MUNITIONS

ABSTRACT: Munitions are critical war-fighting commodities of the modern military. Historically, this industry included a wide variety of weapons: small arms, mortars, cannons, artillery, gun munitions, bombs, rockets, missiles, chemical munitions, mines, demolition material, grenades, flares, torpedoes, nuclear weapons and pyrotechnics - without which a military cannot fight successfully. Munitions, however, are in the midst of a transition from the traditional free-fall weapons ("dumb bombs") to precision guided munitions (PGMs), with the ability to hit specific targets across increasing distances during all-weather conditions with minimal collateral damage. This paper focuses on the ongoing transition. PGMs are becoming more complex and much more expensive. They are requiring increasing amounts of national imagery and communication resources. PGMs promise a greatly improved war-fighting capability, but their management within the Department of Defense (DoD) is fragmented, both within and among the services. Finally, munitions, even the preferred precision guided weapons, are not adequately funded because of other modernization requirements. Budget reductions in both the United States and Europe are driving a wave of consolidations on both sides of the Atlantic. Competition among the remaining firms is fierce. Accomplishing Joint Vision 2020 (JV 2020) goals of precision engagement and focused logistics will require more resources and long range disciplined planning devoted to munitions.

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INTRODUCTION

A Combatant Commander sits up late at night reviewing target sets. He considers what effects, from taking down electrical power in a major city to disrupting air defense sites, will put the most pressure on an enemy. He considers several sites, including some that are close to schools or hospitals. He has the capability to consider these sites because of the development of PGMs. Sixty years ago, even forty years ago, these effects were not possible without a very destructive mass bombing attack. Perhaps a saboteur could destroy some of the sites, but only at the great risk and with low probability of success. Today, the Commander can and must weigh specific effects against the political objective.

At one time, civilian casualties were an unavoidable consequence of bombing campaigns waged against populated areas. Now, however, those casualties are not acceptable for even limited efforts. The technology push in PGMs is being met by a political pull for specific tailored effects. Like all tools, PGMs come at a cost. They are initially much more expensive than older generation dumb bombs because today they are equipped with sophisticated guidance and navigation systems. Because of sophisticated aerodynamic effects and propulsion systems, PGMs can travel today much further from release to its target. PGMs require support from complex information systems, including intelligence, surveillance, and reconnaissance systems. They require trained mission planners supported by state-of-the-art computer equipment. Their very capabilities are causing public demands for even more tailored and considered effects. Public expectations about the cost and value of a military mission drive the Rules of Engagement (ROEs). ROEs drive the development of PGMs, and are themselves driven by the accelerating technology.

All of this technical development is occurring in a world of flat or declining budgets. The declining budgets are pressuring defense companies to consolidate into entities that are more efficient. Falling budgets are also pressuring DoD acquisition officials to search for less expensive weapons systems, developed in ever shorter periods.

The problem that faces all of us in the business of supporting the Combatant Commander is to determine how to maximize the power and flexibility that can be brought to bear in a crisis that is politically feasible and within fiscal constraints. This paper reviews the current state of the PGM industry and technology, considers challenges that exist for that industry, and proposes recommendations for change. Data sources included personal interviews, archival records, recent reports both inside and outside the services, and current news articles. The primary method of analysis is within-case comparisons of data sources. Our goal is to provide an effective and affordable means to allow the Combatant Commander to successfully respond to the full spectrum of present and future military operations.

THE MUNITIONS INDUSTRY DEFINED

In the broadest sense, the term *munitions* refers to the complete range of ammunition products and components used by the military.[1] Since the Persian Gulf War, the focus by DoD practitioners and analysts inside and outside of the Pentagon is on precision or near-precision (accurate) munitions. The distinction between true precision weapons and near-precision weapons involves the circular error probability (CEP) or how close the weapon can get to an intended target. True precision weapons must strike within three meters of its intended target. Throughout this paper, we treat precision and near-precision weapons as synonymous.

Accordingly, the focus of this paper – and of the ICAF Munitions Study overall – is on ***companies*** and ***issues*** associated with the current and future production of guided munitions with near-precision accuracy or better. The PGM industrial base includes government agencies, military commands, and activities to the extent they influence or affect those firms. Derived in large part from product analysis, the primary firms in the domestic market are Boeing, Raytheon, and Lockheed Martin.[2] The principal firm in the international European PGM market is MBDA, a new consolidated firm created in May 2001. We also looked at Bofors Defense, which provides a case study of a different approach – that of a system designer trying to exploit a niche, guided artillery and anti-tank weapons, in the overall guided weapon market. We did not consider munitions manufacturers outside of the United States and Europe because of the relatively small size of that market (approximately 8% of the world sales) and lack of reliable, detailed information.

CURRENT CONDITION

The Importance of PGMs

JV 2020[3] describes the official vision of the future of the US military as follows:

"The overarching focus of this vision is full spectrum dominance – achieved through the interdependent application of dominant maneuver, precision engagement, focused logistics, and full dimensional protection."

Precision engagement is the ability of joint forces to locate targets, use appropriate systems, generate the desired result, assess the result, and reengage with decisive speed and overwhelming operational tempo as required.[4] The principal characteristic of precision engagement is the linking of sensors, delivery systems, and effects. In the joint force of the future, this linkage will take place across the services, and will incorporate capabilities of multinational allies.

State of the Art

PGMs are the preferred tools for precision engagement because of their ability to strike identified targets from an increasing range under all weather conditions with minimal collateral damage. Although DoD used some types of precision weapons since the Korean War, it is only recently that technology developed to the point that it is feasible

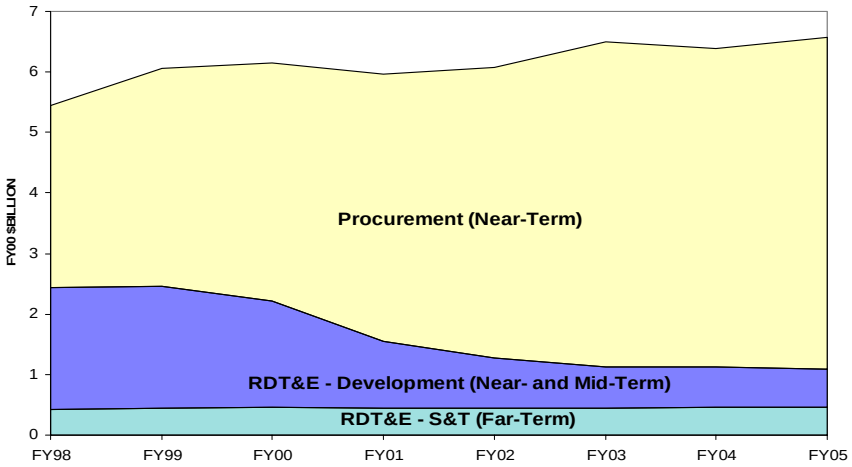
to link various sensors, rapidly identify and program an appropriate delivery system, and achieve a precisely measured effect. For example, in 1944, it took 108 B-17 bombers dropping over 600 bombs to destroy a point target. In Vietnam, similar targets required 175 bombs. Now a single PGM can achieve the same effect. This is how the F-117 destroyed 40% of all strategic targets while flying only 2% of the strike sorties during Operation Desert Storm.[5]

Current weapons provide formidable capabilities. The conventional Tomahawk Land Attack Missile (TLAM), for example, can destroy strategic targets such as bridges or airfields, carrying a 1000-pound unitary or submunitions warhead from a nominal distance of 700 miles.[6] It uses Terrain Contour Matching (TERCOM) and Digital Scene Matching Area Correlator (DSMAC) techniques to update the missile's inertial navigation system (INS) to guide the weapon to a designated target. In contrast, the Joint Direct Attack Munition (JDAM) is a guidance kit that converts existing 500, 1000, and 2000-lb. free-fall bombs into accurate munitions that can be guided to a specific target from up to 15 miles away by an INS capable of receiving updates from Global Positioning System (GPS) satellites.[7] A matrix of weapons and their target sets is found in the Appendix, Table 1.

PGMs now in development will add stealth, additional standoff capability, and warheads with a range of effects, from cluster munitions to deep penetration against hardened targets. The newest effort is the Small Diameter Bomb, currently being developed by the US Air Force. The smaller size of this munition permits existing aircraft to carry many of these, all preprogrammed to hit various targets. Future planned developments will permit the targeting of relocatable and moving targets. Unmanned air and perhaps sea or land vehicles are being designed to carry PGMs that can be targeted either by the unmanned vehicle itself based on stored images of enemy targets, or from military commanders far from the battle lines. In this dawning age of a Revolution in Military Affairs (RMA), DoD must increase its reliance on unmanned systems for the delivery and targeting of PGMs that incorporate stealth and extended range.

DoD Budget Projections are Flat

Unfortunately, as measured by budget share, the current DoD modernization plan places little priority on these capabilities. Figure 1 below reflects DoD's future funding plans for PGMs.[8]



As can be seen from the figure, future year plans for PGM budgets remain near flat, with a slight increase in procurement and some reductions in research and development. This plan does not reflect the importance JV 2020 attaches to precision engagement.

Budget Shortfalls result in Weapons Shortfalls

Despite our experience from the Gulf War and documented lessons learned that call for increased development and procurement of PGMs, recent headlines in defense-related journals note: "Army Says It's $3 Billion Short on Munitions," "Navy Chiefs Paint Stark Picture of Stockpiles of PGMs," "USAF Running Short of Precision Munitions say Service Leaders."[9] There are critical shortages of PGMs in all services.

The Navy needs an additional $1 Billion per year to bring its PGM arsenal up to acceptable levels.[10] For example, the US Pacific Fleet has six carriers with about 275 tactical aircraft that can fire PGMs such as the Joint Standoff Weapon (JSOW). The fleet, however, can arm only about 110 of these aircraft because its inventories are at precipitously low levels. Similar munitions shortages run throughout the fleet. While the Navy is planning to buy new PGMs, such as JSOW, Standoff Land Attack Missile-Expanded Range (SLAM-ER) and Tactical Tomahawk, some of these systems are still in development and others have been or will be bought at such low rates that it will take years to close the Navy's current weapons gap.

Stockpiling sufficient PGMs would appear to be an essential element for preparing the Air Force to achieve its aim of Global Reach, Global Power; however, the Air Force has not purchased the PGMs necessary to support that vision. This is partly due to the cost of PGMs. A 2000-pound Mark 84 dumb bomb costs about $2000. Even the cheapest precision weapons, such as the GBU-24 and 27, are over 15 times as expensive ($35,000). More complex PGMs, such as cruise missiles, cost from $750K to $1M per copy, and the small numbers purchased provide little hope for a decrease in price. In addition, the purchase of munitions must compete with other Air Force requirements.

A 1999 Army study, entitled Precision Munitions and Logistics Study, assessed the relative life-cycle costs, lethality, and supportability of nonguided munitions in relation to a more modern mix of nonguided munitions and PGMs.[11] It found that while the modern mix of nonguided munitions and PGMs was more expensive (because of a higher initial cost), the modern mix was more lethal, transportable, sustainable, saved lives and reduced the time necessary to accomplish battle objectives. The study also found that current budgets supported neither alternative. Essentially, the Army was slowly depleting its stores of unguided munitions, while not investing sufficiently in modern munitions.

In summary, current budget plans for the future do not support the JV 2020 vision of precision engagement. Levels of popular standoff PGMs are low. Munitions stores in general are being depleted. Although war planning is based on the availability of PGMs, funding for PGMs has not kept up with the growing demand.

Effect of Smaller Budgets on Industry

The defense industry, driven by a sharp reduction in DoD spending, has undergone a major consolidation during the last decade. From a peak of nearly $140 billion in 1985, DoD procurement spending in constant 2001 dollars fell sharply to roughly $60 billion in fiscal year 2001.[12] US defense industry consolidated with the intent of removing fixed capacity from the industrial base in order to match the diminishing DoD demand.[13] Consolidation took many forms, from acquisitions of select business units to full mergers of major corporations. Financing for these consolidation efforts came from various sources, including government subsidies, cash reserves, issuance of new debt and equity, and stock-for-stock exchanges. Although the industry downsizing effort was successful in reducing the number of suppliers, many of the firms desiring to remain in the DoD market still suffer from the burdensome effects of consolidation and subsequent restructuring. Within the PGM sector, consolidation resulted in three large prime contractors—Boeing, Lockheed Martin and Raytheon – with Raytheon emerging as the sole air-to-air missile supplier.

Effects of Consolidation – Heavy Debt and Cash Flow

The most aggressive aerospace/defense industry consolidator—Lockheed Martin—used heavy debt financing for numerous acquisitions through the 1990s.[14] Consequently, Lockheed Martin today is a highly leveraged company with $10 billion of debt and annual interest expenses of nearly $1 billion. Raytheon used a more balanced approach to the financing of acquisitions, but also carries nearly $10 billion of debt with a smaller asset base. In contrast, Boeing largely used equity financing during its consolidation activities, reflecting a more reasonable level of debt for this industry. Although higher levels of debt are viable and perhaps even attractive to equity owners if supported with stable returns, PGM profits have diminished and growth projections are flat. As a result, the negative aspects of financial leverage are reflected in very low returns on equity for both Lockheed Martin and Raytheon. Returns on assets and asset turnover ratios are also very low, due in part to the financing of $10 billion and $13 billion of goodwill, respectively. The combination of high leverage and low projected earnings growth obviously did not comfort investors, as the stock prices of both Raytheon and Lockheed Martin suffered severely during an otherwise strong market. Stock prices for these companies today are below 1996 levels.

The high levels of debt and low returns also pushed interest coverage ratios for Raytheon and Lockheed Martin quite low. Accordingly, confidence in their ability to service debt diminished and their credit ratings fell to near junk bond (BBB-) levels.[15] Consequently, the cost of capital for these companies is high. This created intense corporate pressure to generate free cash flow to pay down debt. Raytheon and Lockheed Martin made progress reducing their debt in 2000, and the efforts continue in 2001. Of significant concern, the cash applied to debt reduction reduces available corporate funds for support of research, development and capital investment, which in the long term can diminish both technological innovation and future competitiveness. In contrast, Boeing maintains a much higher AA- credit rating, has slightly increased debt in 2000, and has generated returns on both assets and equity that are more favorable and much closer to market averages.[16]

Fierce Competition Puts Pressure on Earnings

Why are corporate earnings low for these companies? Earnings are low because munitions, and defense in general, is a buyer's market where competition is fierce. DoD conventional weapons research and development funding is falling while procurement funding is growing (note that munitions represent approximately 20% of the total conventional weapons funding).[17] Consequently, the portfolio of munitions programs contractors possess now will largely determine future sales, with only few opportunities for growth except through capture of a competitor's market share or expansion of foreign sales in the face of stringent controls.[18] In addition, planned DoD weapons production levels and quantities are always in jeopardy of significant fluctuation, and can increase due to use in either hostility or foreign sales, or decrease in favor of alternative technology or budgetary constraints.

DoD's emphasis on affordability, and strong industry competition on what few new-start programs there are, forced contractors to bid very aggressively. This risky practice requires commitment of substantial corporate investment during the development phase that is hedged only if the company attains planned production levels, production quantities and perhaps foreign sales. Consequently, contractors endure a substantial negative cash flow during the development phase of most munitions programs that exacerbates the need for corporate cash. Although this contractor "buy-in" represents a munitions-related corporate allocation of cash, it is targeted toward a specific program rather than the independent research and development projects that better nourish long term competitiveness.

Foreign Competition

Foreign competitors are chiefly European and face largely the same challenges as domestic suppliers. In an era when most European countries cut their defense spending by approximately 5% per year, European defense firms are merging and consolidating to compete more successfully with US companies.[19] In 2000, French, German and Spanish companies merged to form the European Aeronautic Defence & Space (EADS) Company. Meanwhile, BAe Systems, a United Kingdom based company, also aggressively embraced consolidation, merging with Alenia Marconi Systems and acquiring two US business units from Lockheed Martin. These mergers were followed by the creation of a major European munitions company through the consolidation of the munitions businesses of EADS, BAe Systems and Finmeccanica, an Italian company.[20] This new munitions company, named MBDA, was created specifically to provide the size and resources to compete with Raytheon and the other large American companies. EADS, BAe Systems and Finmeccanica are the sole shareholders of this new company, but have agreed not to compete with it in the munitions business area. MBDA will maintain an industrial presence in the United Kingdom, France and Italy. An important consequence of the creation of MBDA is the prospect of a standardization of weapons systems among the participating European countries.

Because of the numerous mergers and consolidations, European corporate lineage is difficult to decipher. EADS, BAe and MBDA represent complicated webs of alliances,

partnerships and government equity ownership that few, including some of their own corporate representatives, can unravel. This complexity makes determination of their financial status, business agenda and ultimate loyalties difficult for potential partners and government customers. At present, heavy debt, high interest expenses and few munitions product successes characterize these firms, but they are aggressively pursuing growth and are relatively unbridled by export restrictions. As the European Union develops its own identity, and areas such as the Pacific Rim and the Middle East show increasing demand for munitions products, there is a growing concern that the munitions market will divide into a U.S.-supplier versus European-supplier environment. Such a polarization would adversely affect the exports of US suppliers, as well as on transatlantic cooperation and interoperability.

In evaluating the strength of the US munitions industry and the impact of future competition, it is important to consider current world market share of the various competitors. Figure 2 below reflects the shares that US, European and other producers have of the various PGM markets.

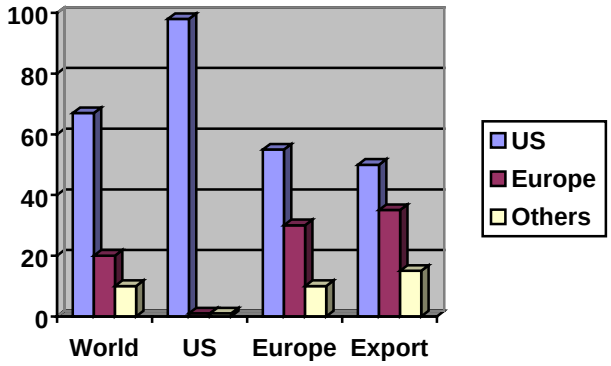


Figure 2: Share of World Market, as of 2001[21]

Figure 2 illustrates several important points. First, the US market is dominated by US munitions companies. Because the US market is twice the size of either Europe's market or the export market, it is a very attractive market for European competitors. Second, US companies provide over half of Europe's munitions and about half of export munitions (munitions purchased by nations outside the US and Europe). European companies would like to compete successfully in the US market and be more competitive in the global market. They see a one-way street in which US companies successfully compete in European markets but European companies are not permitted to compete in US markets. There are reasons for the lack of European competition in US markets, ranging from US protection of its industrial base, to export control regulations, to the historically fragmented nature of European munitions companies. In the future, the European companies will be more competitive in the European markets, especially if Europe sees no reciprocity in transatlantic competition. There will also be strong competition for the export markets. There is a risk, which we discuss later, of a schism developing between US and Europe that could adversely affect coalition relations and interoperability.

Summary

Munitions manufacturing is a profitable endeavor for defense contractors that provides sufficient segment margins to help cover common fixed costs and interest.[22] However, two of the three prime munitions contractors are heavily burdened with debt from consolidation. While opportunities for growth are limited, domestic competition is fierce and European competition is growing rapidly. DoD is pushing hard for affordability, and the contractors, often in a "must-win" situation, are providing it through decreased margins, large initial cash flow deficits and lengthened payback periods. DoD and other government regulations further stifle performance, and long term industry innovation and technology development is under threat from intense competition for human and financial resources. Within the defense industry today, there is an apparent excess of development and production capacity in relation to the current and projected levels of DoD spending for these weapons. Further consolidation within the industry is likely.

CHALLENGES

Fragmented Management of Munitions

Deficiencies in the way in which DoD manages munitions aggravate the general shortfalls in funds budgeted for PGMs. These deficiencies concern both the process by which munitions requirements are ascertained, and the process by which munitions are developed and procured. To determine the number and type of munitions needed, the services annually evaluate their munitions requirements using a multiphase analytical process referred to as the Capabilities-Based Munitions Requirement (CBMR) process. The accuracy of this process is critical as its outcome (1) defines the numbers and types of munitions necessary to defeat potential threats; (2) affects munitions planning, programming, and budgeting decisions; and (3) influences industrial production base decisions.

In brief, the CBMR begins when the Under Secretary of Defense for Policy develops, in consultation with the Chairman of the Joint Chiefs of Staff, the military services, and the warfighting Commanders in Chief (CINCs), policy on munitions requirements for the Defense Planning Guidance (DPG). The Defense Intelligence Agency (DIA) uses the DPG and its accompanying warfighting scenarios as well as other intelligence information to develop a threat assessment. This assessment contains estimates and facts about the potential threats that the US and allied forces could expect to meet for each of the two major theaters of war (MTWs) scenarios. The warfighting CINCs, responsible for the MTW scenarios, in coordination with the JCS, use the threat assessment to allocate each service a share of the identified targets by phases of the war.

Next, the services use battle simulation models and scenarios to determine the number and mix of munitions needed to meet the CINC’s objectives for each MTW scenario. This requirement is then compared with stocks on hand and in the acquisition pipeline to see if there are any shortfalls. If there are shortfalls, the services seek to remedy them through the DoD budgeting process.

Despite DoD efforts to standardize the process and generate consistent requirements, there are considerable areas of overlap and potential weaknesses in the process. For example, each service develops an independent threat analysis that could result in multiple services planning to destroy the same targets and, consequently, overstating munitions requirements. In addition, the increased use of precision munitions in recent conflicts drastically reduced inventories and raises questions about whether DoD is paying adequate attention to the impact of small-scale contingencies on the ability of US forces to respond and sustain significant combat operations for two MTWs. Finally, the Air Force and Navy requirements models show a strong preference for using guided weapons against most targets -- placing a premium on avoiding any aircraft or aircrew losses and minimizing collateral damage. The models tend to select the most accurate weapons with the greatest ranges, even though these may not have the best target-killing characteristics and may be much more costly than alternatives with better target-killing characteristics.[23]

Because each service proposes improvements to its capabilities separately, there is a risk of either redundancies or critical gaps from a joint operations perspective. The services' modernization plans are developed through a requirements generation process that also encourages each service to maintain its own view of how its own capabilities should be enhanced to ensure interdiction targets are hit. Each service is fully engaged in trying to deliver to the CINCs what the service views as the best possible set of its specific capabilities without taking into account the similar capabilities provided by the other services. On one hand, this is desirable because competition among the services produces innovation that yields the dramatically superior military capabilities we need. However, this decision process does not ensure that the services consider the capabilities available in the total force.

While the general threat and analyses may be legitimate, the processes for developing weapon system requirements tend to narrow consideration of alternatives. The services tend to promote particular weapons because of integration costs or current availability, not necessarily the best long-term solution to a valid Combatant Commander's need. For example, the Navy's SLAM-ER and the Air Force's Joint Air-to-Surface Standoff Missile (JASSM) have similar ranges and capabilities. The Navy developed SLAM-ER as an interim weapon after the collapse of a previous program. Now the Navy faces significant costs to integrate JASSM on its aircraft. The cost of integrating SLAM-ER with the F/A-18E/F was approximately $10 million, while the cost of integrating JASSM with the same aircraft will be approximately $95 million.[24] The reason for the price difference is that the Navy had previously integrated SLAM, an earlier less capable version of SLAM-ER, with its F/A-18C/D, and the E/F model uses the same basic avionics as the C/D, so only minor software modifications are required for the E/F to carry the newer missile. For JASSM, a complete integration is required. Thus, there are short-term but significant price reasons for the Navy's interim preference for SLAM-ER, although there would be long-term savings in transportation, logistics and economies of scale were the services to agree to adopt JASSM for the long-range guided attack mission.

In addition to weaknesses in the requirements process, there are weaknesses in the overall management of munitions from development through production and sustainment. DoD has delegated responsibility for the management of conventional ammunition to the Army. The Army has re-delegated this responsibility to a number of different organizations. The Single Manager for Convention Ammunition (SMCA) has responsibility for storage, sustainment and management of the organic industrial base. Development and acquisition responsibilities are largely delegated to other organizations. As described above, each service determines its own requirements for ammunition, based on DoD guidance. Each service also retains control of developing new forms of munitions, and producing service unique munitions, which includes almost all PGMs.

Thus, while the current production base meets US needs, DoD's management system is fragmented and the business environment needs stabilization and modernization.[25] DoD's fragmented management system sub-optimalizes decision making, makes integration of significant changes difficult, and causes turf battles that are difficult to resolve. In addition, munitions lack a strong cohesive voice in the budget process, causing it to take a low priority, especially when competing against the more expensive and politically attractive weapons platforms.

The effect of the fragmentation of control over munitions is to further reduce the "bang for the buck" that the services can obtain for their limited munitions budgets. Each service has laboratories, program managers, and contractors that fight for projects that may be duplicative or not the best choice for the Combatant Commanders.[26] Many of these systems cannot easily be integrated onto the platforms of other services because of the use of legacy software and prior decisions that optimized the systems for one service at a cost of making it unusable by other services. Finally, the independent decisions of each service to develop separate weapons systems combined with a lack of funding means that too many systems are chasing too few dollars. Insufficient funding forces contractors to run the production lines of each system inefficiently, which adversely affects their profits and productivity. Although the contractors want to protect their systems, many of those that we interviewed admitted that the government would be better off if it funded fewer systems, but fully funded these systems.

Integration

Another challenge to joint and interoperable weapons is integration of weapon systems to weapons platforms, whether aircraft, ships or vehicles. The costs of weapons integration onto Navy and Air Force platforms is perhaps the largest driver behind the apparent divergence from joint munitions solutions for similar target sets. Weapons integration is very expensive, and must begin early in the requirements and design phase of the munition. Aircraft chosen for threshold integration will largely be budgeted within the munitions program's budget. Integration costs for those categorized as objective platforms are usually borne by the platform's sponsor. These funding rules can result in integration delays when the service paying for integration has other priorities.

In the design phase, the weapon store must be sized to the pylons, racks, launchers and weapons bays of potential platforms. The structural design must accommodate ranges

in airspeed, internal carriage, external carriage and perhaps catapult shots and arrested landing on an aircraft carrier. In addition, every aircraft has unique aerodynamic flow field characteristics. These flow field conditions determine how well the munition separates from the aircraft, what effect carriage of the weapon has on the flying qualities of the aircraft and what effect aircraft aerodynamics have on the weapon (such as vibration and noise). Finally, the weight and aerodynamics of the munition will have unique structural effects on each platform, and, quite probably, these effects will vary substantially with differing ordnance loadouts. Consequently, there are many factors that must be addressed throughout munitions development and then thoroughly tested, before the munition is ready for operational use.

It is understandable why the services often "talk" joint but rarely deliver. In the longer-term, joint munitions would provide substantial savings. When, however, the yearly budget crunch comes, the less painful answer is usually to continue to develop upgrades of existing systems and let the other services go their own way.

Doing Business with DoD

Several issues inherent in DoD contracting present substantial hurdles to profitability and create disincentives to industry participation. The linking of research and development contracts with production unit procurement costs, progress payment schedules and allocations, and cost caps on highly competitive cost-plus programs fuel heavy corporate investment and excessive cash flow deficits early in the program. Entire programs, payback periods and planned profit margins are structured around optimistic production learning curves that possess a high degree of uncertainty due to program funding through yearly congressional appropriations.[27] Government cost accounting standards are rigid and complex, profit guidelines offer few incentives for cost cutting, and efforts to protect key proprietary processes and technology often require compromise. In addition, the nature of the munitions business makes it subject to the export control regulations of the Department of State. The policies and processes of export control are onerous, sometimes ambiguous, often cause significant delay and directly impact foreign competitiveness. Violation of these regulations can result in heavy fines and potential denial of export privileges.[28]

Brain Drain

Another issue facing munitions contractors is the loss of human talent. The technological demands involved in the guidance, navigation, target recognition and information transmission systems of munitions are very high, and require a stock of intellectual capital and a sustaining inflow of new software engineers. With diminishing profits, traditional compensation plans and government restrictions on contractor pay; the munitions industry has difficulty attracting new recruits when faced with strong "new economy" incentives offered in other high-tech industries. Furthermore, foreign engineers can help little to fill the void because of national security concerns. As a result, the munitions industry workforce is “graying”, which could set up a potential long term chilling effect on industry-wide technological innovation.[29] Recent news articles indicate that the recent dot-com downturn, combined with industry efforts to provide a unique and interesting line of work, may reverse the trend noted above.[30]

Information Assets

Achieving the full potential of precision engagement will require our information processes to become much more efficient, accurate, and real-time. DoD must change its stove-piped, compartmentalized intelligence system to meet the requirements these munitions demand. Today, the US has a tremendous capability to conduct long-range precision strike operations, but deficiencies remain. One of DoD's biggest challenges is its ability as a joint fighting force to rapidly strike pop-up type targets (e.g., SCUDs), movable/relocatable targets (e.g., mobile surface-to-air missiles (SAMs)), and moving targets (e.g., tanks). The primary limitation driving this deficiency is DoD's ability to rapidly pass information. To effectively target time-critical targets, DoD must improve its ability to process and disseminate quality target information to the unit level, to the shooter, and eventually to the weapon itself. DoD can address fixed targets successfully today, but time-critical targets present a significant challenge because of stale information. Unfortunately, the high risk targets for which DoD would most like to use a long range PGM are the same targets with which PGMs have the most trouble. There is a recognized need to disseminate data directly from sensor to shooter, thus permitting the shooter to make a rapid decision whether to fire. Today DoD has very limited ability to do this.

DoD must also streamline its processes at every point along the targeting chain to achieve the effects-based targeting JV 2020 envisions. The competition for bandwidth will increase as DoD continues to digitize the battlefield. Bandwidth is neither free nor unlimited. Our potential adversaries have noticed our reliance on GPS. DoD must assure its continued access to this key capability by actively pursuing an anti-jam capability along with developing other methods of precision guidance, such as the Precision Terrain-Aided Navigation (PTAN) capability being developed for the Tactical Tomahawk. DoD's success on the battlefield will be a function of how effectively and efficiently it gathers, processes, and disseminates information. Information may be one of the greatest challenges because of the private ownership of most information assets, and the commercial demand for information technology.

OUTLOOK

As we look to the future, it is clear the need for and demand on PGMs will continue to grow. PGMs are an essential piece of precision engagement and key to achieving JV 2020's vision of full spectrum dominance. This section will look at how PGMs are evolving to meet the warfighter's most critical deficiency: the ability to kill time-critical targets at long-range and in all weather conditions. This section will also look at the future of the PGM industry.

The trend in conventional weapons development and acquisition is a steady move toward smarter, long-range offensive weapons. These weapons will be capable of finding and destroying targets autonomously and with high precision. Long-range precision strike weapons allow the US to conduct combat operations against heavily defended targets with minimal risk to its warfighters and minimal collateral damage to noncombatants. JV 2020 outlines several operational concepts required to achieve full spectrum dominance.

Precision engagement is one of these key operational concepts, and PGMs are the cornerstone of this concept.

Beyond the operational aspect of precision engagement lies another advantage. Precision engagement may be the real enabler that gives the nation's civilian leadership a viable military option. Recent conflicts seem to indicate that the White House is more able to convince Congress and the American people that use of military force is an acceptable option when the operation will result in very low American casualties and extremely limited collateral damage. Operation Allied Force (OAF), NATO's most recent air campaign against the Former Republic of Yugoslavia, raised this bar to the highest level as the first combat operation without a single US combat casualty.

As a result, precision weapons have become the theater commander's weapons of choice. Each successive conflict has seen an increased use of preferred munitions. For example, the use of PGMs increased from 9% in Desert Storm to 70% in OAF. As we envision fighting future conflicts, PGMs will become increasingly the weapons of choice. The critical question is: Will we have enough of them?

The Consolidation of Weapons Types

Today we have a large number of PGM product lines, developed and procured by all services. Each of these products fills a niche service need, but none are being produced at high production rates. There is no indication that the defense budgets will increase to any significant extent. Based on fiscal constraints, if we are to ensure we have adequate numbers of PGMs, we can no longer afford the overlapping, risk-averse, specialized approach to strike weapons. We need to commit to a reduced number of weapon product lines that will meet the requirements of all services, and then produce these products at efficient rates. The Air Force briefed a plan to reduce its numbers of systems at the 2001 Air Armaments Center. Figure 3 below reflects that plan.

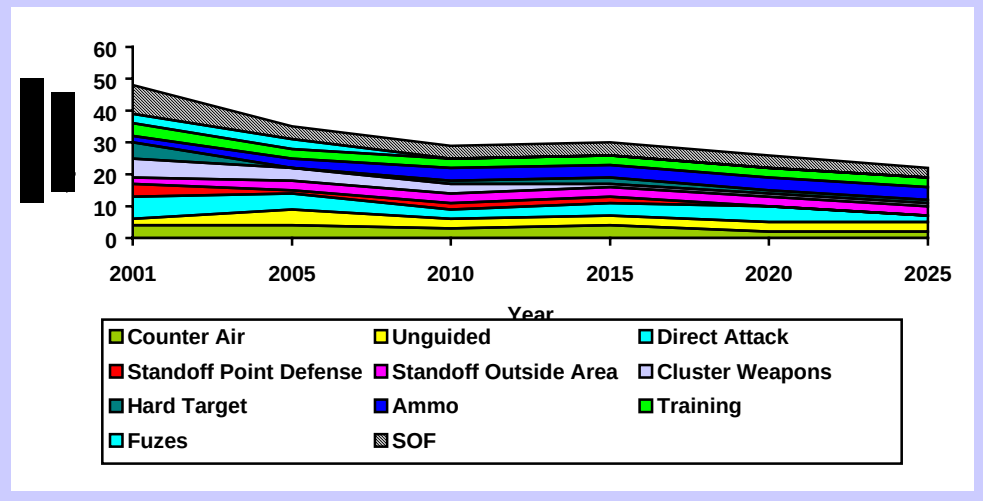


Figure 3: Air Force plan to reduce the numbers of munitions systems[31]

Consolidation of systems must occur among the services as well as within a service. Accomplishing this will require all services to embrace true joint solutions.

Man-in-the-Loop or Autonomous Weapons?

Operation Allied Force underscored the need for all-weather precision weapons when thick cloud cover severely restricted the use of laser-guided bombs that had worked so well in the desert environment of Iraq. GPS-guided weapons like JDAM and JSOW were very effective in bad weather, but do not provide the same capability as true "precision" weapons. The next step is to move these weapons from "accurate" weapons (GPS-guided) to true precision weapons without the constraints of man-in-the-loop, clear weather, limited standoff, and onboard targeting presented by the older laser guided bombs. To accomplish this next step, the services are moving toward automatic target acquisition (ATA) and automatic target recognition (ATR) seekers. An ATA seeker matches the target scene imaged by the imaging infrared (IIR) seeker to the preprogrammed target scene determined by the mission planners. The PGM then guides to the selected point within the target scene. JASSM, for example, will use an ATA seeker.

Automatic target recognition seekers operate a little differently. A PGM with an ATR seeker will fly to a preprogrammed target area and then search the area using its own seeker. It attempts to match what it sees with its onboard database in order to engage those targets it recognizes as threats (i.e., SAMs, tanks), and not engage those targets it recognizes as friendly (schoolbus, friendly tank). A weapon currently under development, Low Cost Autonomous Attack System (LOCAAS), uses an ATR seeker.

There are at least three implications to consider with these next generation smart weapons: the information requirement, mission planning, and Rules of Engagement (ROEs). Both ATA and ATR seekers will put a large demand on high quality imagery. ATA mission planners must have a current, high-quality target image to build the scene for the missile. ATR seekers do not need a current target image, but will require a massive database to be built to catalog all the possible threats we could face and what they look like from various overhead angles. All this information must be loaded into the missile. This database will require continuous updating as threats change. As the database is updated, the missiles must be updated. The area of most concern with an ATR type weapon is: Will the ROEs ever allow it to be used? With today's increasing concern for limiting collateral damage, will theater commanders allow the use of a weapon that autonomously targets and attacks a threat? What is the risk it will engage the wrong target and how will we know if it does? ROE comes from experience, and until decision makers can experience this type of technology, they may continue to put strict restraints on the use of autonomous type weapons.

The Continued Need for Platforms

The vast majority of current PGMs, including laser guided bombs and JDAM, must be released within 15 miles of the target.[32] Most are delivered by aircraft. Both US and European platforms are aging, and need replacement in the near future. Although it is possible that future developments in long range standoff weapons, unmanned vehicles and

small weapons may reduce the need for survivable penetrating aircraft, we need adequate numbers of these aircraft platforms for the foreseeable future. Therefore, the services must balance the purchases of platforms and the types and quantities of PGMs that are necessary for effective employment of the platforms.

Further Consolidation

Current PGM production capacity exceeds current demand. With three US prime contractors and at least one major European contractor all vying for an increased piece of the pie, competition will most likely lead to further consolidation. The benefit to industry will be larger profit potential. The transition from three US contractors barely limping along to two more healthy contractors (or perhaps one in the US and one in Europe) could have a positive affect on the industry as a whole. It better matches industry's infrastructure and production capacity to available government resources with acceptable tradeoffs in loss of competition and defense industrial base. It will also allow the remaining contractors to make a reasonable profit and provide a better, cheaper product to the US government.

Foreign Competition and Teaming

There is a growing separation between the military strategy, combat capabilities, and technologies of the US and its allies. Allied forces are unable to take full advantage of US battlespace information, augment US standoff strikes, or fit into the seamless integration of US sensors, platforms, and weapons. With the allied forces' lack of ability to fully participate comes a growing possibility that US military commanders will marginalize them rather than integrate them. What is causing this gap? First, the US spends twice as much as its allies in research and development and modernization. In addition, the Europeans have excessive personnel, facilities, and support costs (consuming resources badly needed to improve quality and modernize). The US also benefits from a sturdier industrial base and more responsive technical base than exists in Europe. Despite an otherwise integrated European market, European defense firms mostly operate on a national scale – every major European nation remains sufficiently attached to its sovereignty to want to keep at least one major defense contractor.

US defense contractors have traditionally been more competitive than European counterparts in world markets -- indeed munitions are one of America's best export performers. With greater market shares at home and globally, US contractor costs are generally lower than European competitors are, and that translates into lower prices and higher profit margins. In sum, the US can develop smarter weapons, better communications, and more sophisticated sensors than its European counterparts. This causes a vicious cycle. European forces cannot acquire information age capabilities from industries that are not able consistently to provide them at affordable prices. Because they lack the most advanced PGMs, European forces cannot meet the current precision engagement demand that today's conflicts require. Without a demonstrated need, European militaries will not demand their suppliers to become more inventive and efficient. ***This compound effect of weak demand and weak supply is making it harder for the allies to keep up with the US.***

GOVERNMENT ROLES AND MISSIONS

Throughout the Cold War, DoD sought to maintain a broad industrial base, often sustaining weak sectors with more contractors than efficient procurement would allow. Beginning with the famous "Last Supper" hosted by the Deputy Secretary of Defense in 1993, DoD initiated an expensive consolidation of the industry. Despite marginal savings – often merely a reflection of selling excess real estate, reductions in senior workers, and relocation to low cost-of-living regions in the South and Southwest – consolidation continued unabated until 1997. That year, Secretary William Cohen and Under Secretary Gansler opposed a proposed Lockheed-Northrop Grumman merger because it would eliminate competition. This set a new course in industry restructuring, one using cooperation as its model.

In view of such policy shifts, what are the implications for industry and defense planners now? What policy should the U.S. government espouse in this decade? Given the continued trend in mergers and consolidations for stockholder interests, how can DoD ensure an adequate number of world-class PGM suppliers with the best ***technical production capabilities***?

The ICAF Munitions Industry Seminar has developed the following recommendations for ensuring appropriate access to world class PGMs at reasonable prices.

Maximizing Weapons Capability within Fiscal Constraints

The Government, through submission of the annual President's Budget and Congressional enactment of the Defense Appropriations and Authorization Acts, directly controls the quality and quantity of weapons procured. The Government therefore has the ability to stabilize procurement to ensure maximum efficiency of production. In recent years, DoD has delayed or cancelled many PGM programs, causing significantly higher average unit procurement costs and delayed deliveries to operational units. For example, the Air Force at one time planned to procure about 4000 AGM-130s but now plans to buy only 711. As a result, the unit procurement cost is now about $832K vs. earlier projections of under $300K. Reductions in planned procurement funding for the Sensor Fused Weapon (SFW) forced the program to reduce annual procurement rates and stretch out the schedule. As a result, SFW unit costs increased from about $320K to $360K. The Brilliant Anti-Tank (BAT) munitions program has been unstable, with its schedule extended by 5 years. BAT's procurement quantities also dropped by 36%, while program costs increased by almost 8%.[33]

Three factors explain the decisions to reduce quantities and stretch production runs. The first factor is that each service desires to optimize munitions for its own use, avoiding or minimizing participation in joint programs that would enlarge order quantities. The second factor is the desire to keep production lines open for possible wartime or crises production surge. The third reason is the political difficulty of killing acquisition programs – every program has a constituency. Policies that encourage economic production must temper these three factors.

Notwithstanding the existence of the SMCA, each service fragments management of munitions requirements generation, research and development, procurement and sustainment, especially for PGMs. In addition, the services frequently develop duplicative weapons systems, or incompatible weapons systems. To make better use of limited dollars, several changes are required. First, DoD must strengthen the Joint Requirements Oversight Council (JROC) so that it can enforce joint solutions. The JROC currently reviews requirements generated by each service, and combines related requirements into joint programs. However, the JROC has no oversight into program execution. Therefore, the lead service on a joint acquisition may make parochial decisions leading to withdrawal of the other services from the program. The JROC should have sufficient oversight authority on acquisition programs to require optimization of development and acquisition for all services, rather than from the leading service.

Second, a joint weapons requirements office must be established at the Joint Chiefs of Staff or DoD level. This office must have the authority to consolidate service and CINC weapons requirements, preparing a long-term weapons roadmap and looking for opportunities for joint development of future weapons systems to be shared by all services.

Third, DoD must create a Joint Armaments Acquisition Center to manage the development and acquisition of all PGMs. The Air Armaments Center, created by the Air Force, could be a model. The Joint Armaments Acquisition Center would have the responsibility of requiring joint solutions, unless different requirements mandate another approach.

Finally, Navy, Marines and Air Force procurement of the Joint Strike Fighter (JSF) will drive convergence of service requirements for PGMs, ensure interoperability, and enable substantial cost savings in integration and production of weapons. The size of the program will help to finalize industry consolidation, generate sustained profitability, and thus ensure long-term munitions innovation and technical development.

Stabilize Funding at Adequate Levels

Congress funds DoD only for readiness and not for possible contingencies. When a contingency or emergency arises, the money must either come from an internal reallocation (i.e., from raiding investment and other accounts) or from a supplemental appropriation. For example, in fiscal year 1997, 12% of the planned investment accounts (research and development, and procurement) were moved to the operations and maintenance (O&M) accounts to meet unprogrammed O&M requirements and unfunded contingencies.[34] Supplemental appropriations come very late in the fiscal year and almost never provide enough funds. This, combined with overall funding limitations on defense funds, has forced the Defense Department to take funds from the investment accounts. This practice has increased in recent times because defense dollars have declined in relative terms, leaving fewer alternatives. A general underfunding of all accounts since the early 1990s has aggravated this structural problem.

To address this funding problem, DoD must enter into a dialogue with Congress about funding mechanisms for unexpected contingencies. It must also engage in an honest dialogue with Congress about its funding needs, and plan to acquire its requirements in an economically reasonable manner. Reducing the length of the development and production phases of weapons procurement would reduce the chances that a change in world condition will require cancellation of an approved system. DoD should cancel systems when they

are no longer required, but it should reduce the number of cancelled systems through better management of requirements.

Acquisition and Export Control Reform

DoD should continue with acquisition reform initiatives. A recent Defense Science Board Report on Improving the Health of the Defense Industry described many recommended initiatives.[35] DoD has made much progress in implementing these initiatives.[36] With respect to the munitions industry initiatives, full funding of research and development and improved arms export control procedures would be the most helpful. US arms export control policy was created to keep weapons technology out of the hands of Communist Bloc countries during the Cold War. With the end of the Cold War and the globalization of the world economy, US arms export control regulations are increasingly based on business considerations. Raytheon, Boeing and Lockheed Martin representatives confirmed that 25-30% of their business is derived from foreign sales contracts. In 1998, missile sales by the big three totaled over $4.3 billion.

The current export control system spends large amounts of time and manpower protecting against security risks. Additionally, this system is giving the impression of safety by compliance with regulations rather than a true evaluation of risk while driving a wedge between the US and its allies. With difficulties in obtaining export licenses, foreign companies are avoiding US components wherever possible. This avoidance could result in additional interoperability problems such as those that plagued NATO during Operation Allied Force.

To confront these new challenges, the US needs a leaner and more effective export control system. Specifically, the export control system should remove commercial and legacy technologies from scope of export controls, delete duplicative reviews, streamline required reviews, and create a broad waiver program for allies and friends who agree to principles on security and demonstrate the ability and intent to implement such principles. The current export license exemption to Canada is a good example on which to base such a policy.

Increase attractiveness of the Defense Industries for Software Engineers

Every company that we visited mentioned the shortage of software engineers as a principal resource challenge. Government accounting rules limit the amount of compensation the munitions industry can pay, and the munitions industry has difficulty providing the lucrative stock options and other equity attractions that other industries can provide because of low margins. The industry has asked DoD to amend its cost accounting rules to clearly provide for higher payments and benefits for scarce technical personnel. DoD is in the process of amending its rules to facilitate hiring and retention of these engineers. Improved funding of research and development, stabilized funding of systems, and a consolidation of systems to those that are required and can be fully funded would improve the financial strength of the munitions industry, and result in an enhanced ability to provide stock options and equity attractions to both technical and managerial staff. Long term initiatives to encourage science and technology education would also serve to increase the supply of engineers.

Balancing the Health of the US Industrial Base against the Need for International Cooperation and Interoperability

US and European forces must be able to perform together all the operational tasks required by current US military strategy. This means that the US and European governments must work together to develop compatible and adequate forces. Because the US military's selection of European-made systems is such a rarity, Europeans grumble about the transatlantic "one-way street.'

We need a multi-tiered strategy that supports the convergence of European and US strategic outlooks and motivations. There must be a common strategic perspective, recognizing that common critical interests are at stake, that cooperation is essential, and that agreement must occur on core strategic precepts even if details are unresolved. In addition, we must agree on a common set of contemporary military operational problems that US and European military forces can work together to overcome as well as on a set of RMA priorities – communications and information, smart weapons, new military strategies and tactics – that exploit information technology. Third, we must create open network architectures and technical standards that will make networked forces, sensors, and PGMs a coalition capability. Finally, we must create more open transatlantic markets for defense systems, including the underlying information technology. We must foster more joint development programs (followed by joint production). The best way for government to encourage this is to remove all barriers and disincentives, allow the firms to structure the collaboration, and not try to supervise it. If European and US firms are prepared to enter into equity relationships, joint ventures and mergers could yield major benefits not only for the firms but also for the cause of closing the gap – two-way market access, sustained R&D cooperation, and greater commonality in meeting US and European military requirements. Equity relationships have played a key role in spreading the information revolution domestically and internationally; perhaps they can do likewise in spreading the RMA across the Atlantic.

In this regard, the US should not cancel multinational development projects between itself and its allies, without serious consideration of the ramifications. Not only do these cancellations cause a loss of credibility, they can have significant unintended consequences. The cancellation of the JSF, for example, would force the Europeans to select the Eurofighter as their next tactical aircraft. This would greatly reduce the chances that US industry could sell PGMs to Europe because of the cost of integrating US munitions to a purely European aircraft. US munitions will already be integrated to the JSF, thus enabling sales of US munitions at reduced cost to European JSF purchasers. Cancellation of a project such as JSF could cause the separation of the US and European munitions markets, significantly degrading interoperability and future effective coalition action.

Overall, this proposed strategy would require cooperative activities involving US and European political consultations, military planning, force experiments and exercises, industrial ventures, and research collaboration.

CONCLUSION

PGM technology is running ahead of both doctrine and infrastructure. The cost of many PGMs is falling, while their capabilities increase. PGMs provide additional tools to the Commander, but bring additional challenges in the form of potential foes with similar capabilities, greater ROE limitations, and insufficient information assets.

The greatest challenge facing the US with regard to PGMs is fulfilling the JV 2020 vision of joint, interagency and multinational operations. DoD munitions management is fragmented, with each service providing service-specific and occasionally duplicative weapons systems at less than economically viable rates of production. Europe is frustrated with the closed US market and the lack of meaningful joint development opportunities.

DoD can meet the JV 2020 challenge, but to do so will require a far more joint and effects-based approach to weapons requirements and development. The JROC must actively manage weapons systems and control weapons development for joint operations. An empowered joint requirements office must be formed to consolidate and rationalize requirements. We must create a Joint Armaments Acquisition Center to plan and execute the development of joint weapons. This center must also coordinate the related information and platform developments so that all systems work together for maximum effect.

Falling defense budgets in the US and Europe caused consolidation and competition on a worldwide basis. The US PGM industry now largely consists of three large companies: Raytheon, Lockheed Martin and Boeing. The European PGM industry is consolidating down to one large company: MBDA. Heavy debt and excess capacity exist on both sides of the Atlantic. Competition is fierce, and will likely produce additional consolidation and rationalization in the future.

With regard to our European allies, we need a multi-tiered strategy that supports the convergence of European and US strategic outlooks and motivations. First, we must agree on a common set of contemporary military operational problems that US and European forces can work together to overcome as well as on a set of RMA priorities – communications and information, smart weapons, new military strategies and tactics – that exploit information technology. Second, we must create open network architectures and technical standards that will make networked forces, sensors, and PGMs a coalition capability. Third, we need to create more open transatlantic markets for defense systems, including the underlying information technology. In this regard, we need to foster more joint development programs, followed by joint production. We must be sensitive to the connection between PGMs and platforms. Missile defense might be an appropriate joint development program in light of US desire for allied consensus.

The use of PGMs shows a political sensitivity and sophistication that is appreciated around the world. Perhaps more so than any other single weapons program, PGMs will unlock the power of our military in the future so long as we innovate as a team – not in isolation.

[1] Definitions vary. This version from the U.S. Air Force environmental research service and information exchange clearinghouse at http://www.afcee.brooks.af.mil/pro-act/aboutproact.asp. A complete definition of military munitions as defined by the US Environmental Protection Agency is located in Title 40 CFR 260.10.
[2] Northrop Grumman also supplies PGM products, but the three firms above provide more than 80 percent of DoD's PGM requirements.
[3] Joint Vision 2020, approved by the Chairman of the Joint Chiefs of Staff, and published by the US Government Printing Office, June 2000.
[4] Id. at page 28.
[5] 1997 United States Air Force Issues Book, Precision Weapons, found at http://www.af.mil/lib/afissues/1997/app_b_8.html.
[6] Data sheet entitled Tomahawk Weapon System Elements, dated 09/01/89, provided by Raytheon.
[7] Thompson, Loren G., "The Joint Direct Attack Munition: Making Acquisition Reform A Reality," NSSQ, Spring 2000.
[8] Office of the Secretary of Defense. (2001). Conventional Munitions Master Plan FY98-05. Washington, DC.
[9] Roosevelt, Ann. "Army Says It's $3 Billion Short on Munitions," Defense Week, (No. 10, 5 March 2001); Holzer, Robert. "Navy Chiefs Paint Stark Picture of Stockpiles," Defense News: (5 February 2001); and Lowe, Christian. "Services Outline Strike Weapons Road Map," Defense Week, (No. 4, 22 January 2001).
[10] Holzer, supra; Lowe, supra; Keeter, Hunter. "Gansler Approves Navy, Army Coordinated Munitions Roadmap," Defense Daily (Issue 10, 14 April, 2000).
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[13] Harbison, Moorman, Jones & Kim. U.S. Defense Industry under Siege—An Agenda for Change. Booz, Allen & Hamilton Inc. (2000) [On-Line]. Available:http://www.bah.com/viewpoints/.
[14] See Appendix, Table 2 – Summary of Fiscal Reports for 2000 for Raytheon, Boeing and Lockheed Martin.
[15] Defense Science Board Task Force. Preserving a Healthy and Competitive U.S. Defense Industry to Ensure our Future National Security. Washington, D.C. (Final Briefing May 2000)
[16] Defense Science Board Task Force 2000, supra.
[17] Conventional Munitions Master Plan FY98-05, supra.
[18] Defense Science Board Task Force 2000, supra.
[19] Nicoll, Alexander, "Europe's Defense Spending Falling," Financial Times, May 17, 2001.
[20] -----, "BAE Systems, EADS and Finmeccanica were Set to Sign Final Agreement," Aviation Week & Space Technology, Vol. 154, Issue 18 (April 30, 2001).
[21] From briefing by Matra BAE, May 2001.
[22] See for example, Boeing, Lockheed Martin & Raytheon. (2001, April). Munitions Industry Discussion Notes. Munitions Industry Domestic Field Trip, Industrial College of the Armed Forces, Washington, DC.
[23] For example, the Navy's model selects Tomahawk missiles (@ $1M each) for many types of targets, even against some targets where its effectiveness is poor. While the specific situation may dictate the use of a Tomahawk due to target location or threat, other weapon choices could be more effective and less costly if other factors such as aircraft attrition don't overcome the weapon's cost advantage.
[24] These figures came from discussions with a representative from Navy (N78) Strike Weapons Requirements Office, May 2001.
[25] See, for example, the findings of Pacific Northwest National Laboratory, Recommended Strategy for Configuring and Managing the US Munitions Industrial Base, (Richland, Washington, April 1997).
[26] See the weapons for various target sets in Table 1, Appendix.
[27] Defense Science Board Task Force 2000, supra.
[28] Lockheed Martin Corporation. Annual Report 2000. Bethesda, MD (2000).
[29] Defense Science Board Task Force 2000, supra.
[30] See, for example, Lawlor, Maryann, "Industry Confronts Personnel Dilemma Using Unconventional Methods, Perks," Signal, Vol. 53, Issue 5, January 1999; also Mitchell, Graham, Kelly H. Carnes, and Cheryl Mendonsa, America's New Deficit: The Shortage of Information Technology Workers, Office of Technology Policy, US Department of Commerce, Washington D.C. 1997.

[31] From a presentation by Mike Harrison, to the 2001 Air Armaments Summit, March 15, 2001
[32] See Appendix, Table 2.
[33] See Davidson, 2001; Tiboni, 2001; GAO/NSAID-98-16; and GAO/NSAID-97-23.
[34] Berry, Carl, "Information Technology Lowers Weapon System Life Cycle Costs," National Defense, Vol. 82, No. 531, October 1997.
[35] Defense Science Board Task Force 2000, supra.
[36] See Letter from the Honorable Jacques Gansler to Mr. Phil Odeen, Chairman of the DSB Task Force, dated 21 December 2000, detailing actions being taken to implement the recommendations of the Task Force.

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Appendix - Table 1[36]
Guided Weapon Options by Target Class

Target Class	In Inventory	In Production	In Development
Mobile Hard (includes tanks and artillery)	Maverick (AF/N) GBU-10 (AF/N) GBU-12 (AF/N) GBU-24 (AF/N) GBU-27 (AF) Walleye (N) GAM (AF) SFW (AF) Hellfire II (A)	SFW/WCMD (AF) Gator/WCMD (AF) JDAM (AF/N) Hellfire II (A) Longbow Hellfire (A)	ATACMS Block II/IIA BAT Submunition Improved BAT (A) JSOW/BLU-108 (AF/N)
Mobile Soft (includes trucks, vans, and personnel carriers)	Maverick (AF/N) GBU-15 (AF) GAM (AF) TLAM (N) AGM-142 (AF) ATACMS Block I (A) Hellfire II (A) SFW/WCMD Gator/WCMD JSOW/Baseline (N/AF)	AGM-142 (AF) SFW/WCMD (AF) CEM/WCMD (AF) TLAM (N) JDAM (AF/N) JSOW/Baseline (AF/N) ATACMS Block 1A (A) Hellfire II (A) Longbow Hellfire (A)	ATACMS Block II/IIA BAT Submunition Improved BAT (A) JSOW/BLU-108 (AF/N)
Fixed Hard (includes bridges and underground or heavily reinforced facilities)	Maverick (AF/N) GBU-10 (AF/N) GBU-12 (AF/N) GBU-15 (AF) GBU-24 (AF/N) GBU-27 (AF) Walleye (N) GAM (AF) AGM-130 (AF) AGM-142 (AF) TLAM (N) SLAM (N)	AGM-130 (AF) AGM-142 (AF) GBU-18 (AF) TLAM (N) SLAM (N) SLAM-ER (N) JDAM (AF/N)	JSOW/Unitary (N) Tactical Tomahawk (N) SLAM-ER (N) JASSM (AF)

Table 1 (continued)
Guided Weapon Options by Target Class

Target Class	In Inventory	In Production	In Development
Fixed Soft (includes general purpose buildings, manufacturing facilities, roads, and rail yards)	Maverick (AF/N) CALCM (AF) GBU-10 (AF/N) GBU-12 (AF/N) GBU-15 (AF) GBU-24 (AF/N) GBU-27 (AF) HARM (AF/N) Walleye (N) GAM (AF) AGM-130 (AF) AGM-142 (AF) TLAM (N) SLAM (N) ATACMS Block I (A)	AGM-130 (AF) ATACMS Block IA (A) AGM-142 (AF) TLAM (N) SLAM (N) SLAM-ER (N) SFW/WCMD (AF) Gator/WCMD (AF) JDAM (AF/N) CEM/WMCD (AF) JSOW Baseline (AF/N)	ATACMS Block II/IIA BAT Submunition Improved BAT (A) JSOW/Unitary (N) Tactical Tomahawk (N) SLAM-ER (N) JASSM (AF/N)
Maritime Surface (includes ships)	Maverick (AF/N) GAM (AF) AGM-142 (AF) Harpoon (AF/N) TASM (N) Walleye (N) SLAM (N) Penguin (N)	AGM-142 (AF) JDAM (AF/N) SLAM (N) SLAM-ER (N)	JSOW/Unitary (N) Tactical Tomahawk (N) SLAM-ER (N) JASSM (AF/N)

Table 2: Selected Industry Financial Data

(2000 data in millions) Financial Data	Raytheon	Lockheed Martin	Boeing
Sales	16,895	25,329	51,321
Munitions % of Total Sales	4.5%	3.5%	0.7%
Operating Income	1,625	1,614	3,058
Interest Expense, Net	(736)	(919)	(445)
Net Income	141	(519)	2,128
Goodwill & Other Intangibles	13,281	9,943	5,214
Total Assets	26,777	30,349	42,028
Total Debt	9,931	9,959	8,799
Total Equity	10,823	7,160	11,020
Diluted EPS from Total Ops	$0.41	($1.30)	$2.63

Key Financial Ratios	Raytheon	Lockheed Martin	Boeing	S&P 500
Recent Price	$26.60	$34.90	$53.00	-
Price to Earnings Ratio	18.3	N/A	21.8	27.8
Sales vs Previous Year	-1.8%	-0.8%	-11.5%	20.7%
EPS vs Previous Year	-0.6%	N/A	-2.4%	21.4%
Total Debt to Equity	0.9	1.4	0.8	0.9
Total Debt to Assets	37.1%	32.8%	20.9%	36.0%
Interest Coverage	2.2	1.8	6.9	10.6
Gross Margin	19.9%	6.4%	14.8%	48.5%
Operating Margin	9.6%	6.4%	6.0%	18.2%
Total Debt to Equity	0.9	1.4	0.8	0.9
Interest Coverage	2.2	1.8	6.9	10.6
Gross Margin	19.9%	6.4%	14.8%	48.5%
Operating Margin	9.6%	6.4%	6.0%	18.2%
Net Profit Margin	3.0%	-1.7%	4.2%	12.5%
Return on Assets	1.9%	-1.4%	5.6%	9.0%
Return on Equity	4.6%	-6.3%	18.2%	22.4%
Asset Turnover	0.6	0.8	1.3	1.0

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