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# **WEAPONS**

## **A Report on the Industry**

**Industry Study 5240-11**

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## **ABSTRACT**

The weapons industry – with products ranging from nuclear weapons to non-lethal arms – is large and complex. Despite this complexity, it maintains an especially close relationship with its main customer, the United States military. Therefore, while the weapons industry faces many of the same challenges as other industries, it also faces unique issues as a major supplier to a transforming military. This paper examines the industry’s ability to perceive and effectively incorporate disruptive innovations, as defined by Clayton Christensen, which may dramatically change the nature of the industry. Ability to anticipate and respond to change is not only necessary for a victorious military, as noted by General Giulio Douhet, the Italian air strategist, but is also vital for the survival of an industry.

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# WEAPONS

*“Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.”*

Giulio Douhet, 1921

## INTRODUCTION

Three major forces are driving change to the weapons industry: globalization, changes in warfare, and the introduction of disruptive innovations on a scale not seen since WWII.

### Trends Shaping the Weapons Industry

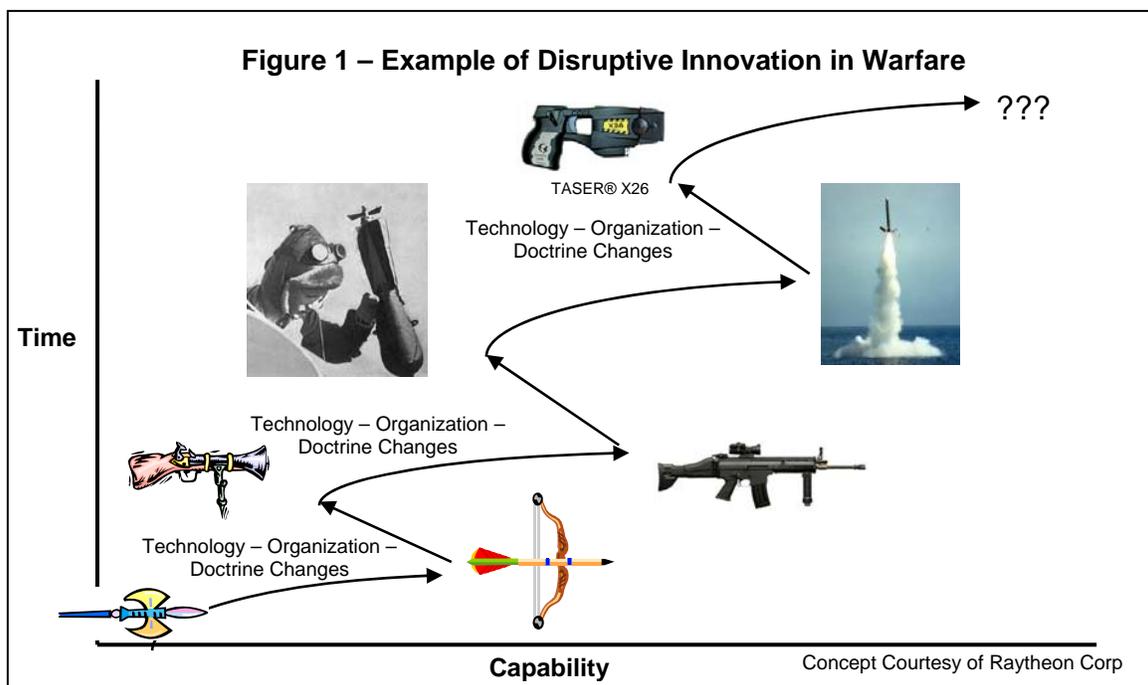
- Globalization
- Changes to military warfare
- Disruptive innovations

Proliferation of information is motivating structural changes in politics, the military, economics, and other facets of society throughout the world. The weapons industry is not immune to this globalization process. As decreased government spending on weapons forced consolidation of US suppliers, the importance of foreign ownership of parts of the supply chain has grown. This is seen by the increase of overseas suppliers of critical components, as well as in the number of foreign firms buying US companies to gain access to the US market. Conversely, US industry is increasing its foreign sales, allowing production lines to remain open longer and increasing corporate revenues.

The military is demanding more of its industrial partners as it continues to evolve in a post-Cold War world. Two factors driving this evolution are the movement toward net-centric warfare and the need for products that meet the needs of warfighters across the entire spectrum of conflict. Net-centric warfare involves systems that operate in a larger, more integrated operational environment. Moreover, today’s global environment is much more complex with the rise of national and international non-government organizations, transnational corporations, supranational organizations such as the European Union, and what Tom Friedman calls superpowered individuals.<sup>1</sup> The military’s need to operate in this integrated and complex environment requires a more diverse set of tools than previously required. As the military is compelled to change the ways in which it makes war, the weapons industry will be required to make its own changes to stay relevant.

The final change driver is the appearance of fundamentally new innovations in the industry. These disruptive innovations introduce new value propositions by either creating new markets or reshaping existing ones. Organizations must be able to scan the environment to see potential technological disruptions, and must have the flexibility required to adapt rapidly to and incorporate the technology. There are two types of disruptive innovations: low-end and new-market.<sup>2</sup> Low-end disruptive innovations happen when existing products and services are overpriced relative to the value customers can use. The use of Unmanned Aerial Vehicles (UAVs) may be considered a low-end disruption in that they replace expensive satellites and manned airplanes for reconnaissance and surveillance work. New-market innovations occur when they provide new benefits for the customer. Non-lethal weapons (NLWs) are a new-market disruptive technology because they allow soldiers to use weapons without killing – a potentially valuable tool on today’s battlefield. UAVs and NLWs represent product-based disruptive innovations in weapon systems that are responsive to changes in the nature of warfare. Both are discussed in further detail in the Essays section of the report.

Truly disruptive innovations require changes in doctrine and organization to harness the full value of their power. These changes, often made at the expense of some entrenched constituency, are very difficult to achieve in practice, and the necessary cultural shifts to effect change can take generations to implement fully. This suggests that although industry may be poised to place innovative weapons systems in the hands of operators, the military may be unable to adapt rapidly enough to make full use of them. The Department of Defense (DOD) is struggling to organize, train and equip to face the new broad spectrum of warfare challenges of the 21<sup>st</sup> century. Doctrinally, DOD may not be able to adapt fast enough to take advantage of these innovations at the pace they are emerging. Essays on “The Fight in 2024” and “Organization and Doctrine” further explore the challenges faced by the US military and its industry partners in transforming for the future fight. Figure 1 demonstrates how disruptive changes in technology, organization, and doctrine have changed the face of warfare.



## DEFINING THE WEAPONS INDUSTRY

This industry almost defies clear, unambiguous definition as weapons can be defined as virtually anything under certain legal and moral conditions. As such, we attempt to focus attention into the otherwise ubiquitous weapons industry.

The weapons industry includes the international population of organizations and businesses that envision, design, build, upgrade, and maintain weapons throughout their entire lifecycle. Both private firms and public sector agencies are included, as both have direct impact on the industry. Private firms manufacture and deliver weapons to the end user, typically the US government. The government, in turn, uses these weapons to produce necessary capabilities and effects as part of the National Military Strategy. Industry responds by some combination of improving existing capabilities or inventing new ones, energizing the military’s strategy-to-employment loop.

Considering all this, the weapons industry is an agglomeration of philosophy, strategy, resources, products, and application. We define the weapons industry as the cadre of political, military, and industrial professionals whose purpose it is to provide the technical expertise, manufacturing capability, and strategic vision to furnish effects-based capabilities to DOD in meeting National Security Strategy objectives.

What is a Weapon?

- Anything used to apply force against an adversary
- Offensive or defensive, lethal or not, high or low technology
- Depends on the entire sensor-to-target chain

**CURRENT CONDITIONS**

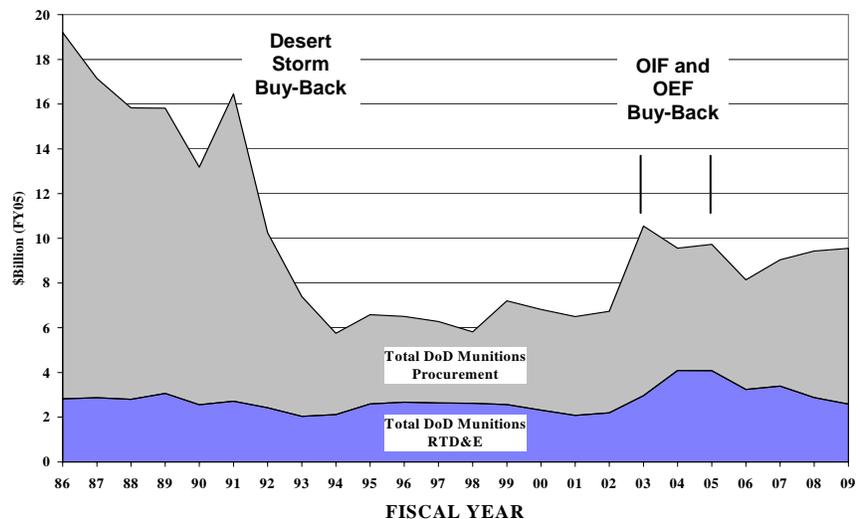
Given such a broad scope, it is difficult to assess the state of the industry as a homogenized unit; rather, different segments of the industry are often experiencing very different conditions. Discussing the weapons’ budget and industrial base status illustrates this point. One aspect of the situation applicable across the board is the impact of industry globalization.

Budgets

Over a decade ago, approximately 90% of the US weapons industry collective business was with the US DOD; today, that figure is approximately 50%.<sup>3</sup> Growth of the non-DOD customer base comes from the global market, as well as from various national security activities such as the Department of Homeland Security. Even so, DOD remains the primary customer of the weapons industry and plays a critical role in influencing the industry’s activities.

Weapons budgets are dispersed among a variety of accounts. Funding for traditional munitions, such as ammunition, bombs, and missiles, is in the munitions account. As shown in Figure 2, the combined munitions’ Research, Development, Test and Evaluation (RDT&E) and procurement funding accounts run between \$8B and \$11B for

**Figure 2 - DOD Munitions RDT&E and Procurement**



Fiscal Years 2003 through 2009.<sup>4</sup> Operations ENDURING FREEDOM and IRAQI FREEDOM (OEF/OIF) have generated some increase in funding to replace inventory,

but production levels of certain munitions such as air-to-air missiles and torpedoes remain low because they are not being used in ongoing operations. The industry is experiencing traditional problems of underfunding in R&D programs and robbing of future programs to meet current operational funding requirements. This problem will be exacerbated since a large portion of recapitalization of the military inventory has not yet been integrated into the DOD budget. Finally, the administration's push to reinvigorate tactical nuclear weapons for use against deeply buried targets will require further substantial investment.

UAVs continue to increase their role in the execution of the National Security Strategy. As such, the portion of the DOD budget allocated to UAVs continues to grow along with the industrial base supporting it. Over the last decade, DOD spent over \$3B on UAVs.<sup>5</sup> Fiscal year 2005 represents the first time annual UAV funding hit \$2B, almost a ten-fold increase over the last ten years and the UAV FY05 Future Years Defense Program totals \$11.5B. Weaponized UAVs are a small percentage of UAV platforms; however, the budget is growing.

In the centralized RDT&E funding line for NLWs, total 2002 budget authority was \$38.5M, growing to a high of \$45.7M in 2009.<sup>6</sup> It is difficult to discern the level of procurement budget levels for NLWs, but it is generally considered to be fairly low in comparison to funding for other weapon systems. For example, the Army's NLW munitions line grows from approximately \$1M in 2004 to only \$13M in 2006.<sup>7</sup> A radical change in military thinking that accepts the reconstruction and stabilization mission – and the significant role that NLWs can play in executing that mission – is required before NLW budgets will significantly increase.

### Industrial Base

Overall, the industrial base situation is relatively healthy and capable of meeting surge requirements, as demonstrated in the response to the recent conflicts in Afghanistan and Iraq. The financial health of large defense firms that serve as prime weapons contractors has improved with increased defense spending since the terrorist attacks of September 11<sup>th</sup>, from realized efficiencies of on-going consolidation, and from easy access to capital. In sectors of the industry where there have been surge requirements, the US increased production to meet those requirements and supplemented its need through procurements from allies.

Despite the overall health of the industry, two major underlying trends require ongoing DOD vigilance. There has been significant consolidation in the weapons industry since 1993 when Deputy Secretary of Defense William Perry told defense industry executives at the so-called "Last Supper" that the industry must eliminate excess capacity. This drawdown generated a perceived partial degradation of the US industrial base and the weapons development capability but, to the contrary, the consolidation actually invigorated industry by driving out product development inefficiencies, strengthening domestic and global corporate alliances, optimizing weapons acquisition strategies, and spawning a revolution in innovative technologies. Though not considered a formal administration policy, the consolidation fortified the US defense industrial base and prophetically positioned it for the future challenges of the 21<sup>st</sup> century.

However, with consolidation the industry has been reduced to a handful of prime contractors and suppliers of key components. As a result, the ability of DOD domestically to obtain cost efficiencies and technology advancements through competition is reduced. There are also some industry segments – such as small-arms ammunition, batteries, and fuses<sup>8</sup> - where consolidation appears to have reduced national capacity for innovation and timely response. In those areas where US industrial innovation and capital investment lagged, foreign suppliers took the opportunity to enter the US market, a move often necessary for their growth and survival. Foreign companies have shown the ability to compete successfully, to innovate, and meet surge requirements. They also make capital investment in areas neglected by the US.

Today, the US weapons industry is adequate for near-term requirements, has some ability to surge, and maintains substantial technological advantages over potential competitors. Some segments, such as UAVs, are experiencing a dramatic increase in R&D and production activity, while others are struggling to attain a healthy and robust capability. Consolidation, low production, and R&D austerity could, over time, erode the ability to surge for wartime requirements and maintain technological advantages. DOD must monitor this industry to ensure that as US national security threats evolve, the weapons industrial base is adequately positioned to meet those threats.

#### Summary of Weapons Industry Health

- OEF/OIF driving recapitalization of traditional munitions budgets, while UAV budgets grow and NLW budgets remain low
- Industrial base is relatively healthy and capable of meeting surge requirements
- US remains global leader, but foreign firms have become suppliers, competitors, and niche innovators

#### Globalization

Globalization – defined as the flow of large quantities of trade, investment, and technologies across national borders – is a phenomenon that has been occurring throughout the last century and has accelerated throughout the last two decades. As a result, the industrial base supporting the DOD and weapons industry is becoming increasingly international in character to the point where globalization is a fact of life for the industry. “This transformation is due largely to the confluence of four factors: (1) deep cuts in US defense investment in the Cold War’s wake (procurement and R&D are down 70 percent and 25 percent in real terms, respectively, since the late-1980s); (2) an explosion in commercial sector high-tech R&D investment and technological advancement; (3) a sustained DOD acquisition reform effort; and (4) a shift in procurement emphasis from weapons and platforms, per se, to the sophisticated information technologies so amplifying their capabilities.”<sup>9</sup>

US weapon contractors are actively pursuing growth in their global customer base. Major prime contractors continue to move up the value chain searching the globe for component suppliers, a strategy that allows the contractors to find the best suppliers and to enter foreign markets by giving them a cut of the action. Not all globalization flow is outward from the US. Indeed, there were several significant acquisitions of US firms by major foreign companies, such as the recent buyout of United Defense Inc. by BAE Systems North America.<sup>10</sup> Additionally, as defense budgets around the world stay low or

are decreasing, foreign companies have built major facilities in the US to facilitate their ability to enter the US market. This is not all bad, as these facilities hire US workers and help sustain the US industrial base.

Foreign firms have developed some extremely innovative niche products, such as 40mm airburst ammunition, that are vastly superior to the US inventory. However, this is the exception rather than the rule. The US remains the global leader in weapons by almost any measure - design, development, innovation, and manufacturing - and its lead is increasing. The issue is that the US is in danger of technically outpacing even its closest allies, to the point that they may no longer be able to keep up with the development of new US doctrine, tactics, and technology. Even countries with world class commercial and technical expertise are finding it nearly impossible to keep pace with US military transformation and the changes it drives to the industry. How this technology gap will impact the industry remains to be seen, and how the US will work in coalition operations with partners nowhere near its level of sophistication, will require some significant thought.

## **CHALLENGES**

### Impact of Globalization

Although the US has laws that require conventional arms transfers to be consistent with foreign policy and national security objectives, we are seeing the effect of globalization in the defense sector. Economics are at least as important as political considerations with respect to the international conventional arms market. “The economic pressure on firms to export, combined with their government’s willingness to let them do so and with the increasing level of cross-border collaboration, will progressively erode the effectiveness of conventional arms and defense technology export controls worldwide.”<sup>11</sup> The challenge to the government is allowing companies to remain economically viable through increased exports while protecting critical national security technologies and trying to avoid regional arms races. Industry’s concern is managing its intellectual property in multinational ventures and maintaining market share as foreign entrants seek to enter the lucrative US market.

#### Main Challenges Faced by the Weapons Industry

- Technology transfer issues resulting from globalization
- Integration and interoperability of weapons systems and platforms
- Addressing barriers in bringing disruptive innovations to market

### Interoperability and Integration

Interoperability and integration challenges abound within each service, between the services, in the interagency process, and between coalition partners. Globalization is also a factor as standards and interoperability characteristics are becoming more important as the weapons marketplace consolidates and conventional systems are made available throughout the world. For many companies, interoperability is becoming a marketing tool rather than a service- or government-directed requirement.

Net-centric warfare provides unique challenges to interoperability and integration. With net-centric warfare, errors previously localized to a single platform now get

transferred or magnified. Better integration of capabilities across the spectrum of warfighting is also necessary. For example, the number of different UAV systems currently operating exacerbates intelligence synchronization problems from the battlefield commander to the squad leader. As NLWs come to play a more significant role, they must be integrated with other weapon systems through command and control networks, and doctrine to place a seamless continuum of effects on our adversaries.

With the push towards net-centric warfare and the increase in systems-of-systems programs, industry will be challenged to find new ways of working together to provide the integrated capabilities the DOD desires. The Lead System Integrator concept for the Army's Future Combat System and the Missile Defense Agency's National Missile Defense program is an example of new industry roles. Recent teaming arrangements in support of the Common Weapons Data Link and the Universal Armament Interface programs are other examples of contractor relationships driven by the DOD push for increased interoperability and integration.

### Barriers to Innovation

From the government perspective, barriers to innovation include: locating sources of appropriate technologies; maintaining a viable industrial base; determining suitable metrics and processes for technology selection; retaining immature yet promising technologies; and eliminating biases in determining technology maturity.<sup>12</sup>

That said, industry has its own unique barriers to innovation: developing investment strategies to deal with uncertainty in technology requirements and production quantities; adapting to competition with government laboratories for small production quantities; eliminating biases in determining technology maturity; and accepting new vice incumbent technologies by both government and industrial decision makers.<sup>13</sup>

Both government and industry are challenged by a shortage of US scientists and engineers. As this generation of baby-boomers retires, a significant number of replacements able to obtain national defense program security clearances will be required. As America gained much of its national power from the innovations of past scientists and engineers, we must find ways to continue to provide global technical leadership through a new base of scientists and engineers.

## **WEAPONS INDUSTRY OUTLOOK**

### Disruptive Threats

The next two decades will require a military adept at working across the spectrum of conflict. Disruption in the form of asymmetric approaches by adversaries – undertaken by both state and non-state actors – will

become the dominant characteristic of most threats to the US homeland. As a defining challenge for the US, they will require a strategy that maintains focus on traditional, low

#### Looking ahead

- Innovative and adaptive new enemies require a more diverse set of capabilities
- DOD's transformation will significantly shape industry's future
- A growing trend to use contract personnel in maintaining and operating weapons systems

technology threats as well as preparing for potential adversaries who harness elements of advancing technologies.<sup>14</sup> The National Security Strategy frames the challenge of preparing for disruptive threats by declaring “in rare instances, revolutionary technology and associated military innovation can fundamentally alter long-established concepts of warfare. Some disruptive breakthroughs, including advances in biotechnology, cyber operations, space, or directed-energy weapons could seriously endanger our security. Such breakthroughs can be unpredictable; we should recognize their potential consequences and hedge against them.”<sup>15</sup>

### DOD Transformation

Because of the strong interrelationships between the weapons industry and DOD, the requirement for defense transformation across the spectrum of conflict will shape the future of the weapons industry. Therefore, to truly understand the future of the industry it is necessary to examine how DOD intends to reconstitute itself to meet future challenges.

On October 29, 2001, Secretary of Defense Donald Rumsfeld established the Office of Force Transformation to coordinate and manage the transformation of US national defense. The most recent major changes in DOD precepts and direction were driven by the 2001 Quadrennial Defense Review (QDR), which is required every four years to assess all elements of defense policy and programs, outline national defense strategy, and visualize the defense program for the next 20 years.<sup>16</sup> The 2001 QDR was a radical departure from the past in that it changed the foundation of defense planning from “threat-based” to a “capabilities-based” planning construct. It is anticipated that the 2005 QDR will refine the course set in 2001 and set direction for future DOD acquisition with its consequential effects on the weapons industry.

### Industry – Shifting from Products to Services

The use of contractors in traditional military roles is a growing trend, as shown by their large numbers in Iraq. The business – followed by subject expert Peter Singer – is worth \$100B globally and is steadily increasing.<sup>17</sup> The trend is not only in the support, maintenance, logistics and other behind-the-front functions, but also in military operations. Sophisticated weapon systems brought to the fight require detailed technical knowledge for efficient and effective operation. Increasingly the DOD has chosen to use civilian contractors intimately familiar with the systems for their operation, rather than train a soldier to perform the function. This was particularly noted in the operation and support of UAVs, but is seen in other areas as well.

There are unresolved issues in the government’s use of contracted military services. Although the military claims their use improves overall efficiency, not all implications of integrating these contractors on the battlefield have been examined thoroughly. In any case, the military is likely to continue increasing its use of services, mirroring many other sectors of the US economy. The result is a growing segment of the weapons industry focused on providing direct services to DOD.

## GOVERNMENT: GOALS AND ROLE

### Government responsibilities

- Provide resources
- Communicate direction
- Articulate requirements
- Regulate exports

### Resourcing

WWI catapulted the US from a regional to a global power; WWII completed the US transformation into a global superpower. With the end of the Cold War and the emergence of today's globalized environment, US hegemonic influence is unchallenged. This influence is felt throughout the world as evidenced by the successful campaigns in Afghanistan and Iraq, although the US did not achieve these victories alone. Staunch allies such as England, Australia and Canada, among others, have come together with the US to fight terror and stand up to global tyrannical forces. Key to these successes is the consistent diplomatic, military, and economic resources put forth by the US and other coalition nations. The weapons industry is a major resource contributor in each of these elements of power, both domestically and globally.

The US continues to be the dominant player in global weapons development, which brings certain imperatives if that position is to be maintained. One of these is to continue to ensure its ability to resource current and future operations. A perceived lack of US financial commitment will cause a cascading erosion of support across the global community. International cooperation is crucial to get needed weapons developed, procured, and fielded. Current policies, processes and practices that encourage the flexibility to draw upon domestic and global weapon industries highlight the robustness and effectiveness of the US weapons base to support coalition operations. Government relations with industry present a foundation of global strength and send a message to those would-be-adversaries that the US and its allies can and will effectively resource and sustain the fight well into the future.

### Roadmaps

Industry clearly looks to the government to take the lead in determining what the long-term fight will look like and what capabilities are required to support the fight. Realistically, it is the government's responsibility to consider ways, means, and ends with regard to national security. Industry currently believes the government is too focused on immediate issues such as funding the Global War on Terror, the Base Realignment and Closure Commission, force transformation, and the national budget crunch to adequately fulfill this role. Of particular concern are shortfalls in the government's near-term focus on long-range planning, from both the personnel as well as an investment in future technology and innovation perspectives. This appears to frustrate many industry advanced concept and long-range planning groups.

### New Requirement Processes

The DOD shifted from a threat-based to a capabilities-based requirements process by implementing the Joint Capabilities Integration and Development System (JCIDS). The JCIDS process provides more focus on how adversaries may challenge us, than on whom

those adversaries might be or where we might face them. JCIDS helps ensure the most efficient use of available resources in planning, training, and equipping the military forces. Through JCIDS, the combined strategy of dedicated joint warfighting and capabilities-based acquisition will allow the DOD to be more flexible, agile, and responsive to current and future asymmetric threats.

The industry made substantial shifts to align with the JCIDS process. Realignments and corporate mergers were made to stay aligned with the DOD customer base and remain competitive in a dwindling budget environment. Additionally, increased investment in advanced and disruptive technologies has been made to ensure the US maintains its technological superiority and to respond to changes in the nature of warfare.

### Regulation

The US views the sale, export, and retransfer of defense articles and services as an integral part of safeguarding national security and furthering foreign policy objectives. Authorization to transfer defense articles and provide defense services, if applied judiciously, can help meet the legitimate needs of friendly countries, deter aggression, foster regional stability, and promote the peaceful resolution of disputes. Recognizing the potentially adverse consequences of indiscriminate arms transfers, the US strictly regulates exports of defense items and technologies to protect its national interests and the interests of the broader international community.

Industry has long urged loosening of US arms export policies. During the Cold War the US restricted arms exports to preserve national security and worked closely with allies to limit arms proliferation. President Clinton substantially eased these restrictions, explicitly recognizing for the first time supporting US economic concerns as a criteria in making arms export decisions. The Bush Administration, with the blessing of industry, is considering further relaxation of US arms export restrictions. The DOD and the US weapons industry claim that further relaxation is needed to keep pace with a globalized economy, to increase allied defense capabilities, to ensure continued US access to foreign arms markets, and to increase the likelihood of global industrial mergers.

Critics of relaxing arms export legislation point out that the Global War on Terror (GWOT) requires a strengthening of export controls in order to limit their availability to terrorists or hostile nations. The critics also question the economic need for exports to prop up the US weapons industry, since the US already exports more than 50% of the world's total arms exports. Moreover, they point to traditional fears about fueling regional arms races. In any event, it is important that the DOD participate in future decisions balancing advantages to increased globalization of the weapons industry with the potential dangers to national and global security.

## **ESSAY REPORTS**

### ESSAY ONE: MILITARY USE OF UNMANNED AERIAL VEHICLES (UAVs)

A UAV is a remotely controlled or autonomous aircraft used for intelligence, surveillance, reconnaissance (ISR) and strike missions. These aircraft are useful in situations where it is impractical to use manned aircraft. The UAV is a new disruptive

technology on the modern battlefield, giving the warfighter enhanced battlespace awareness via visual, infrared or radar sensors, along with a target kill capability.

### Current Conditions

At present, the UAV industry can be categorized as a hobby shop for the big boys. UAVs are being developed faster than almost any battlefield technology in recent memory. Today more than 50 US companies, academic institutions, and government organizations are developing over 150 UAV designs. Forty firms have some 115 of these designs flying (i.e., at least one working prototype built), whereas 15 companies have 26 UAV models in, or ready for, production.<sup>18</sup> Globally, UAV development in Europe, the Middle East, and Asia has also taken on strategic scope with both reconnaissance and weaponized systems under development or deployed.<sup>19</sup>

Building UAVs is labor intensive. For example, General Atomics' Predator is a marvel of human ingenuity. Molds and forms are used in conjunction with hand-laid composite material to create the fuselage, wings, and tail sections. Then, the pieces are fitted together and connection points are drilled by hand. The product is hand-sanded and then painted in an enclosure used by the auto industry. All of the wiring assemblies are built and installed by hand, as are the sensor package and weapons system payloads. Yet for all the labor-intensive work, a Predator is built – from cutting fabric to final test – in fifty days for a comparatively low cost of \$4-10M dollars. In comparison, manned aircraft routinely run from \$20M+ for rotary wings to over \$100M dollars for fixed wing.

### Forecast

Requirements for military use of UAVs can be broken into two distinct requirements; intelligence/surveillance/reconnaissance (ISR) and weaponized systems. Military UAVs are primarily used to dwell over a target and stream signals or electronic intelligence, live video, infrared, or radar images to analysts. Technology is increasing the capabilities of the sensor packages, yielding more resolution at lower weight and potentially less cost. This reduction in weight increases payload size and available flight time. Weaponized systems give the warfighter the ability to combine real-time surveillance with a lethal punch. While cost tends to be the final word in any system, battlefield management of technologically advanced payloads will dictate the future of the UAV industry. As long as the military command and control structure can direct a sky full of UAVs, there will be countless opportunities for new missions and systems.

Safely operating UAVs in Federal Aviation Administration (FAA) or International Civil Aviation Organization (ICAO) airspace is an issue. The FAA requires UAVs to have manned chase aircraft when operating below 18,000 feet outside of military restricted airspace, due to liability associated with "see and avoid" flight rules. In military restricted airspace and in combat operations, attempts are made to procedurally deconflict aircraft using altitude, position, and/or timing. Despite these precautions, UAV and manned aircraft have collided midair; as the number of UAVs in the battlespace grows, the number of collisions is likely to increase. There are hosts of solutions to mitigate this risk, but at present they are only in development.

Opportunities abound for companies willing to invest in the science rather than the fiction of UAVs. Taking the place of expensive satellite systems or manned ISR vehicles, the need for UAV missions to fly higher and longer, be smaller and quieter, or carry effective ordinance should fuel competition well into the future. Companies that can produce a UAV to fly into an enemy command center, conduct ISR, and silently egress will corner the market for the special operations and intelligence communities.

UAVs can also play in the machine-to-machine, sensor-to-shooter-to-target, net-centric warfare realm by reducing the timeline for accurate targeting and weapons engagement and by automating previous manpower intensive tasks. Vice Admiral Cebrowski, lead of DOD's Force Transformation Office, considers the USAF Network-Centric Collaborative Targeting (NCCT) effort as the most important net-centric capability in development. It ties ISR sensors together using existing radios for a multi-sense ability to share information without human intervention for sensor and weapons queuing, for time-critical targeting, and for strike missions.

### Recommendations

Currently, several systems are heavily relied upon, such as Global Hawk and Predator. At issue is that UAVs are used mainly as platforms with sophisticated payloads, not as fully networked nodes in the sensor-to-shooter realm. For instance, the NCCT concept currently being developed and tested as an Advanced Concept Technology Demonstration (ACTD) by US Central Command, still relies on manned aircraft to provide data to the warfighter. Neither Global Hawk nor Predator is included in the ACTD. Therefore, UAVs should be incorporated into the NCCT ACTD to further explore the challenges and opportunities presented by UAV integration into the network.

Military requirements fuel the imagination of industrial designers and engineers alike, but military planners need to clearly understand mission scope, operational command and control requirements, and the desired end-state for UAV use. UAV requirements should be thoroughly vetted across DOD to preclude single designs from flooding the battlespace. A robust command and control system must be developed, along with the doctrine necessary to enhance the capability of the UAV to complete its mission.

As the Air Force moves to operationalize the UAV, it is developing traditional air wings, groups, and squadrons. However, in a net-centric environment where information flow is key, a more "flat" organization might make more sense. The government must study how the telecommunication, cable, and satellite companies are organized to supply on-demand data with quality of service. Concurrency of planning and operation in a networked world requires a different approach to the battle than in past environments.

### ESSAY TWO: NON-LETHAL WEAPONS

Non-lethal weapons (NLW) represent a spectrum of technologies intended to cause less-than-lethal effects. They are explicitly designed and primarily employed so as to incapacitate while minimizing fatalities, permanent injury, and undesired damage. Common categories include kinetics (bean bags, rubber bullets), chemicals (tear gas, pepper spray, malodorants), electricals (tasers) and directed energy (lasers, high power

microwave). Although NLWs are not new, the directed energy category represents a disruptive technology that is currently in early stages of development, discovery, and use.

### Current Conditions

US involvement in Somalia, Kosovo, and now Afghanistan and Iraq demonstrates a shift away from large-scale warfare toward asymmetrical, often urban, peacekeeping, and humanitarian assistance missions. This strategy shift creates a greater need to limit collateral damage and facilitates the use of weapons that can be used for activities such as crowd control and infrastructure security. Though NLWs have been in use by law enforcement and the private security industry for some time, US military operations have begun to increase demands on the NLW segment of the weapons industry.

Overall, NLWs remain a low priority for the services. The executive branch has not formally assigned responsibility for the stabilization, reconstruction, and peacekeeping missions to any single department, and that indecision is proving problematic. The military establishment – with its rich history of warfare still entrenched in destruction and annihilation – tends to apply technology for force-on-force warfare rather than Military Operations Other Than War (MOOTW). However, during the last two decades, and especially during OIF, a pressing need arose for non-lethal effects when combat is supplanted by stability operations and population control. Much of the military's current NLW demand is focused on affordable and available technology, placing the market equilibrium at the low-end on products such as kinetic bean bags and rubber bullets.

Increasing the NLW market without DOD support is not expected despite GWOT. The Department of Homeland Security (DHS) and law enforcement agencies are simply too small a market to sustain a profitable industry. However, the DOD trend towards acquiring more services may be relevant in this situation; contracting of security related services may increase future demand for NLWs.

In 1997 DOD named the USMC executive agent for NLW through the Joint Non-Lethal Weapons Directorate (JNLWD), mostly due to their propensity for MOOTW. The JNLWD provides warfighters a family of systems with a range of non-lethal capabilities across the full spectrum of threats and crisis. However, the JNLWD only has Research, Development, Test and Evaluation (RDT&E) budget authority for NLWs, with individual services responsible for procurement and Operations and Maintenance (O&M) funding. This discontinuity of funding is a major problem.<sup>20</sup>

The US is the global leader in NLW research and development. Industry focus is in directed energy weapons, specifically the high powered microwave (HPM) area. The Active Denial System (ADS) is the hallmark HPM technology – a microwave beam that induces intense pain, causing immediate surrender or retreat. ADS effects are truly disruptive, in that a new coercive, less-than-lethal option is provided to the warfighter. Crowds can be dispersed and opposing forces disarmed without injury. The ADS product is differentiated from other NLW products because unintended death is very remote with its use. The ADS is currently an Advanced Concept Technology Demonstration project.

Government laboratories perform the bulwark of research in these next generation technologies. Transition to a production market requires commitment from one of the services, barring independent industry investment. Even with ADS successes, its relative immaturity and high cost has so far precluded the critical funding commitment from

either side. However, that should change. Within the next decade, ADS technology will be sufficiently mature, scalable, and affordable to allow a firm production commitment. In the interim, only the largest defense firms have sufficient capitalization to make the heavy investments necessary to continue development of this critical technology.

### Forecast

Numerous challenges exist for this market outside of funding. Defense capability requirements for peacekeeping and security operations are currently a low priority and not well-defined – a shortfall that should be addressed during the 2005 QDR. To remedy this situation, specific NLW capabilities must be identified and resourced for technology maturation and transition to production.

The JNLWD argues that procurement funding is their biggest concern. Service funding usually does not occur until late in a program, serving to stymie long-term NLW production and support. Further, OIF is raiding NLW funds for higher priority needs.<sup>21</sup> One can conclude that the services are interested in this gap-filling technology, but not at the expense of current operations. The Joint NLW Program Office construct, though useful in consolidating the development of this critical technology, is incapable of transitioning products into production and fielding because they lack procurement responsibilities. Unless concentrated in a single office, this transition seam will continue to be a point of discontinuity and failure.

Within the area of HPM, technological challenges associated with sources, such as gyrotrons and solid state transmitters, remain barriers to the creation of a weapon scalable from man-portable to major platform applications. Costs associated with these technologies will continue to fall, but typically the technology is ready before the affordability threshold is reached. These factors indicate a significant shift in acquisition strategy may occur within ten-years.

Within the industrial base, a significant barrier to entry is the cost associated with investment in these technologies. Only first-tier defense companies have sufficient investment capital; even if small companies emerge with critical enabling technologies, the current business climate indicates these larger companies will merge, acquire, or create a strategic partnership to maintain market control. Balancing these challenges are significant opportunities for companies that invest in NLW technology. Directed energy weapons will become the newest class of munitions, and could displace many conventional kinetic applications. Shifting DOD emphasis from major war to peacekeeping and security, and the emergence of DHS as a major buyer, will continue to increase the market for NLW technology.

### Recommendations

Non-Lethal Weapons – especially directed energy weapons – represent leap-ahead technology for tactical, MOOTW type operations. Once DOD accepts its role as guarantor of the peace, NLWs will gain greater prominence and the industry will blossom. For this to happen, JCIDS must clearly define and emphasize the non-lethal capabilities that will be required in the near and distant future. Maturing the technology for improved performance, reduced size, and increased affordability is key and DOD

funding can represent confidence in a technology. Prototype NLW systems must be built and tested by prospective DOD, interagency, and law enforcement end users, if only to demonstrate their capabilities and develop new potential applications. Once users trust the technologies and develop the required operational doctrine to integrate non-lethal systems into the full spectrum of warfare options, funding will flow.

Obviously, there is risk associated with these recommendations. Industry risks their profit against DOD cyclical funding and changing priorities. That risk can be mitigated by fixing a broken product transition process. Creating a single acquisition authority, with centralized funding authority, is the way to make it happen.

### ESSAY THREE: THE FIGHT IN 2024

For DOD, readiness to “fight the fight” in 2024 is defined as the ability to have desired effects-based capabilities to achieve US National Security Strategy objectives. For industry, it is the ability to provide technology, manufacturing, and materiel solutions to resource those effects-based capabilities.

#### Current Conditions

Though DOD is extremely effective in planning and executing real-world operations, it falls short in providing a long-term requirements and resources vision. DOD lacks an overarching, consolidated mid- to long-term roadmap on which specific capabilities it needs to develop and maintain. A recurrent theme is that of inconsistent, disconnected and, in some cases, non-existent roadmaps across weapon sectors, across service common platform systems, and – more disturbing – within the Office of the Secretary of Defense.

DOD has two entities that help identify, manage, and monitor future needs -- the Defense Science Board (DSB) and the Defense Advanced Research Projects Agency (DARPA). The DSB, composed of senior civilian experts, advises the military on technological threats including disruptive innovations. The board’s mission is “...to advise the Secretary of Defense and the Chairman of the Joint Chiefs of Staff on matters relating to science, technology, research, engineering, manufacturing, acquisition process...and will ensure the identification of new technologies and new applications of technology in those areas to strengthen national security.”<sup>22</sup>

Once key areas are identified, DARPA is tasked “...to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.”<sup>23</sup> Innovative ideas are communicated from DSB and DARPA to the services through DOD policy and through their publications. However, these initiatives compete for funding against high priority service-identified weapon system requirements. Even though the DSB and DARPA are effective in their own right, there continues to be a lack of a coherent and consistent DOD long-term vision, contributing to the inefficient allocation of scarce resources and unnecessary extension of weapon system delivery schedules.

Despite the lack of a coherent DOD roadmap, industry continues to invest in advanced technology research to provide a foundation for future solutions. Their efforts tend to be focused in high speed, stealth, directed energy, and net-centric warfare.

Research revealed that the majority of industry's efforts are technology-pull associated with estimated program needs, while less than 30% of the efforts are technology-push. DARPA seems to be playing a role in working these long-term efforts, but it is not clear how integrated DARPA's plans are with the industry, the services, or with OSD in general. The lack of an integrated, consistent customer vision and stable capabilities-based requirements are the most crucial current-day concerns voiced by industry.

## Forecast

All of the services have transformation roadmaps that define future warfighting concepts, capabilities, technologies, and programs. Both the Air Force and the Navy/Marines discretely call out their plans for the far-term, but it is more difficult to identify the Army's far-term plans. Though the timelines in the transformation roadmaps are focused far enough out, they are not integrated nor do they share common resources to leverage from each other. Our review of these documents uncovered three common trends in weapons capabilities that could be used to help integrate these roadmaps: network-centric warfare, directed energy, and hypersonic weapons.

Net-Centric Warfare: This term broadly describes the combination of strategies, tactics, techniques, procedures, and organizations that a networked force can employ to create a decisive warfighting advantage.<sup>24</sup> It generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, high tempo of operations, greater lethality, increased survivability, and a degree of self-synchronization.<sup>25</sup> While net-centric warfare is a fundamental pillar in today's military transformation, implementation is likely to take a decade or more before the full benefits are realized.

Directed Energy: Research into directed energy weapons has been going on for years, but practical implementation has been illusive due to a variety of technical problems. However, they continue to hold promise and garner government research dollars for their desirable attributes – high speed and pinpoint accuracy. High-powered microwaves are one of the promising technologies in non-lethal weapons. Solid state lasers, powered by electricity rather than toxic chemicals, appear to be practical enough to begin incorporation into specific weapons platforms such as aircraft, ships and land vehicles.<sup>26</sup>

Hypersonic Weapons: Dedicated research in ultra-high speed weapons that would allow the US to hit targets anywhere on earth within two hours of launch has begun. The ultimate aim is a reusable Hypersonic Cruise Vehicle (HCV), slated for around 2025, that can take off from a conventional runway in the US and strike targets up to 16,700 kilometres (10,350 miles) away.<sup>27</sup> "There is a strategic military need to be able to strike potentially dangerous military targets that are far away and may only be accessible for a short period of time," explains Daniel Goure, an analyst at the Lexington Institute, a think tank in Washington DC. The services are exploring various platforms and technologies to marry potential materiel solutions with future time sensitive targeting concepts to mature this next generation weapons era of hypersonics.

Within these common threads, the ability to develop, procure, and sustain our future capabilities in a joint resourcing environment is promising. Encouraging efforts are unfolding within the DOD that shows signs of cultivating that joint environment. The Joint Requirements Oversight Council (JROC) recently sponsored a project to develop

“An Evolving Joint Perspective: US Joint Warfare and Crisis Resolution in the 21st Century,” focusing on the characteristics and conduct of US joint warfare transforming to a 21<sup>st</sup> century force. “The key feature threaded throughout this common joint warfighting perspective is the overall capability for the joint force to successfully and effectively conduct operations to achieve full spectrum dominance across the range of military operations, inclusive of robust support for US Homeland Security efforts as directed.”<sup>28</sup> The need to operate and resource in the joint environment will be challenged by the services across the parochial boundaries of a shared roadmap.

### Recommendations

In spite of these challenges, there are opportunities for the combined DOD and industry team to make significant headway in successfully preparing and planning for the fight in 2024. DOD has positioned itself well with the implementation of JCIDS and the rejuvenated joint warfighting processes to ensure it maintains its global military superiority. DOD needs to continue to focus on joint operations and, more importantly, joint acquisition and resourcing. Working closely with industry is necessary to ensure the appropriate capabilities-based solutions are developed and fielded. Key to this effort is the need to breakdown service requirements and the acquisition stovepipes that drive inconsistent and conflicting direction to the industry. By generating a single, clear customer path for weapons development, usage and strategy, the combined team can ensure it is organized and aligned in the most efficient manner possible to be ready to resource and fight the fight in 2024.

### ESSAY FOUR: ORGANIZATION AND DOCTRINE

DOD is leading defense transformation by emphasizing joint operations and interoperability with foreign military partners. In terms of organization structure and doctrine, there is little active transformation apparent in peacetime, CONUS-based services. Development is more apparent in the acquisition arena and in the combatant commands. Increased emphasis on acquiring interoperable, multi-use systems today will facilitate jointness once the services accept its value in the future. Combatant commanders are effectively employing joint forces now, proving operational concepts in the battlespace that will become doctrine in future years.

### Current Conditions

Organizational structural inertia is an acknowledged problem in the military; fortunately the military does not fight the way it is organized. Budget realities demand that the services align their functional units to be more effective and efficient to meet the war fighter’s needs. A side benefit would include enabling cost-effective outsourcing of nonmilitary services. But, the services are not aggressively pursuing action in this area.

Unified Commands are leading the way. US Special Operations Command (SOCOM) is uniquely organized to train, equip, and employ the nation’s special operation forces and has inherent acquisition authority to provide timely and more effective products to its operators. US Central Command (CENTCOM), US Joint Forces

Command (JFCOM), and US Transportation Command (TRANSCOM) are also effective in organizing and conducting joint service operations and working with other federal agencies, like the State Department and the Central Intelligence Agency, in executing shared missions. More effective power projection in the Global War on Terrorism is a direct result of the success of these joint operations.

However, the services are resisting the transition to jointness. Unlike the unified commands, the services generally recruit, train, and equip within their particular tradition. There are no standing joint forces. The best soldiers, sailors, marines, and airmen in the world learn to fight together only after they deploy, a costly practice measured in treasure and blood. Unified leadership is essential for organizational adaptability and flexibility in meeting the joint warfighting needs of tomorrow.

Doctrine is authoritative, combat-proven direction on how to perform a military function in wartime. Joint warfighting doctrine is produced by JFCOM and published by the Joint Chiefs of Staff. It is normally not hardware specific, and normally takes two to ten years for inter-service coordination and approval. Service-specific doctrine is produced by centers of operational expertise within each service and published by the respective service doctrine chief. Like joint doctrine, service-specific doctrine is non-volatile and takes one to two years for intra-service coordination and approval. Doctrine is taught in service schools and provides a common frame of reference across the entire force. A rule of thumb among warfighters is 'If you can't think of a better situation-specific way to achieve an objective, then follow the doctrine.'

Tactics, techniques, and procedures (TTPs) are more current, environment-specific, and hardware-specific than doctrine. TTPs change in real-time to meet current needs, and may be service specific or joint. The joint Air Land Sea Action (ALSA) Group at Langley AFB was chartered by the doctrine chiefs of the four services to create TTPs for operations involving two or more of services. ALSA performs its mission well, but is manpower constrained and is approaching (or may have already passed) the point where it expends more effort on document maintenance than on producing new TTPs. Giving ALSA additional resources for publications maintenance would be a good investment, as its independent status provides maneuver room and authority to develop joint TTPs quickly and effectively, filling a much needed gap.

Innovations that create military advantage are identified in separate but related operations planning functions of the Secretary of Defense, the Combatant Commands, and the individual services. Some are also created by the weapons industry. In an ideal world, all such innovations would be created, adopted, and fielded by American forces to defeat our adversaries. Unfortunately, it does not happen in the real world.

## Forecast

How the military organizes to fight the fight is fundamental to success on the battlefield. Since Operation Desert Storm in 1991, US forces have dominated all conflicts against conventional forces as a result of intense and realistic joint training, leadership focus on the operational level of warfare, mass, intelligence, and technological superiority. Although the organizational structures of the military services are relatively rigid and hierarchical, the Unified Command structure enables Combatant Commanders the flexibility to bring tailored and interoperable joint forces to the fight in creative ways:

Net-centric warfare: This is a sweeping innovation being applied across the military to create operational advantage. It uses communications and information technology to link sensors, shooters, and commanders real-time across the battlespace -- and denies the adversary this same integration. A primary challenge to faster improvement in net-centric warfare is the hesitancy of the services to jointly train and equip. Although some joint tactics, techniques, and procedures were developed to meet the jointness demands of net-centric warfare, much remains to be done. Service stovepipes hinder progress.

Non-state entities: SOCOM is currently synchronizing US military and interagency activities in the GWOT. Its mission is not only to prepare, equip, and train forces to defeat entities threatening US interests, but it also takes forces afield to disrupt and defeat terrorists. Significant challenges are retention of skilled operators, tweaking the force structure, and making the interagency work together better. Additionally, structural reform in the law enforcement and intelligence communities will benefit the GWOT.

New technologies: There is an amazing array of technological innovations marketed to the military by the weapons industry. For example, autonomous vehicles can navigate, find and destroy targets, gather intelligence, and return without a human onboard. Consequently, the future will see fewer combat pilots. Precision munitions in smaller packages will mean fewer sorties are needed to achieve the same effects. Improvements in the 'kill chain' will enable improved performance on time critical targets.

Manpower: Recruiting and funding skilled military members is a primary challenge, certain to grow. As the budget sags under the weight of entitlements, defense funding will likely face cuts at the same time weapon system recapitalization is needed. Reservists were essential in OEF/OIF but they were over-used, which adversely affected their quality of life and may have reduced recruitment. As a consequence, force structure must be adjusted to ensure that essential skills are available to the COCOM. In the future, contractors will provide opportunities to meet some needs; however, contractors will also challenge the military to obtain best value and to appropriately limit the scope of their activities. Today, the realization that contractors are working for America in the battlespace is controversial, but they will be a key resource in the future.

## Recommendations

Three important truths must be highlighted. The first is that innovations that provide military advantage are not always new hardware. Most often, they are new tactics for employing existing hardware, people, or capabilities. Second, our adversaries are also innovative – US forces must be able to quickly adapt. The third truth is that potential enemies are a motley group. US military strategy and doctrine must be broad enough to touch them all, while capabilities, TTPs, and training must be extensive and adaptable to defeat them. Maintaining significant capability advantages over known and likely adversaries enables US forces to dominate the battlefield and negate the effect of disruptive innovations by opposing military forces.

Current initiatives to manage military capability overmatch should be done cautiously, and with sensitivity to the potential for political and inter-service interference that could compromise the decision making process. DOD should balance the need for maintaining battle-proven service organization structures and systems with the needs of the joint battlefield of the future.

## CONCLUSIONS AND RECOMMENDATIONS

The US weapons industry depends on DOD for its survival, while DOD is strongly influenced by the industry as their main supplier of arms and equipment. Unlike other industries, the actions of a single customer – albeit the world’s largest – drive sector performance, determine industry’s health, and map their future direction. DOD and the weapons industry are, and will continue to be, tightly coupled and properly so. But, the industry must be profitable or it will cease to exist. Unless DOD continues to prod industry to push technology to the edge, they will be reluctant to migrate from comfortable, short-term sustaining innovations to high risk, high payoff disruptive innovations. The time is now. As DOD is changing to meet new challenges posed by asymmetric threats, the weapons industry must develop disruptive innovations of its own.

The industry must chart its course for the future while it is still relatively healthy and capable of meeting GWOT surges. DOD can help by flattening historically oscillating funding and guaranteeing orders within the confines of political reality. Net-centric and full-spectrum warfare is DOD’s future and the actions industry takes in response to globalization, DOD transformation, and advancing technology will dictate its future. Globalization is a fact of life, presenting many benefits. Yet, DOD must balance these with national security and intellectual property needs and work the interagency process to develop appropriate arms export legislation and policy. Getting disruptive technology to the battlefield sooner rather than later is a great challenge and it must be done quickly.

GWOT has changed the nature of war. New asymmetric threats require DOD to anticipate future threats and neutralize them before armed conflict. Long-standing perspectives must change; data and communications are now just as important as bombs and bullets. While technology is pushing industry, DOD continues to follow the paradigms of old. Weapons integration, now and in the future, challenges industry to operate outside of their standard business model and challenges DOD to develop the roadmaps, tactics, procedures, and doctrine for success on the battlefield. The government can no longer accept industry provided solution sets; it must shape the market as the provider of the nation’s defense.

Weaponized UAVs are a prime example of low-end disruptive innovation existing outside net-centric warfare, although that is changing through the evolution of joint organizations and doctrine. NLWs, on the other hand, are a new-market innovation as they bring an entirely new capability to peacekeeping and stabilization missions. Yet, current operations soak up every available DOD dollar, preventing long term funding of even the most promising initiatives. Industry must realize these financial constraints and assume greater risk if they want to maintain long term comparative advantage. Finally, disruptive innovation drives changes in doctrine and organization. Systemic change does not happen overnight or within the immediacy of conflict. Working together, DOD and the weapons industry can assure continued US technological superiority, economic survival, and dominance on the battlefield.

### KEY RECOMMENDATIONS FOR DOD ACTION

- Develop arms export legislation that better balances benefits and risks of globalization
- Build integrated roadmaps and doctrine that define capabilities required for the future and define how innovative technologies will be integrated into the battlefield
- Improve the process that transitions innovative technologies to the battlefield

## END NOTES

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- <sup>1</sup> Friedman
- <sup>2</sup> Christenson, What's Next
- <sup>3</sup> Coffman
- <sup>4</sup> Melita
- <sup>5</sup> OSD UAV Roadmap
- <sup>6</sup> OMB, JNLW R-1 Shopping List
- <sup>7</sup> OMB, USA Shopping List
- <sup>8</sup> OUSD(IP) Annual Industrial Capabilities Report to Congress
- <sup>9</sup> OUSD(AT&L) DSB Report
- <sup>10</sup> AP Article
- <sup>11</sup> OUSD(AT&L) DSB Report
- <sup>12</sup> Ibid.
- <sup>13</sup> Ibid.
- <sup>14</sup> NIC 2002-02, pages 14-15
- <sup>15</sup> Ibid. pg. 7
- <sup>16</sup> CJCS Logistics Campaign Plan
- <sup>17</sup> Singer
- <sup>18</sup> UAV Forum Website
- <sup>19</sup> Wilson
- <sup>20</sup> Tradieac and Levine interviews
- <sup>21</sup> Levine interview
- <sup>22</sup> DSB Charter
- <sup>23</sup> DARPA Mission Statement
- <sup>24</sup> Gartska, page 58.
- <sup>25</sup> Office of Force Transformation, page 4.
- <sup>26</sup> Pae
- <sup>27</sup> Bieber
- <sup>28</sup> An Evolving Joint Perspective, pg 7

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