beacons and a C2 Vehicle. The BARIER system is designed to replace expensive observation towers that are easily avoidable by intruders and highly vulnerable. The system allows for permanent automatic surveillance of difficult access areas (like mountains, deserts, creeks, etc.).
- **EVPU Defence Mobile Monitoring and Surveillance Systems (Czech Republic):** The Mobile Monitoring and Surveillance Systems can be used especially for monitoring and surveillance of areas such as borders, airports, power plants, and

¹⁸⁹ "Identification of applicants (EURODAC)," European Commission. Accessed on 9 March 2015 at http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/asylum/identification-of-applicants/index_en.htm.

other areas with increased demands, for flexible protection against penetration of intruders during day or night.

- **RADA Electronic Industries Three-Dimensional Perimeter Surveillance Radar (Israel):** RADA has marketed a Three-Dimensional Perimeter Surveillance Radar that provides comprehensive border and perimeter surveillance through detection, classification, and tracking of surface and aerial intruders, such as pedestrians, vehicles, slow and small aircraft, vessels, and more, at ranges of up to 40 km. A RADA brochure claims that its 3D Perimeter Surveillance Radar Systems are “the systems of choice for borders, coasts and critical infrastructure protection solutions.”
- **EXAVISION Optronic Solutions (France):** EXAVISION designs and produces complex optronic solutions for protecting goods and people in sensitive sites, mainly in the defense, homeland security, and nuclear sectors. The company’s main products and solutions dedicated to site protection are:
 - **Fixed infrastructure solutions** – Multi-sensor observation systems (MOS series), radar coupling (EXA-RADAR), sensor supervision/VMS (VIGISENS) and automatic target and/or area tracking (SADEZ). Ruggedized and waterproof pan and tilt camera solutions for short- to long-range surveillance (OMNICAM Long Range and EPERVIER).
 - **Mobile and embedded solutions** – Rapid deployment solutions: full range of cameras and optronic solutions for rapid deployment on vehicles (OMNICAM DUO), observation and neutralization robots (ROBSON), and tethered balloons (EYEBALL 36). Portable solutions include body worn cameras, binoculars, and viewfinders for night vision.
 - **Multi-sensor supervision software (optronic, radar, AIS, other)** – Range of application software designed for analysis, control, and video management, GPS, automatic target and zones tracking, image, data management and fusion, and visible and thermal image fusion (THERMVIS).

Companies offer more than just individual detection and monitoring systems; they now network capabilities that link: (1) surveillance and detection, (2) information processing and collection, (3) information sharing, (4) situational awareness, and (5) interception and strike functions. A Coastal Defense System offered by Poly Technologies at DSA 2016 illustrates these networked complexes in the following figures.

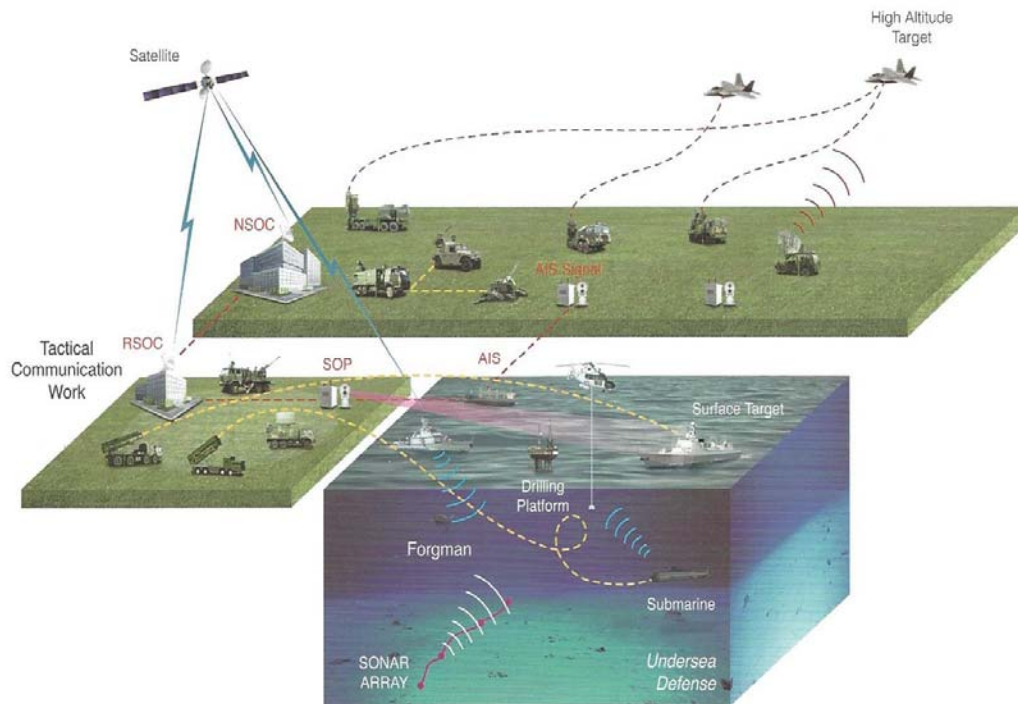


Figure 94. China's Poly Technologies Coastal Defense System Overview Brochure at DSA 2016

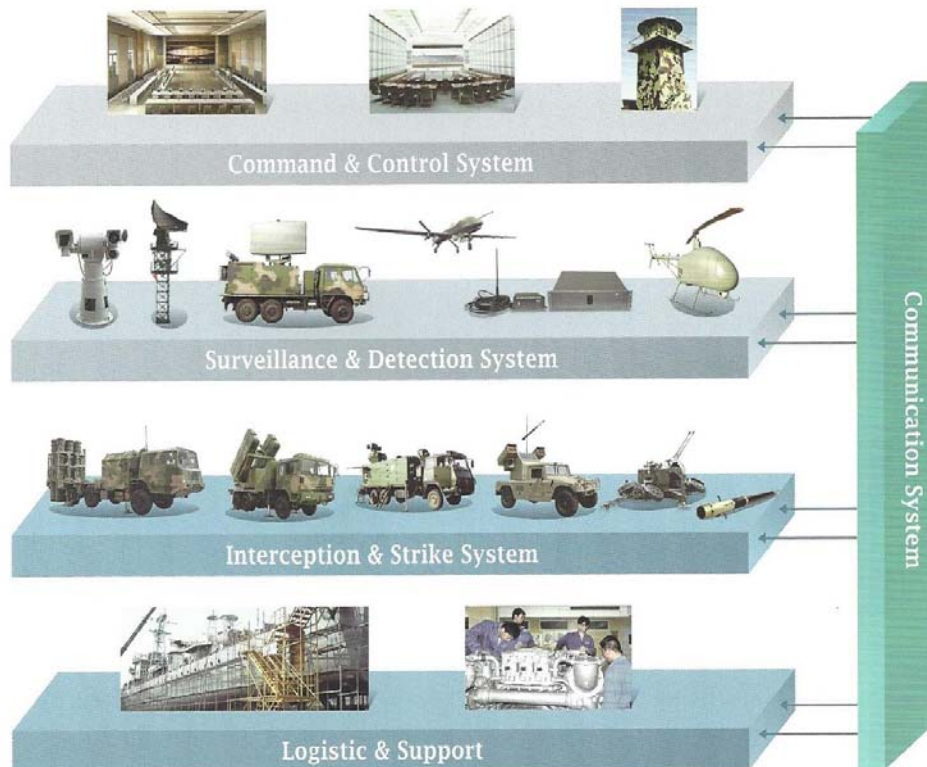


Figure 95. China's Poly Technologies Coastal Defense System Composition Brochure at DSA 2016

Table 42. Equipment Used in Poly's Coastal Defense System

Airborne Platforms	Sensors	Air Defense	Artillery and Rocket Systems	Anti-Ship Missiles	Vessels
- Armed Helicopter - Z-5 UAV - CH-803 UAV - CH-4 UAV - ASN-209 UAV	- Electro-optic - Thermal IR - Laser range finder - Sonar - JH-8 coastal radar - LB-63 OTH coastal radar	- FD-2000 SAM - LY-80 SAM - LY-60D SAM - FB-6A SAM - FN-16 MANPADS 35mm air defense guns	- CS/SH1 122mm truck-mounted howitzer - WS-1B 300mm MLRS - WS-3A 400mm MLRS - Rocket-Launched ASW Torpedo	- C602 - C802 - C704	154m Destroyer 95m OPV 132m Frigate 119m Landing Ship 65m Missile Boat 45m Twin-Hull Missile Boat 46m Patrol Boat 63m Patrol Boat - Conventional Submarine

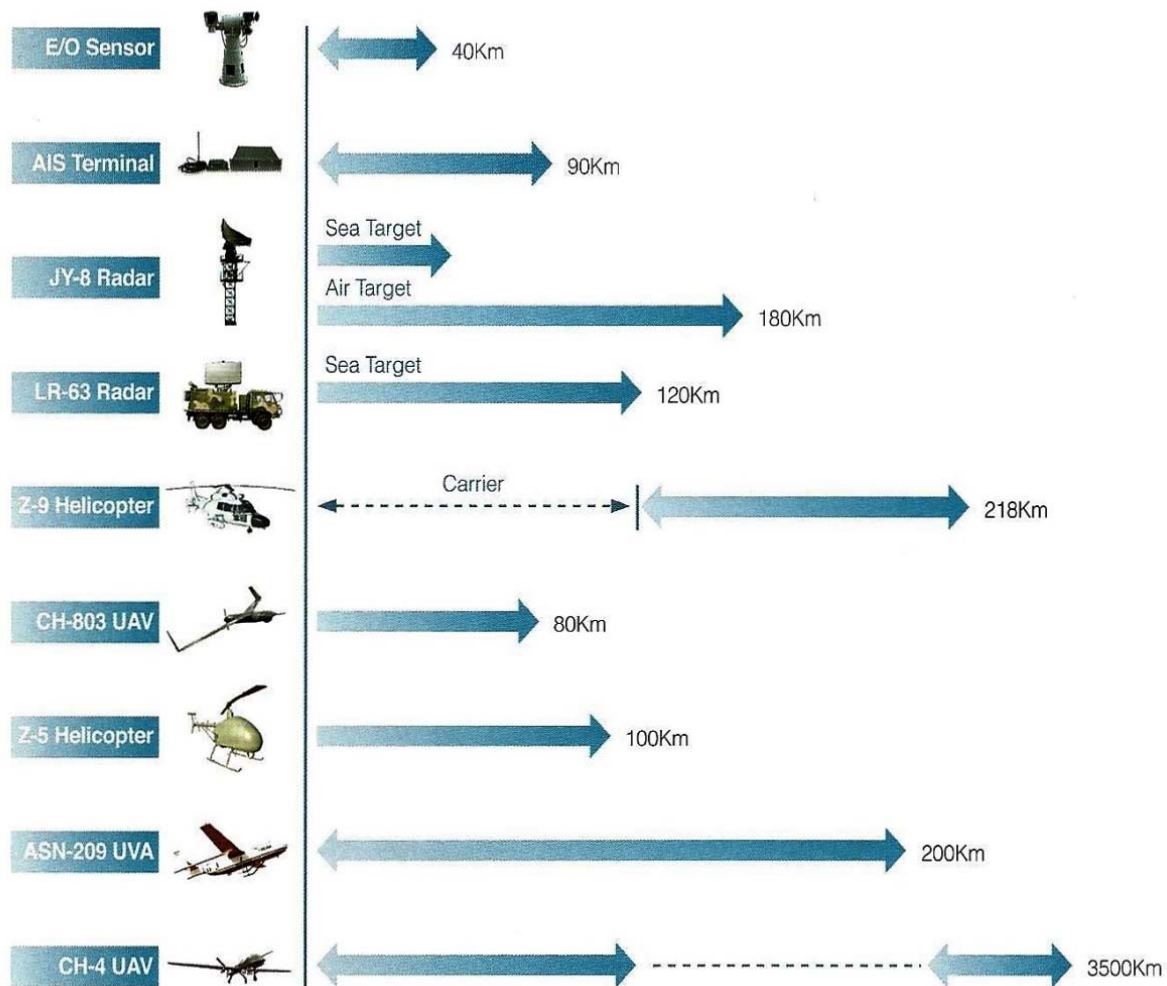


Figure 96. China's Poly Technologies Coastal Defense System's Range of Surveillance and Detection Systems Brochure at DSA 2016

The Modular Security Systems (MGUB) designed by Turkey's Aselsan is another example of an integrated system. MGUB provides (1) day/night surveillance and detection, (2) reaction by remote weapon station, (3) special design habitation units, and (4) turnkey military bases. MGUB incorporates: (1) security management center, (2) armored security vehicles or stationary towers, (3) ground surveillance radars, (4) panoramic 360 degree situational awareness system, (5) wireless sensor networks, (6) remote weapons systems, (7) ballistic protection systems, (8) physical security systems (e.g., barbed wire, fences, etc.), and (9) various special design habitation units.

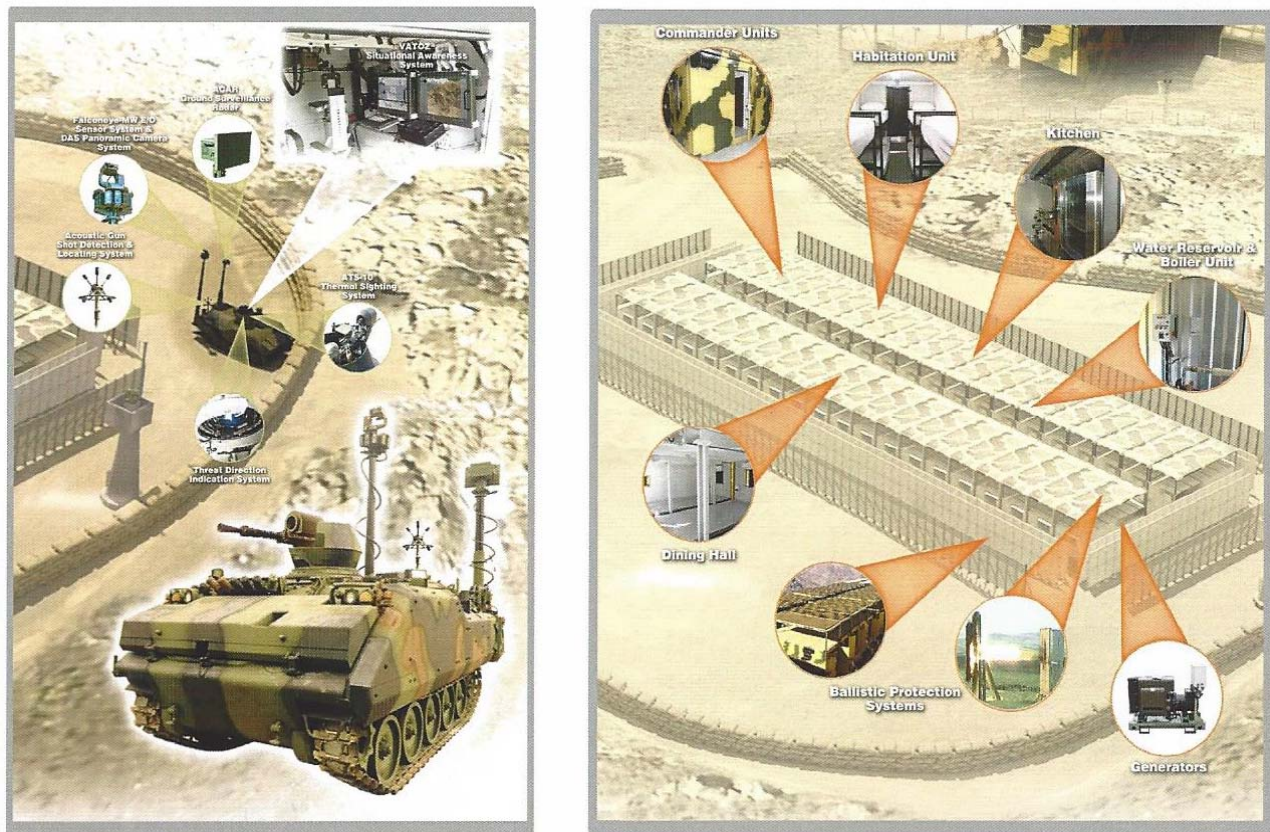


Figure 97. Turkey's Aselsan Turnkey Military and Force Protection Modular Security Systems (MGUB) Brochure at DSA 2016

T. Flexible Response Warheads

Lockheed-Martin, BAE Systems, and TDW GmbH (an MBDA company) have been experimenting with flexible response or scalable warheads since 2009, but only in the last couple of years have such capabilities been advertised at international arms shows. Most of the focus has been on a “dial-a-yield” fusing to allow an operator to select different explosive output levels from a single munition. Developers are touting the possibility of reducing the number of different weapon systems needed in the future by offering a single product with multiple uses that saves money by reducing the number of platforms, logistic complexity, and lifecycle costs.

TDW GmbH advertised even more flexibility at DSEi 2015 with its family of scalable effect warheads. (See Figure 98. Europe's for an illustration of the range of capabilities.) This family consists of:

- **Scalable Effect Warheads (Dial-a-Yield)** that offer a way of managing layered detonation and deflagration of high explosives.
- **Switchable Mode Warhead (Dial-a-Mode)** offering various modes to include fragmentation or perforation effects, allowing the operator to engage a wide range of targets, from soft targets to heavy armored vehicles.
- **Aimable Warheads (Dial-a-Direction)** that optimize the lethality by focusing the blast/fragmentation effect in the desired direction.
- **Multi-Effects Warhead (Dial-an-Effect)**, which TDM GmbH calls the “ultimate lethal package,” combining a shaped charge, a blast/fragmentation, and a penetrator effect.



Figure 98. Europe's TDW GmbH (an MBDA Company) Flexible Response Warheads Briefing Slide at DSEi 2015

6. Recommendations

Any set of recommendations involves a number of stakeholders, both inside and outside of DOD. Table 43 provides an overview of the various stakeholders involved in any set of recommendations that ensures the continuing dominance of the U.S. in the international arms market over the next 5 to 10 years.

Table 43. DOD and Non-DOD Stakeholders Interested in Maintaining U.S. International Arms Market Presence

DOD Stakeholder	Ensuring Continued Dominance
Operators-Doctrine Writers	Potential uses, limitations, and vulnerabilities of exporting U.S. weapon systems
Policy Makers	Implications for policies of DOD as a facilitator of U.S. weapons on the international arms market
Testers	Testing methodologies suited to various foreign user communities for emerging weapon class such as unmanned systems and ISR software
Requirements Community	Requirements process adopting early consideration of exportability of new weapon systems, software and subcomponents
Acquisition Community	Identification of new high-payoff programs with potential to capture or maintain major international arms market segments Maintain an acquisition strategy where export potential remains an essential element of the strategy
DOD S&T Community	Identification of priority focus areas for aligning technology that can be exported or available in export variant to maintain an advantage in the international arms market
Non-DOD Interests	Vested Interest in a Maintaining a Presence
Academia	Maturing technology to enable solutions to important, hard problems where the U.S. has a current advantage and find areas in new weapon concepts where no market currently exists (e.g. unmanned systems and autonomy)
Start-Up Companies	Facilitate potential new markets in developing markets such as cyber and unmanned systems
Commercial Industry	Incentivize exploration of potential new markets without the normal burden of government contracting or regulation
Defense Industrial Base	Understanding system integration opportunities for future programs of record both in the U.S. and overseas for export potential

This study provides recommendations aligned with five over-arching international arms market vectors affecting the ability of the U.S. to remain competitive in major weapon systems, subcomponents and software in the next 5 to 10 years: (1) DOD Organizational Response, (2) Defense Industry Competition, (3) Regulatory and Technology Control Environment, (4) Market Competition and (5) Cost Competition.

DOD's organizational response to a more competitive, globalized international arms market should include assessing the implications of these trends on U.S. national security interests, defining U.S. objectives related to the international arms market, and developing a strategy to achieve those goals. AT&L (International Cooperation) could play a prominent role in that process. Precursor actions that could be taken to support the development of such a strategy include:

- DOD Organizational Responses
 - Propose study by the Defense Science Board Summer Study or other independent organization on “Emerging challenges to international defense cooperation and U.S. defense trade.” AT&L (International Cooperation) could assist in drafting the terms of reference and participate in that Defense Science Board Summer Study.
 - Host/sponsor a conference with academia, think tanks, and industry focused on developing a national strategy.
 - AT&L (International Cooperation), with assistance from the Directorate of Defense Trade Controls of the Department of State and the International Trade Administration of the Department of Commerce, could lead a DOD team in drafting a DOD-wide defense export strategy: “Defense Trade a Key Element in National Soft Power: DOD's Defense Export Trade Strategy.”
 - Establish a mechanism for an intelligence community liaison whose sole purpose is to provide insight into emerging foreign weapon system developments and requirements trends on the international arms market.
- Defense Industry Competition
 - Host/sponsor a multi-day regional defense trade symposium on emerging defense trade issues, and host this on an annual basis.
 - Explore the creation of a public-private defense board to examine the consequences of alternative U.S. positions in the international arms in the face of growing competition.
 - Sponsor a study to identify and assess emerging threats and opportunities to the current U.S. position as a major provider of second- and third-tier technology, subcomponents, and software.

- Regulatory and Technology Control Environment
 - DOD, working with appropriate interagency partners, could assess the effects of the U.S. arms control regulatory regime against the objectives for that regime, and develop alternative or supplementary courses of action that might better achieve U.S. objectives.
 - Host a government-wide conference on how best to regulate defense technology in light of new market realities that are emerging over the next 5 to 10 years
 - Convene a working group in AT&L looking at implications for the U.S.'s position in the international arms market in emerging markets where the U.S. is not positioned to be competitive or have presence due to the U.S. regulatory environment.
- Market Competition
 - Make consideration of the export potential a strategic element in the acquisition process and urge that design for export be the default whenever possible. (DOD's Defense Exportability Features initiatives may be of assistance in this effort.) The AT&L (International Cooperation) office role could be to assess all of the acquisitions in the DOD pipeline on a continuing basis to determine if due consideration is being given to Defense Exportability Features. In some cases, it may mean DOD buying a limited number of the export variants (e.g., for aggressor squadrons), since that is a big consideration for other countries' purchasing and assures them of a continuing logistics train.
 - Given the importance of defense exports as a component of U.S. national security relationships with foreign partners, AT&L (International Cooperation) could serve as an advocate ensuring that U.S. suppliers provide suitable platforms for export markets.
 - Create and fund an ongoing analytical effort to monitor, assess, and inform DOD of current trends in the international arms market to identify emerging opportunities for international cooperation and defense trade, as well as impediments to those opportunities.
 - Produce an analytical framework and assessment of the size of the U.S. defense technology export markets in design, services, and software.
 - Request appropriate U.S. government agencies provide assessments of likely new weapon systems, technologies, and subcomponents that they believe will transform the international arms market in the next 5 to 10 years. The office of AT&L (International Cooperation) could synthesize these two viewpoints to develop a strategy and candidate/product list of potential cooperative international programs that addresses identified advanced technologies and potential buyers' needs.

- Cost Competition
 - Cost is often a decision driver/barrier for potential buyers. Many U.S. systems are too expensive for the markets. If the objectives are to deter/defeat neighboring states and support internal security missions, then lower-quality/less expensive “good enough” systems may suffice. AT&L (International Cooperation) could participate with other U.S. Government agencies in identifying where there is a reasonable opportunity for economic return. DOD should then encourage U.S. industry to identify and address opportunities such as the private low-cost SpaceX initiative which designs, manufactures, and launches advanced rockets and space craft.
 - Produce a study on U.S. weapon systems cost competitiveness on the international arms market in the next 5 to 10 years when compared to increasing competition among traditional suppliers and numerous off-set providers (e.g., newly emerging defense manufacturing RD&A in countries such as Turkey, South Korea, and United Arab Emirates).

Appendix A.

Selected Weapons Delivery to Developing Nations 2008 to 2015

A. Introduction

The following tables were developed by the Congressional Research Service based on data supplied by the U.S. Government for selected weapons deliveries by the U.S., Russia, China, Major Western European states, all other European States, and all other nations.¹⁹⁰ The category “Major Western European” states cover deliveries by France, United Kingdom, Germany, and Italy and presents an aggregate number for those states. “Developing nations” excludes the U.S., Russia, Europe, Canada, Japan, Australia, and New Zealand.

B. Overview of Deliveries to Developing Nations 2008 to 2015

Table A-1. Overview of Number of Weapons Delivered to Developing Nations 2008 to 2011

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	348	630	490	360	550	50
Artillery	155	110	340	140	600	190
APCs and Armored Cars	188	570	620	420	1,630	580
Major Surface Combatants	0	2	3	5	5	4
Minor Surface Combatants	0	8	113	64	52	118
Guided Missile Boats	0	2	0	0	0	4
Submarines	0	2	0	4	1	0
Supersonic Combat Aircraft	58	170	30	40	130	50
Subsonic Combat Aircraft	0	0	20	50	20	80
Other Aircraft	62	20	130	50	160	40
Helicopters	35	270	20	150	70	50
Surface-to-Air Missiles	1,088	8,160	2,080	360	650	500
Surface-to-Surface Missiles	1,285	70	0	0	0	10
Anti-Ship Missiles	133	260	80	80	10	50

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

¹⁹⁰ Catherine A. Theohary, “Conventional Arms Transfers to Developing Nations, 2008-2015,” Congressional Research Service, op. cit.

Table A-2. Overview of Number of Weapons Delivered to Developing Nations 2012 to 2015

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	76	430	130	80	390	10
Artillery	232	130	250	40	630	430
APCs and Armored Cars	1	680	760	960	920	460
Major Surface Combatants	0	3	6	13	2	4
Minor Surface Combatants	0	8	19	67	67	86
Guided Missile Boats	0	0	2	2	0	7
Submarines	0	4	0	8	0	2
Supersonic Combat Aircraft	45	100	20	20	20	40
Subsonic Combat Aircraft	0	0	0	20	10	30
Other Aircraft	35	20	50	130	260	50
Helicopters	2	280	40	140	30	50
Surface-to-Air Missiles	346	6,300	1,310	1,130	240	630
Surface-to-Surface Missiles	163	80	10	0	0	0
Anti-Ship Missiles	116	40	110	210	0	20

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

C. Deliveries to Latin America 2008 to 2015

Table A-3. Number of Weapons Delivered by Suppliers to Latin America 2008 to 2011

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	0	110	0	260	0	0
Artillery	1	70	0	20	60	0
APCs and Armored Cars	39	60	20	160	230	50
Major Surface Combatants	0	0	0	3	0	2
Minor Surface Combatants	0	0	2	14	14	12
Guided Missile Boats	0	0	0	0	0	0
Submarines	0	0	0	0	0	0
Supersonic Combat Aircraft	0	10	0	10	20	30
Subsonic Combat Aircraft	0	0	0	0	0	60
Other Aircraft	41	0	30	0	40	10
Helicopters	9	60	0	30	10	10
Surface-to-Air Missiles	0	3,080	110	0	30	0
Surface-to-Surface Missiles	0	0	0	0	0	0
Anti-Ship Missiles	0	0	0	0	10	10

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

Table A-4. Number of Weapons Delivered by Suppliers to Latin America 2012 to 2015

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	0	30	0	40	0	0
Artillery	0	80	40	10	70	0
APCs and Armored Cars	0	340	190	0	30	10
Major Surface Combatants	0	0	0	3	0	1
Minor Surface Combatants	0	0	1	13	8	11
Guided Missile Boats	0	0	0	0	0	0
Submarines	0	0	0	2	0	0
Supersonic Combat Aircraft	0	0	0	0	0	10
Subsonic Combat Aircraft	0	0	0	0	0	10
Other Aircraft	11	0	10	40	70	10
Helicopters	2	20	10	30	0	10
Surface-to-Air Missiles	0	2,260	0	0	30	0
Surface-to-Surface Missiles	0	0	0	0	0	0
Anti-Ship Missiles	2	0	0	0	0	20

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

D. Deliveries to Asia and Pacific 2008 to 2015

Table A-5. Number of Weapons Delivered by Suppliers to Asia and Pacific 2008 to 2011

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	0	390	230	100	40	10
Artillery	5	40	140	10	80	70
APCs and Armored Cars	25	310	130	0	610	100
Major Surface Combatants	0	2	3	2	3	2
Minor Surface Combatants	0	6	2	14	1	45
Guided Missile Boats	0	2	0	0	0	2
Submarines	0	0	0	3	1	0
Supersonic Combat Aircraft	18	130	10	10	10	0
Subsonic Combat Aircraft	0	0	10	50	0	20
Other Aircraft	14	0	60	30	50	20
Helicopters	2	110	10	30	20	20
Surface-to-Air Missiles	441	1,130	1,640	360	0	500
Surface-to-Surface Missiles	1,285	20	0	0	0	10
Anti-Ship Missiles	133	150	80	30	0	0

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

Table A-6. Number of Weapons Delivered by Suppliers to Asia and Pacific 2012 to 2015

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	24	190	70	30	10	0
Artillery	96	10	70	20	100	30
APCs and Armored Cars	0	320	10	570	240	30
Major Surface Combatants	0	3	5	3	0	1
Minor Surface Combatants	0	8	2	13	0	36
Guided Missile Boats	0	0	2	0	0	0
Submarines	0	4	0	5	0	2
Supersonic Combat Aircraft	0	80	10	0	10	30
Subsonic Combat Aircraft	0	0	0	20	0	10
Other Aircraft	9	10	20	40	110	10
Helicopters	0	180	10	60	20	20
Surface-to-Air Missiles	110	160	430	210	130	0
Surface-to-Surface Missiles	149	20	0	0	0	0
Anti-Ship Missiles	94	40	110	40	0	0

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

E. Deliveries to Near East 2008 to 2015

Table A-7. Number of Weapons Delivered by Suppliers to Near East 2008 to 2011

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	288	50	60	0	70	10
Artillery	149	0	120	100	340	50
APCs and Armored Cars	124	130	160	130	670	250
Major Surface Combatants	0	0	0	0	1	0
Minor Surface Combatants	0	2	0	32	23	17
Guided Missile Boats	0	0	0	0	0	0
Submarines	0	2	0	0	0	0
Supersonic Combat Aircraft	16	30	0	20	80	0
Subsonic Combat Aircraft	0	0	0	0	0	0
Other Aircraft	7	20	20	10	50	0
Helicopters	24	30	0	60	0	10
Surface-to-Air Missiles	647	3,830	330	0	150	0
Surface-to-Surface Missiles	4572	50	0	0	0	0
Anti-Ship Missiles	0	110	0	50	0	40

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

Table A-8. Number of Weapons Delivered by Suppliers to Near East 2012 to 2015

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	52	210	0	10	80	10
Artillery	136	40	60	0	170	280
APCs and Armored Cars	1	10	10	250	560	180
Major Surface Combatants	0	0	1	7	2	2
Minor Surface Combatants	0	0	0	18	32	0
Guided Missile Boats	0	0	0	0	0	0
Submarines	0	0	0	1	0	0
Supersonic Combat Aircraft	45	10	0	20	0	0
Subsonic Combat Aircraft	0	0	0	0	0	0
Other Aircraft	15	10	0	30	60	20
Helicopters	0	50	0	40	0	20
Surface-to-Air Missiles	236	3,880	390	920	20	270
Surface-to-Surface Missiles	14	60	0	0	0	0
Anti-Ship Missiles	20	0	0	170	0	0

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

F. Deliveries to Africa 2008 to 2015

Table A-9. Number of Weapons Delivered by Suppliers to Africa 2008 to 2011

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	60	80	200	0	440	30
Artillery	0	0	80	10	120	70
APCs and Armored Cars	0	70	310	130	120	180
Major Surface Combatants	0	0	0	0	1	0
Minor Surface Combatants	0	0	109	4	14	44
Guided Missile Boats	0	0	0	0	0	2
Submarines	0	0	0	1	0	0
Supersonic Combat Aircraft	24	0	20	0	20	20
Subsonic Combat Aircraft	0	0	10	0	20	0
Other Aircraft	0	0	20	10	20	10
Helicopters	0	70	10	30	40	10
Surface-to-Air Missiles	0	120	0	0	470	0
Surface-to-Surface Missiles	0	0	0	0	0	0
Anti-Ship Missiles	0	0	0	0	0	0

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

Table A-10. Number of Weapons Delivered by Suppliers to Africa 2012 to 2015

Weapons Category	U.S.	Russia	China	Major West European*	All Other European	All Others
Tanks and Self-Propelled Guns	0	0	60	0	300	0
Artillery	0	0	80	10	290	120
APCs and Armored Cars	0	10	550	140	90	240
Major Surface Combatants	0	0	0	0	0	0
Minor Surface Combatants	0	0	16	23	27	39
Guided Missile Boats	0	0	0	2	0	7
Submarines	0	0	0	0	0	0
Supersonic Combat Aircraft	0	10	10	0	10	0
Subsonic Combat Aircraft	0	0	0	0	10	10
Other Aircraft	0	0	20	20	20	10
Helicopters	0	30	20	10	10	0
Surface-to-Air Missiles	0	0	490	0	60	360
Surface-to-Surface Missiles	0	0	10	0	0	0
Anti-Ship Missiles	0	0	0	0	0	0

Source: U.S. Government.

Note: Developing nations category excludes the United States, Russia, Europe, Canada, Japan, Australia, and New Zealand. All data are for calendar years given. Data relating to surface-to-surface and anti-ship missiles by foreign suppliers are estimates based on a variety of sources having a wide range of accuracy. As such, individual data entries in these two weapons delivery categories are not necessarily definitive.

*Major West European includes France, United Kingdom, Germany, and Italy totals as an aggregate figure

Table A-11. Countries in Each Region of the Arms Delivery Tables

Asia	Near East	Europe	Africa	Latin America
Afghanistan	Algeria	Albania	Angola	Antigua
Australia	Bahrain	Armenia	Benin	Argentina
Bangladesh	Egypt	Austria	Botswana	Bahamas
Brunei	Iran	Azerbaijan	Burkina Faso	Barbados
Burma (Myanmar)	Iraq	Belarus	Burundi	Belize
China	Israel	Bosnia/Herzegovina	Cameroon	Bermuda
Fiji	Jordan	Bulgaria	Cape Verde	Bolivia
India	Kuwait	Belgium	Central African	Brazil
Indonesia	Lebanon	Croatia	Republic	British Virgin Islands
Japan	Libya	Czechoslovakia/	Chad	Cayman Islands
Cambodia	Morocco	Czech Republic	Congo	Chile
Kazakhstan	Oman	Cyprus	Côte d'Ivoire	Colombia
Kyrgyzstan	Qatar	Denmark	Djibouti	Costa Rica
Laos	Saudi Arabia	Estonia	Equatorial Guinea	Cuba
Malaysia	Syria	Finland	Ethiopia	Dominica
Nepal	Tunisia	France	Gabon	Dominican Republic
New Zealand	United Arab	FYR/Macedonia	Gambia	Ecuador
North Korea	Emirates	Georgia	Ghana	El Salvador
Pakistan	Yemen	Germany	Guinea	French Guiana
Papua New Guinea		Greece	Guinea-Bissau	Grenada
Philippines		Hungary	Kenya	Guadeloupe
Pitcairn		Iceland	Lesotho	Guatemala
		Ireland	Liberia	
Singapore		Italy	Madagascar	Guyana
South Korea		Latvia	Malawi	Haiti
Sri Lanka		Liechtenstein	Mali	Honduras
Taiwan		Lithuania	Mauritania	Jamaica
Tajikistan		Luxembourg	Mauritius	Martinique
Thailand		Malta	Mozambique	Mexico
Turkmenistan		Moldova	Namibia	Montserrat
Uzbekistan		Netherlands	Niger	Netherlands Antilles
Vietnam		Norway	Nigeria	Nicaragua
		Poland	Réunion	Panama
		Portugal	Rwanda	Paraguay
		Romania	Senegal	Peru
		Russia	Seychelles	St. Kitts & Nevis
		Slovak Republic	Sierra Leone	St. Lucia
		Slovenia	Somalia	St. Pierre & Miquelon
		Spain	South Africa	St. Vincent
		Sweden	Sudan	Suriname
		Switzerland	Swaziland	Trinidad
		Turkey	Tanzania	Turks & Caicos
		Ukraine	Togo	Venezuela
		United Kingdom	Uganda	
		Yugoslavia/Serbia/	Zaire	
		Montenegro	Zambia	
			Zimbabwe	

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Appendix D. Acronyms

AGM	Artillery Gun Module
ALIT	China Aerospace Long-March International
APC	Armored Personnel Carrier
AT	Anti-tank
ATGM	Anti-Tank Guided Missile
AT&L	Acquisition, Technology and Logistics
CAsMM	Common Anti-surface Modular Missile
CATOD	Center for Technical and Operational Analysis
CEP	Circular error probability
CETC	China Electronic Technology Corporation International
CONOPS	Concepts of Operation
COTS	Commercial-Off-the-Shelf Technology
C-RAM	Counter Rockets, Artillery and Mortar
CROS	Crisis Response Operations Simulator
DGA	Délégation générale de l'armement ("Directorate of General Armaments")
DOD	Department of Defense
DRDO	Defense Research and Development Organization
DRFM	Digital Radio Frequency Memory
DSA	Defense Services Asia
EEZ	Exclusive Economic Zone
ELINT	Electronic Intelligence
EURODAC	European Data Protection Supervisor
EUROPOL	European Police Office
EW	Electronic Warfare
FAHW	Fast Attack Helicopter Weapon
FCC	Flight control computer
FELIN	Fantassin à Équipements et Liaisons Intégrés ("Infantry with Integrated Communication and Equipment")
GIAT	<i>Groupeement des Industries de l'Armée de Terre</i>
GICAT	Groupement des industries de défense et de sécurité terrestres et aéroterrestres ("Group of Land and Air Defense and Security Industries")
GLONASS	Global Navigation Satellite System
GmbH	Gesellschaft mit beschränkter Haftung ("company with limited liability")
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
Gripen NG	Gripen Next Generation
IAI	Israel Aerospace Industries
IDA	Institute for Defense Analyses
IDEX	International Defense Exhibition
IED	Improvised Explosive Device
IMI	Israel Military Industries
IMU	Inertial measurement unit
INS	Inertial Navigation Systems
IR	Infrared
IRNSS	Indian Regional Navigation Satellite System
ITAR	International Traffic in Arms Regulations
K-FX	Korean Fighter Xperimental
KMW	Krauss-Maffei Wegmann
LTO	Laboratory Technical-Operational
MANPADS	Man-Portable Air Defense System
MAP	Multi-Purpose Armored Platform
MBT	Main Battle Tank
MCS	Modular Charge System
MGUB	Modular Security System
MLRS	Multiple Launch Rocket System
MRAP	Mine-Resistant Ambush Protected
NAVDEX	Naval Exhibition and Conference
NIR	Near infrared
NORINCO	North China Industries Company
NetCOS	Network Centric Operations Simulation
PAK-FA	Perspektivny Aviatsionny Kompleks Frontovoy Aviatsii ("Prospective Airborne Complex of Frontline Aviation")
PDMS	Polydimethylsiloxane
PzH	Panzerhaubitze ("armored howitzer")
RAE	Russian Arms Expo
RAM	Radar absorbing material
RCS	Radar Cross Section
R&D	Research and development
RDT&E	Research, Development, Testing & Evaluation
RF	Radio frequency
ROK	Republic of Korea
SA	Small Arms
SAP	State Armaments Plan (SAP)

SP	Self-Propelled
SIGINT	Signals intelligence
TIR	Thermal infrared
TRDI	Technology Research and Development Institute
TTPs	Tactics, Techniques and Procedures
TV	Television
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UMEX	Unmanned Systems Exhibition and Conference
UV/VIS	Ultraviolet/visible

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