REFORMING THE MARKETPLACE

THE INDUSTRIAL COMPONENT OF NATIONAL DEFENSE

Chester W. Richards

THE CENTER FOR DEFENSE INFORMATION

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ABOUT THE AUTHOR

CHET RICHARDS began his career as an action officer for air-to-air programs contributing to force effectiveness analyses in the Office of the Secretary of Defense (OSD). He drafted the issue paper that led to procurement of the F-16 and F-18, and wrote computer simulations for comparing alternative force options. For the Royal Saudi Air Force, he performed regional analyses, advised on procurement alternatives, and established the Systems Analysis Group.

Richards has also worked strategy issues at Northrop Grumman and Lockheed Martin, shifting his focus from what makes an effective military force to what makes an effective commercial competitor. He wrote the article on time-based competition that appeared in the *Handbook of Business Strategy,* and has lectured and conducted seminars for numerous commercial and military organizations.

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If you were designing the F-22 today, there's no way it would look the way it does - we know so much more about electronics and stealth aerodynamics now.

-Col. John Warden, USAF, Ret.[1]

I. INTRODUCTION

Why should weapon systems take a human generation to develop? Why should each new weapon double or triple the cost of its predecessor? Why do we find it so difficult to change or stop programs once they get started, regardless of what has happened elsewhere in the world? Just to bring the F-22 program in under congressional cost ceilings, contractors must identify and successfully implement cost reductions that are greater on a per-unit basis than the total cost of the aircraft it replaces.[2] And even if the U.S. Air Force tactical air modernization plan is executed perfectly – no cost increases and Congress provides 100 percent of the planned funding every year – the average age of all U.S.A.F. aircraft will increase roughly 60 percent over the next 15 years.[3]

These questions are especially difficult when compared to the non-defense sector, where product development cycles are accelerating, costs are stable or even coming down, and competitors introduce new models and cancel old ones with ruthless efficiency.

The simple answer is that the commercial sector has adopted fundamentally new ways of designing and building things. Although the specifics differ from industry to industry, they all fall under the name "lean production," and are based on a coherent set of principles first codified by Toyota and still known as the Toyota Production System. When applied properly, lean production delivers significant improvements in cost, quality, and delivery span *simultaneously*, and it is the *only* production system in the history of mod ern industry to do so.

The larger question, then, is whether lean production can prove the salvation of the defense sector. If we could reduce the cost of new weapons by 25 percent (instead of doubling them), cut their design and delivery spans by 50 percent, and reduce defects by an order of magnitude or more, we could provide our forces with a stream of effective weapons incorporating innovative technologies while the threats they are designed to counter still exist.[4]

This paper will examine the possibility of making improvements of this magnitude in the production of defense equipment. It will not question whether we should be producing any particular weapon system, other than to note that the political forces that select and fund weapon systems also shape the manufacturing strategies that defense contractors can employ. This is, in fact, a major theme of this paper. It begins with a look at the current status of the defense industry and how it evolved into its present state. Next, it examines the strategies individual companies use to survive and prosper in the unique defense marketplace and some of the consequences for defense planning as a whole. Then, it explores lean production and examines whether it could work its magic in the production of weapon systems. Finally, it closes with recommendations for changes that could propel the evolution of the defense procurement system towards something more efficient, if not actually "lean," and that do not strain political credibility.

The paper will focus on the defense aerospace sector because primes like Boeing and Lockheed Martin are better known to most readers than FMC, and because three of the largest programs in the defense budget – the F/A-18E/F, F-22, and Joint Strike Fighter (JSF), accounting for some $400 billion – are built by these companies.

Topology of the defense industry

In 1993, there were 21 companies that could be classified as "major defense contractors." Today there are five.

In 1993, there were 21 companies that could be classified as "major defense contractors." Today there are five (Lockheed Martin, Boeing, Raytheon, Litton, and Northrop Grumman). In aerospace, we are down to two major primes, Boeing and Lockheed Martin, from seven as recently as 1980, although Northrop Grumman still hopes to retain the capability of bidding as prime on selected major programs.[5] In a sense, this attrition in major contractors is not surprising. The end of the Cold War produced a glut of military equipment and severely reduced the need for new purchases of current weapons, such as M1 tanks and F-15 fighters. New weapons, like the Lockheed Martin F-22 that will replace the F-15, would not be ready for procurement until 2001 at the earliest. As of the writing of this paper, there is only one major aircraft program still to be decided, the Joint Strike Fighter (JSF), and its first operational aircraft will not be delivered until FY 2008, if the program stays on the current schedule. The result has been a "procurement holiday," with very little money flowing to prime contractors.

This situation spelled death for a number of historic names in military aviation, which found themselves with no market for their existing products and little possibility of creating new programs. Grumman, for example, had ruled Navy aviation since the days of the F4F Wildcat and island hopping in the Pacific.[6] The end of the Cold War and redefinition of Navy missions meant that there was no need for new F-14s or A-6s, or even for new aircraft to replace them. The F/A-18 performed both these roles well enough for battle against non-Soviet enemies. The small remaining market for E-2C electronic surveillance aircraft (five in the 2001 budget) would not sustain Grumman, and Northrop absorbed that line when it bought the company.

Similarly, such hallowed names as Republic (F-105), North American Rockwell (F-100, B-1), General Dynamics (F-111, F-16), and McDonnell Douglas (F-4, F-15) were absorbed by former rivals or disappeared entirely.

When the Department of Defense was encouraging contractors to combine, the stated goal was efficiency, reflecting the belief that fewer companies meant more efficient use of resources and so lower prices to the government. There is considerable debate over whether this has in fact been achieved.[7]

The reason for this perhaps counterintuitive result lies in two other factors that emerged as the number of players decreased: the increased political influence of the remaining players and the effects of an economic system trending towards monopoly. This paper examines both of these in some detail.

Industry view

One might think that consolidation, with the elimination of competition, has ensured the prosperity of the two survivors. Boeing has been able to use its large commercial aircraft business to protect itself from reliance on military contracts. For Lockheed Martin, much more reliant on defense, the result has been a disaster, at least from the standpoint of the company's market valuation. From November 1998 to April 2000, the company's stock dropped some 65 percent, at a time when the Dow was rising 26 percent. Several top officers of the company retired much earlier than they had expected. The company's recovery since then more reflects merger subsidies, and a 40 percent increase (1999 to 2005) in

the defense procurement budget, than an improving ability to operate more competitively.[8]

As this illustrates, life in the defense economy is not a guarantee of profitability or even survival. As the prime contractors view the world, they are trapped in a sector where there is very little commercial market for their products, where technology lags behind their civilian counterparts (especially in information technology) so that hiring or retaining top talent is extremely difficult, where the opportunity to create new products comes once in a career, where one election or political appointment can cancel out years of hard work, where the customer can specify how work is to be done to a degree unprecedented elsewhere (although the maze of regulations is easing somewhat), where cost savings must be returned to the government rather than (as everywhere else in the economy) be added to the bottom line, and where they are routinely vilified as rapacious, ethically-challenged merchants of death. It is easy to see how defense contractors might develop a siege mentality.

If the current system is not delivering affordable, effective weapons in reasonable time and at justifiable cost, and if the major participants are unhappy with it, how could it be changed?

II. EVOLUTION OF THE MILITARY-INDUSTRIAL (-CONGRESSIONAL) COMPLEX

It is important, when considering solutions to the problems of escalating weapons costs and lengthy development cycles, to keep in mind that nobody designed the current Military-Industrial (-Congressional) Complex (MICC) this way. It evolved in fits and starts in response to stimuli such as the Cold War arms race with the Soviet Union, unprecedented government involvement in private industry, rapid development of technology, and the abrupt end of the Cold War. Proposed fixes to the problems fall into the same league - one more set of stimuli that impel a minor evolutionary shift, after which the process will proceed in ways that are no more predictable than they were in 1950.

Until the end of World War II, most of the items needed by militaries were similar to those required by civilians: clothing, small arms, wagons, tents, and other needs of ordinary life in the outdoors. There was no "defense" industry as such. Commercial companies, much like the militia members themselves, "converted" production to wartime use and then "reconverted" back to civilian production with the signing of the peace treaty.[9] Lockheed's statement of mission from the late 1930s, for example, called for it to be the world's premier designer and manufacturer of commercial airliners, and to rapidly convert to wartime production should the need arise.

For those few items with no civilian value, mainly cannon and warships, the government maintained arsenals.

At the start of the Korean War, there was a fundamental change. As the Cold War placed the nation on a permanent war footing, the system of "minutemen" militia and convertible companies was replaced by a standing army of dubious constitutionality[10] and a "military-industrial complex" to supply its increasingly specialized needs. The Department of War had just been replaced with the more permanent-sounding "Department of Defense," which also included the previously independent departments of the Navy and Air Force. Only the Coast Guard escaped incorporation into the new, unified DoD.

This new defense establishment, born of and wedded to competition with the Soviet Union, required increasingly specialized weapons. As the arms race progressed, these weapons began to look less and less like their counterparts in the commercial world, if indeed there were any

the KC-135 tanker (both derive from the Dash-80 prototype), but there were no commercial sales of the next two military airlifters, the C-141 and C-5. The Air Force's next major tanker/transport, the KC-10, was converted the other way, from commercial to military.

And there was clearly no commercial need for air defense missiles, like the Nike Ajax and Hercules, or ballistic missiles, or nuclear warheads, or missile-launching submarines, or sophisticated fire control systems for tanks, or electronic warfare, or indeed for the great bulk of military-oriented research and development (R&D).

> ...(the) Defense Production Act of 1950... gave the government an unprecedented degree of control over private industry...

To provide these weapons, Congress expanded the arsenal system to include commercial companies via the "Defense Production Act of 1950" (Public Law 81-774, signed Sept. 8, 1950). The act gave the government an unprecedented degree of control over private industry, if it were deemed to be in the interest of national security. Title I, for example, gave the president of the United States authority to require that defense-related contracts be accepted and performed, even ahead of a company's existing commercial business. Other sections allowed the government to control wages and prices, allocate scarce resources (including consumer and real estate credit), and purchase strategic raw materials.

Congress and DoD also levied requirements on defense contracts, and so on defense contractors, that were not required of commercial items or their producers. One of these was to further the difference between the defense and commercial marketplaces perhaps beyond repair, the shift in emphasis required by "cost-plus" contracting. On its surface, reimbursing costs incurred performing government contracts only seems fair. The problem is that the commercial world doesn't work that way. Whereas the government will spend tens of thousands of hours negotiating with the sole source what a submarine or missile should cost, a consumer will simply go out into the marketplace and make the best deal. Whether Toyota happened to make or lose money is real counterparts. True, the harbinger of the jet age, the Boeing 707, was developed in tandem with ly not relevant to the customer – he or she had the ability to choose among competitors, so discipline of the marketplace helped to ensure that the best deal was in fact a good deal.

The difference between cost-plus and fixed price is profound. In the marketplace, cost reduction should be a constant activity since it preserves strategic options. In a declining market, for example, low costs allow a producer to reduce prices, if necessary, and still make a profit. If, on the other hand, demand for the product is high, and customers are willing to pay a premium for it, then low costs add to the company's margins, which can be used to prepare for the future (for example, to pay off debt, build up reserves, and invest in R&D), or reward itself by raising salaries and paying bonuses and dividends. All else being anything like equal, lower costs are always good.

Unfortunately, this is not the case in the cost-plus world. Here the goal is not to lower costs, but to justify them. The more cost a contractor can convince the government to accept, the more people it can hire, the more executive positions it can create, and perversely, the more profit it can make, since profits are generally negotiated as a percentage of the allowable costs. Programs survive not just on the marketplace virtues of cost, quality, and delivery span, but also on the ability of organizations to play political "power games," such as front-loading and political engineering.

Implications

As the Cold War progressed and defense companies adapted to the cost-plus environment, they began to diverge from their commercial counterparts in ways that proved impossible to reverse. In fact, the whole concept of "defense re-

conversion" became moot, not only in this country but even in our former adversary, the Soviet Union. In both societies, the results of such attempts were, in the words of former Lockheed Martin Chairman Norm Augustine, "unblemished by success."

Among the many reasons why, three stand out: technology, people, and most important, the lack of a competitive marketplace.

Technology

As mentioned previously, defense technology began to look different from civilian technology in many areas. In the last five years, U.S. civil R&D spending has greatly outpaced defense, and even U.S. government non-defense spending, increasing from roughly equal to some 75 percent greater than the sum of all U.S. government research funding.[11]

Although there were "spin-offs," a company that specialized in developing products for defense often found little demand for its products and services on the outside. The hallmark of the F-22 fighter, for example, low radar observability (stealth), would not appear to be of much use for a civilian airspace crowded with commercial airliners. And even where military technology had civilian application, defense contractors could rarely produce products suitably priced for the commercial world.

One might expect that this divergence would lead to a military sector vastly more advanced than its commercial counterpart, that defense technology, manufacturing techniques, software development and integration, and computer technology would be significantly more advanced and, classification levels permitting, would be driving the national economy with spin-offs.

One graphic illustration that this is not the case is the growing movement towards using "commercial off the shelf" (COTS) software and components where available. DoD now recognizes that where commercial products are available, they are generally superior to, and practically always cheaper than, the same products specially developed for military use.[12] The reason of course, is that the burgeoning marketplace brutally selects out companies that are slower or less efficient in creating products that meet customer needs.

For example, consider the software for the F-22. Lockheed Martin has been developing this highly specialized and critical component since 1991, when Windows 3.1 was the standard personal computer operating system. In the years since, Microsoft has brought out Windows 95, Win NT, Win95 OSR2, Win 98, Win 98 SE, Windows 2000, and Windows ME. When finally completed, the F-22's software suite will be less than one-tenth the size of Windows 2000.

In the marketplace, cost reduction should be a constant activity since it preserves strategic options.

This is not to imply that the software needed to operate a supersonic jet fighter and all of its weapons is comparable to the operating system for a personal computer. Obviously, the word "crash" has different meanings in the two situations. But it vividly shows the difference in the two sectors as marketplaces. The basic architecture, systems engineering, programming, and even hardware configuration of the F-22 are approaching 10 years old, new by DoD standards but several generations behind what is happening outside. It is hard to believe that Microsoft will find much to spin-off.

The largest difference, however, between defense and commercial technologies in the early 21st Century lies not in exotica, such as stealth coatings, but in production. This statement may surprise many readers, who see articles on advanced manufacturing technologies in the various journals and magazines that cover defense, and who suppose that low-rate production (which characterizes defense at this time) would have allowed contractors to remove the last traces of waste from the line.

One indication that the defense industry is not using the latest commercial production technologies is that costs in the defense sector continue to escalate faster than the economy as a whole. The technology of defense production resembles its 1950s forebears much more than it does an advanced lean production line from the electronics or automobile industry. Aerospace production lines, particularly for large items of equipment, are still largely push-type mass production systems, where a centralized scheduling department issues shop orders to the floor, and there is limited incentive or opportunity for the people doing the work to improve or more important, to eliminate it.

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It is very difficult, even in highly competitive industries, to change the basic system underlying a mature production line. Some defense production lines are older than the people working them (the F-16 went into production in 1976; the C-130 in 1954). The people working in the system know it, are comfortable with it, and understand how to circumvent the problems that it causes. Managers, similarly, have limited inspiration to make radical changes, since they rose to their positions through the current system and so it must be fundamentally sound.[13] As long as the system delivers the product, and the customer is willing to absorb cost increases (there is rarely any competitive supplier for major defense systems), the prudent path is to make improvements at the margin and not take risks with high potential, but potentially high risk, transformations.

All defense contractors have improved specific processes (such as incorporating high-speed machining) and some have adopted techniques from lean production (such as cellular manufacturing). In the areas where such improvements have been made, costs have often been reduced, and these are the data that appear in articles and press releases. However, these should be regarded as islands of improvement in a sea of traditional practices that continue to increase the costs of defense production.[14] When faced with a real need to cut costs, defense primes revert to the same slash and burn tactics they have always used, announcing outsourcing and massive layoffs, despite cover articles in the trade press touting their lean accomplishments.[15]

People – Managing high tech skills

As the commercial economy continues to expand, while defense remains static, defense contractors are finding it increasingly difficult to recruit and retain talent. Nowhere is this more evident than in information technology. It is difficult for the old, hierarchical defense companies to compete with the get-rich-quick atmosphere of the IT world, with its relaxed working environments and campus-like surroundings. Even the government, which competes for the same pool as defense contractors and can offer a much more stable career path, is experiencing hiring and retention problems. The Pentagon, which still has nearly 300,000 civilian employees working in some aspect of procurement (that number is not a misprint), could lose some 50 percent to retirement starting in 2005.

There is no data that a shortage of technical personnel *per se* has delayed any major aerospace program. However, if a company must subcontract to a high-tech firm rather than hire the employees directly, it will likely raise costs, since the prime will add its own overhead and profits to the cost of the subcontractor.

On the other hand, a firm that specializes in IT or some esoteric technology may well do a better job of managing these functions. From the prime's standpoint, the problem shifts from managing employees, an area where they have decades of experience, to working more as peers with companies in fields where the primes may not only lack deep expertise but be unable to even hire people capable of managing IT experts. As the cost of weapon systems increasingly migrates

to these technologies and away from bending metal, traditional primes will face growing challenges and could even increasingly occupy secondary roles.

Competitive environment

The problems of technology and people are severe challenges to the defense industry. They can be (and to some extent are) ameliorated through such devices as more partnering with IT and professional services companies (keeping less of this work in-house), virtual organizations that can incorporate cutting-edge organizations and individuals for specific projects, and a generally more relaxed attitude towards such 19th century relics as the time clock.

However, these devices will not protect the industry from the major difference between defense and commercial marketplaces. That difference is the diluting of competition as the number of potential bidders shrank and, perhaps even more pertinent, the nearly universal practice of granting a contractor monopoly status very early in a program's development cycle.

Some may not see this lack of competition as a problem. Even with a single prime (e.g., if there were a single "U.S. Aerospace and Defense Corporation," which is the route the Europeans have taken), the government could simply decide what it needs, then place orders with that company to develop and build it. Presumably this would maximize efficiency, since the wasteful effects of competition (such as discarding losing designs and prototypes) would be eliminated. It is a mystery why socialism, for that is the system just described, having been thoroughly discredited in the commercial world, should be seen as the salvation of the military procurement world.

The benefits of competition have been spelled out from the founding of the republic (*The Wealth of Nations* was published in 1776), and include innovation in the creation and incorporation of new technologies as well as a self-correcting mechanism for determining prices. These are well known in the commercial world.[16] When a consumer goes to buy a car, for example, he or she can trade-off features, quality, style, delivery times, service, reputation, and prices from a variety of brands and dealers. If a particular brand lets its lines become dated, or experiences quality problems, or lets its costs get too high, then consumers will begin to go elsewhere. If it happens often enough, the company goes out of business. Similarly, if someone has a better idea for a product or service, the marketplace is there to test that idea and, if successful, reward it. Although the mechanism may be imperfect due to limited availability of capital and large corporations with predatory legal departments, it does work. Dell can become number one, and Digital can disappear.

> It is difficult for the old, hierarchical defense companies to compete with the get-rich-quick atmosphere of the IT world.

This mechanism for innovation is lost under a legal monopoly (whether owned by the state itself, as in pure socialism, or by private investors, as with a public utility). In fact, it is the policy of the major primes not to undertake significant R&D efforts unless they are fully reimbursed by the government under some form of cost-plus contract.

Competition has another benefit that is more difficult to quantify: the customer not only gets a cheaper product but often a better one, as data show that the marketplace tends to reward higher quality, and even enables producers of such goods and services to charge higher prices. The market's implicit pricing mechanism performs the task of determining the worth of quality or innovation, or any other property offered by competitors.

Unlike in monopolies or other non-market settings, market pricing mechanisms are self-correcting because there is no central decision authority to mandate what will be offered, how it will be built, and what the price will be. The market simply selects out inferior brands and dealers. Many economists argue that the market

cannot work under central direction, that prices are an emergent property of millions of consumers making their choices from among tens or hundreds of competitors offering a changing array of features and quality at whatever prices they can get the market to pay.[17] If these economists are correct, then the defense sector, with central direction from its one customer and with at most four aerospace primes, cannot be or ever become a true marketplace.

> ...it is increasingly difficult to answer the question, "What should a weapon system cost?"

For this reason, it is increasingly difficult to answer the question, "What should a weapon system cost?" Without a market to offer alternatives, the answer can only be determined through negotiation between the government and the (single) supplier of the weapon system in question. Furthermore, without other competitors to propose lower priced or more advanced alternatives, there is little reason for the (single) supplier to do the hard work needed to substantially reduce costs, improve quality, or develop risky but potentially useful innovations.

Some have raised the objection that the United States has in fact preserved competition, at least as far as it is possible to do so, in the defense sector. The F-22, for example, was the result of a competition that initially involved seven aerospace primes and was decided by a fly-off between the Northrop YF-23 and the Lockheed YF-22.

There are at least two limitations to this type of competition, however. First, prototypes often bear a superficial resemblance to the final production models, which is why there is typically a five to seven year engineering and manufacturing development (EMD) phase following down-select for a major weapons program.

But perhaps more important, the vast majority of programs – and all the large ones – become monopolies once a prime contractor is selected for EMD. In the case of the F-22, the selection occurred in 1992. All the innovation that the Northrop-Grumman team could have contributed or that competition would have spurred in Lockheed Martin has been lost to the Advanced Tactical Fighter, which is scheduled to reach initial operational capability as the F-22 in 2005. Many will assert that, given the cost and unique nature of major weapons programs, monopolies at EMD are inevitable. This question will be revisited in the Recommendations. The point for now is that, without a marketplace to offer alternatives, pricing in the defense sector will diverge from comparable civilian items.

For example, in 1990, prices for a Lockheed Martin C-130H and a Boeing 737-400 on the international market were roughly the same, which is not surprising since they are approximately the same takeoff gross weight (155,000 lb) and use virtually identical manufacturing technologies. By 1998, both companies had introduced new models, the C-130J and the Next Generation 737 family, respectively. Although the prices of both aircraft had increased, Lockheed Martin had let C-130 costs balloon to where it was approximately twice the price for which Boeing was selling the 737-700.[18]

One key strategic difference was that Boeing was locked in a vicious competition, not only with the Airbus A320 series for single-aisle sales, but also with the emerging genre of regional jets. Because price is a driving factor in airline purchase decisions, Boeing could either control its costs or watch its profit margins, and then revenues, disappear. Lockheed Martin, on the other hand, knew that early in the 21st century, the Air Force would have to replace its Vietnam-era C-130Es and that the C-130J would be the only game in town. This strategy appears to be working. Lockheed Martin has even been able to use bureaucratic leverage or "power games" (to be described in the next section), such as threatening to add overhead costs to the F-22 program, to move up Air Force funding for the C-130J.

Ironically, international customers often have more choices than their domestic counterparts,

thus preserving something of a marketplace. Lockheed Martin's success in obtaining government funding of the C-130J at higher prices has created openings for competitors. There are, for the first time in 40 years, two non-U.S. C-130 category programs. The An-70 is in production for the Russian and Ukrainian Air Forces and promises to sell well to traditional buyers of Russian equipment. It may also capture market share among price-sensitive countries that traditionally buy C-130s.

At the other end of the tactical spectrum, the Airbus A400M now has more than 200 orders, and has defeated the C-130J in sales to the United Kingdom and Italy. It will end the C-130 market in Western Europe, and also compete well in the international marketplace for customers who need a larger, faster, and longer-range aircraft than the C-130J and can pay the marginal difference in price.

At the very high end of the category, the C-17, at less than $200 million, is now a legitimate competitor to the C-130 on a procurement-dollar-per-ton basis, since it carries four times the payload at three times the price, at around 150 knots faster, and can carry outsize equipment that will not fit in a C-130 at all. This can be a devastating argument, especially for countries that have an inventory of C-130s, as the recent British acquisition of C-17s demonstrated.[19]

In summary, the moral is that companies that optimize to play the defense procurement game will find themselves increasingly handicapped in either commercial or international marketplaces.

III. SURVIVAL STRATEGIES FOR THE WORLD OF DEFENSE

Specialize in defense

Since defense technologies, production methods and rates, and competitive environment continue to diverge from the commercial sector, companies have to choose between the two. The primary defense industry survival strategy is to make a virtue of necessity and adapt totally to the defense environment. The defense procurement budget is still a $60 billion per year funding stream that is not going to go away, and it does have its unique attributes. Stealth, for example, may have limited usefulness on the outside, but within defense it is required for any new combat aircraft.

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Raytheon, the number three defense contractor, has been selling its non-defense units to pay off a $10 billion debt that has contributed to a 50 percent decline in its stock market share price. It has now apparently made the decision to focus on defense even more. The company recently engaged an investment banking house to help it divest its aircraft company, which primarily makes civilian turboprop and small jets for the commuter airline and business aviation sectors. This divestiture is expected to bring in $4 billion (about 20 percent of Raytheon's expected 1999 sales).[20]

Companies in the defense sector may complain about excessive regulation and worry about highly specialized technologies, but these do constitute barriers to entry. Defense contractors must maintain legal staffs that understand the thousands of pages of Federal Acquisition Regulations (FARs) and the even more complex world of DoD requirements. Commercial companies, without such infrastructure, will find it difficult to play.

Look like the customer

A basic strategy – once a company or business unit has decided to forgo the commercial world and specialize in defense – is to organize itself to mirror the customer as closely as possible, generally as a well-structured bureaucratic hierarchy. In the minds of its participants, especially at the higher levels, the company is defined by the latest set of organization charts and job descriptions, and this is often how formal briefings to outsiders begin. Defense contractors even talk about their chains of command, commission "task forces" and "tiger teams," and compile volumes of internal regulations. Many still maintain a rigid division between enlisted (hourly) and officers (managers and salaried professionals). Their offices, like those in any headquarters, are allocated strictly according to corporate rank. Their counterparts in the defense procurement community can feel comfortable with such a structure.

The defense procurement budget is...a $60 billion per year funding stream...

In a practical sense, it does make it easy for customer personnel to navigate the contractor's system and find the appropriate people. It also helps members of the customer community understand where they might fit into the corporate structure when and if they leave government service, a topic that will be explored in detail under "The Revolving Door."

Front-loading

Because defense systems typically involve considerable R&D, and so technical and operational risk, it is impossible to know years in advance exactly how much time and money it will take to get them to the field. In the primal struggle for funding, few ideas for programs will ever see the light of production. Any admission of uncertainty may be seized upon by a program's competitors and opponents to force early termination so that they may feast upon its fiscal carcass. Over the years, programs (that is, the program sponsors in DoD and Congress and their counterparts in the participating companies have developed tactics to improve their chances for survival, many of which involve some type of "front-loading."[21]

The basic idea in front-loading is to downplay the likely adverse consequences of future decisions in order to obtain permission (and funding) to proceed. Invariably, front loaders make the lowest cost estimate for developing and building the weapon that approval authorities will find acceptable. Note that this may or may not have anything to do with what the bidder actually believes it will take to bring the program to fruition.

Complex projects that push the state of the art in several areas are easier to front load than straightforward applications of proven ("mature") technology. Such projects are inherently more uncertain, yet they can also promise great leaps in effectiveness.[22] Program proponents can drape themselves in the flag, painting those who object as betraying U.S. troops in combat: "…whenever a man or woman jumps in to one of our cockpits, I want them to realize they have the world's best. And if they have to engage, they will win 100 percent of the time."[23] It is never noted that under this assumption it is the hardware, not the man or woman, who is doing the engaging.

Perhaps the classic case of front-loading in recent times is the F-22, which was originally promised to the American taxpayer for $35 million per copy (1982 dollars), and at the time of this writing, is nudging up against its congressionally-mandated cap of around $200 million.[24]

At this stage, it would be appropriate to mention that accomplished practitioners of front-loading do not lie. For one thing, knowingly making a false statement to Congress or one's military superiors is, technically, against the law. In this day of immortal e-mail, it would be imprudent, as well as unnecessary, to take such risks. The uncertainty inherent in defense R&D allows even

moderately creative generals and executives ample room for front-loading. Simply produce the copious analysis to show that performance will (almost) certainly come in at the high end of the range, and cost will (almost) certainly curve down to the low end, with an impressive degree of confidence. One can play the same game with schedule, technology maturation, threat, allied alternatives, whatever, all limited only by the imagination.

Once the program is approved, however, it is prudent for the original proponents to distance themselves from the front-loaded estimates as rapidly as decorum permits, since it is highly unlikely that *all* of the optimistic assumptions behind them will come true. Because estimates always admit to some uncertainty (but not too much, otherwise program opponents would have seized upon this weakness to delay the program or cancel it entirely), this reality can be used to salvage credibility just long enough to employ the much more powerful and effective tool of political engineering, which will be described next.

Front-loading, of course, is not limited to DoD programs. The space shuttle program has just reached 100 flights as this is written. According to its original justification, it should be making its 1000th. The idea is not even limited to government procurement. The basic idea behind front-loading is to promise something – even though it likely cannot be delivered – in order to make the sale. In the commercial world, chipmakers may announce new processors with higher megahertz ratings to keep customers from jumping to a rival but then only ship limited quantities while manufacturing processes mature. Perhaps even more egregious is the practice of vaporware, where a software maker, to forestall sales of a rival's product, will announce a new package months, or even years, before it is actually ready to ship.

The point is that games to influence buying decision are not unique to the defense sector. The critical difference is that in the commercial sector, there is a marketplace to discipline companies that consistently fail to deliver on their promises. In the defense sector, there is a very limited concept of marketplace, and given the willing participation of players up to and including Congress, limited discipline also.

Political engineering

Since weapons purchases in peacetime are political decisions, they reflect the political geometry of the times. This has changed radically since the mid-1980s, so that the interests of the defense industry are now concentrated in five or so gigantic corporations rather than diffused among more than 20. When Lockheed Martin, for example, lobbies on behalf of one of its programs, it speaks with the force of 145,000 employees, $1 million in PAC money, untold tens of millions in various forms of lobbying, and plants or vendors in practically every congressional district in the United States.[25] Thus, for 92 members of the Senate, a vote for the F-22 puts money and jobs into their states, and reaps the resulting political rewards.

The space shuttle program has just reached 100 flights… according to its original justification, it should be making its 1000th.

These contracts did not appear in 46 states by accident. The tactic of spreading the defense wealth in order to preserve political support is called "political engineering," and it is as important to the survival of the program as design engineering is to the survival of the system in the field. There is nothing illegal about political engineering. In fact, given the way our political system currently works, any defense contractor that did not employ it would put its programs in serious jeopardy. One does not have to be a systems engineer, however, to appreciate the risks of sending U.S. troops weapons funded for their political, rather than their military, effectiveness.

As with front-loading, the more expensive and complex a program is, the easier it is to politically engineer. Such programs require more ven-

dors and subcontractors, and so can be spread to more congressional districts, than either simpler alternatives or modifications to existing programs.[26]

One result of political engineering is that it has become extremely difficult to cancel programs that are no longer needed or that experience serious technical problems during development. A well thought-out political engineering campaign can cushion a program from the inevitable shocks of failed tests, schedule slips, cost overruns, performance shortfalls, and threat changes that plague programs as they make their way, decade by decade, through the real world. So with the possible exception of programs funded by Major Program 11 (for Special Operations), all of the major systems now in development were originally conceived to defeat the next generation of weapons from the Soviet Union.

...the power of the individual surviving contractors... can have an unprecedented influence on overall foreign policy.

There is a more nefarious aspect, however, to contractors' attempts to influence the demands for their products. In at least one case, there is strong evidence to suggest that U.S. foreign policy decisions reflect to some degree the need for contractors to maintain their production levels. In a Sept. 21, 2000 hearing by the House International Relations Subcommittee on the Western Hemisphere, Clinton administration officials were grilled not on the disturbing implications of involving U.S. military personnel in Latin America, but on why Sikorsky had not yet received its contract – and its price – for 18 new Black Hawk helicopters.[27]

This is certainly not the first time that contractors have tried to highlight the foreign policy advantages of buying their equipment. The sale and delivery of 79 F-14 aircraft to Iran represents a most striking example. At the time, these were the most advanced fighters in the world, and U.S. pilots might well have had to confront those same aircraft had military actions followed the fall of the Shah. The United States may be creating a similar situation in the Middle East by continuing sales of the latest variants of F-15s and F-16s to marginally stable monarchies. There is certainly nothing illegal about contractors arguing their case. However, the risk today is that the power of the individual surviving contractors is so great it can have an unprecedented influence on overall foreign policy.

Political influence and engineering affects efficiency in a subtle way. Companies and programs that are protected from the consequences of their decisions naturally tend to become inefficient. When protected from strong competitive pressures, companies simply find it more comfortable to continue in their old, inefficient ways.

As this paper has shown, front-loading favors greater technological complexity as does political engineering. So replacing monument programs with a larger number of smaller, more agile projects might be appealing, as Air Force Col. John Warden and others have argued, but without fundamental change in the MICC, it is not going to happen.[28] Under the current system, defense procurement will continue to evolve towards a small number of technically complex programs – typically one per service per generation – because these are easier to launch and easier to defend politically. Under the current U.S. system, it is irrelevant that such programs are also more likely to experience problems and overruns, be more difficult for troops in the field to maintain, and are almost guaranteed to be obsolete or irrelevant, or, at the very least, no great improvement over their predecessors, by the time they finally reach the using forces.[29]

The "Revolving Door"

The final power game is both the most pernicious and, since it involves Constitutional rights of individuals, the most difficult to control. This is the practice of senior military officers, DoD civilians, and to a lesser extent congressional staffers leaving government service to take po-

sitions with defense contractors. There is nothing illegal about this practice. In fact, the infusion of expertise from the buyers and users to the developers and builders is undoubtedly beneficial.

The problem, of course, is that this is a legal way for companies to reward serving members of the government for "desirable" behavior. A colonel retiring in 2001 with 26 or more years of service, for example, will draw around $57,000 per year in retirement pay. If he or she accepts a senior position with a defense contractor, take home pay could triple, while still retaining the medical and other benefits of military retirement. This is more temptation than mortals should be required to bear.

Undoubtedly, the vast majority of government employees, both military and civilian, would be rightly offended at the suggestion that they would make decisions contrary to the national interest in the hope of receiving employment after they leave. (It is generally illegal to recruit government employees before they have submitted their paperwork to separate or retire, at which point they should be transferred to other duties). There are, however, gray areas – depending on how close each side wishes to push the ethical limits – within which company and employee can signal their intentions. This can be facilitated when the company representative is a former colleague and all communication is verbal. Where there is a will, and large amounts of money are involved, there are ways. In any case, the government employee can be quite sure that a history of playing hardball with a contractor will not lead to favorable consideration when time comes to change careers.

Industry consolidation has aggravated this situation. When there were half a dozen or more primes and more than 20 major players, one could take the risk of offending one of them and still preserve options for working in industry. With just two primes and five majors, and with each a subcontractor to the others, options are more limited: one either plays the game or changes careers completely after retirement or separation.

There is something terribly wrong with an organization that takes disciplinary action against a government employee who accepts a $50 dinner from a contractor, then holds a gala retirement party for that same employee as he leaves for his new $100,000 per year position with that same contractor.

IV. THE COMMERCIAL ENVIRONMENT IS DIFFERENT

The previous sections have described techniques that defense contractors and others have developed to influence their customer. Companies in the commercial world also try to influence their customers, of course, but brute force techniques like front-loading, political engineering, and legal extortion, as with the revolving door, have limited applicability in a marketplace of millions of customers.

The most effective commercial technique is called "shaping the marketplace;" that is, helping define what customers find desirable. Companies do this by introducing a stream of innovative products and services at various levels of quality and performance, keeping costs (not necessarily prices) under those of the competition, assessing the effects on the marketplace, and learning from what they find. Data suggest that companies that can shape the marketplace reap higher profits than passive responders.[30]

> ...lean production is proving difficult to apply in the commercial world and will likely prove even more difficult to implement in defense.

The primary technique that has proven effective in fostering innovation, reducing costs, and improving quality in the commercial manufacturing world is called "lean production." The degree of improvement can be remarkable: costs reduced 40 percent, delivery spans cut in half (or more), new models introduced twice as fast, and defects cut by 90 percent.[31] In commercial

competition, a lean manufacturer will invariably capture market share from all of its conventional competitors and generally drives the weaker ones out of business.[32]

Surely lean production would be the cure for escalating costs and lengthening R&D cycles in the defense sector as well. This may yet turn out to be the case, but despite its undeniable benefits, lean production is proving difficult to apply in the commercial world and will likely prove even more difficult to implement in defense.[33]

Unlike traditional production systems, which are designed to be as idiot-proof as possible, a lean system is "fragile"...

To understand this paradox, as well as to illustrate a fundamental difference between the commercial and defense sectors, it is useful to review some of the basic concepts of lean production and then discuss how, and to what extent, lean concepts can apply to defense programs.

A synopsis of lean production

Before lean production (which will be described shortly), U.S. production management texts taught that to improve quality meant increasing costs. It was logical: end-item quality was improved by buying higher quality (and so more expensive) components, by inspecting more often during assembly, and by repairing or replacing the defects these inspections caught. The more one inspected and fixed, the higher the quality. One could even quantify these relationships, so that to reduce defects X percent, one would have to raise costs Y percent. Marketing departments determined how much customers would pay for improved quality. Armed with this information, managers could draw cost curves and demand curves. Where they crossed defined how much quality would be "inspected in."

Under this orientation, it did not pay to make a higher quality product since customers would not recognize, and would not pay for, the additional costs of quality. This was business strategy reduced to the level of freshman calculus.

For about 30 to 35 years this paradigm held sway, and would probably be widely accepted still today if it were not for the perturbations suffered by the automobile industry from the twin oil shocks of the 1970s. The quadrupling of oil prices between 1973 and 1979 caused a sizable number of Americans to consider buying cars from Japan. These had been available in the United States since the 1950s, but since they were smaller and generally slower than their gas-guzzling domestic competitors, Japanese brands had been unable to move out of their niche market.

As the oil crisis continued, and an increasing number of Americans bought cars from Honda and Toyota, they discovered a very strange thing. Not only were they generally less expensive than comparable models from GM, Ford, and Chrysler, they were of vastly higher quality. They had an order of magnitude fewer defects, as *Consumer Reports* regularly informed its readers, but were not the tinny, loud, and rough running vehicles that many Americans associated with cheap imports. In the intervening years, Detroit and Japan had switched places in the hierarchy of quality. American companies, locked into traditional mass production paradigms, could only cut costs by lowering quality. Compared to Vegas, Chevettes, Pintos, K-Cars, and worst of all, X-cars (from GM), a Honda or Toyota ran like a Swiss watch.

U.S. manufacturers cried "Foul!" It was demonstrably impossible for the Japanese to sell such high quality cars in the United States for prices less than their domestic competitors (whose offerings could charitably be described as junk). Amidst the political maneuvering for punitive tariffs (unpopular with too many voters) and import ceilings (enacted "voluntarily," but which merely added to Japanese profit margins and accelerated their long-intended move into U.S.-based manufacturing), the auto industry sponsored a study by MIT to prove once and for all that the Japanese were not playing fair. The re-

sults were reported in a series of articles in the mid-80s and in the best selling book, *The Machine that Changed the World*.

The International Motor Vehicle Project (IMVP) measured inputs and outputs of various manufacturing plants around the world, including Japanese plants in both Japan and the United States, and reported its results in terms of man-hours (not costs, since these depended on wage scales and exchange rates). Results were normalized to account for variations in size of vehicles and the amount of subcontracting (more of which would tend to understate labor hours). Man-hours were inclusive, including hours spent inspecting and fixing as well as those used in manufacturing. So if the Japanese were inspecting in more quality, it would have run up their labor hours.

The results were devastating to U.S. automakers. The Japanese were building cars with one-tenth the defects and were doing it with up to 25 percent fewer labor hours than comparable GM, Ford, or Chrysler plants in the United States. Japanese plants in the United States, however, were only slightly less productive than their onshore counterparts, which undercut the myth of some unique attribute of Japanese culture. Could the answer be robotics? This was unlikely, since spending on factory automation in Japanese plants was no higher than in U.S. factories and was actually less than in the average GM plant. Unions? It turned out that one of the best plants in the United States was the New United Motors Manufacturing Inc. (NUMMI) plant in Fremont, CA, which was jointly owned and operated by GM and Toyota. As a condition of its approval, NUMMI kept in place the United Auto Workers workforce inherited from GM's Fremont plant and which GM had used as an excuse for closing the factory in the first place.

What lean production is

The answer was that Toyota and a limited number of other Japanese manufacturers had evolved a new way of making things. This is a key point that is often misunderstood. The Toyota Production System (TPS) – lean production – is not simply an improved version of traditional mass production as practiced in the United States and elsewhere since the advent of the Industrial Revolution, and improved by countless industrial engineers, including Henry Ford and Frederick Taylor. One will not arrive at the TPS by starting with, say, a GM plant from circa 1980 and just "removing all the waste." The TPS represents a fundamentally different way of approaching the problem of producing large numbers of previously designed items.

The technology of lean production is well understood and can be quantified. Briefly put, it is a pull-type production system (often simplistically described as "just-in-time") with no buffer stock to cushion any lapses in quality. It relies on the active participation of its employees to fix problems as they arise and to constantly improve the system over time. This last point is key. Unlike traditional production systems, which are designed to be as idiot-proof as possible, a lean system is "fragile," and requires the people operating it to stay engaged and think about what they are doing. Because it requires participants to manage their own immediate operations, rather than simply following predetermined rules, it demonstrates many of the attributes of a "complex adaptive system."[34]

(There are many other subtleties. For example, there is the lexicon of lean production – kanban, kaizen, pokeyoke, jidoka, heijunka and the like. Unlike zero defects platitudes, these are specific and well-defined practices. To avoid misunderstanding and simplistic descriptions, interested readers should consult the writings of the Japanese themselves, particularly the Toyota vice-president, Taiichi Ohno, who deserves perhaps the lion's share of credit for spurring its evolution; Shigeo Shingo, an industrial engineer who worked for Taiichi Ohno and codified many of the principles of the TPS; and Yosihiro Monden, a writer who spent many years studying the sys-

tem at Toyota and describing it for outsiders.[35] For the technology of the TPS, there is an excellent and thorough description at the web site of the Production Systems Design Laboratory at MIT, *http://www.psd.mit.edu)*.

V. STRATEGIC EFFECT OF LEAN PRODUCTION

Lean production systems achieve their greater competitive advantage because they can manipulate time. The founders of the system are very clear on this point:

The Toyota Production System is based on the idea of constantly decreasing the time between when a customer orders a car and when we deliver.

– Toyota Motor Corp.,
"Toyota Production System," 1992.

"Why not just build more inventory?" is the conventional answer to delivery span questions. Faced with a lean competitor inventory does not work. It runs up costs but, more importantly, it is impossible to know beforehand what customers will buy. Inventory-based companies are constantly having fire sales to clean out unwanted or obsolete merchandise, which does little for their reputations as quality suppliers. The classic case in recent times is probably Dell, a build-to-order pioneer in personal computers, versus Compaq. Not only has Dell surpassed Compaq in PC sales but its profitability often exceeds twice Compaq's.

Time-based competition is truly the business analog of manuever warfare...

People who have studied time-based systems agree. In fact, one of the most comprehensive books on the subject, by George Stalk and Tom Hout, was entitled *Competing Against Time*.[36] There are two reasons time works as a competitive weapon. First, by "making things fast," as Indiana Professor Robert Shemmener entitled a well-known article,[37] the TPS reaps the added benefits of lower cost and higher quality (again, in contradiction to traditional manufacturing, which needed more time and higher costs in order to improve quality).

But the more important effects of time-based strategy lie in its ability to engage in shaping and being shaped by the marketplace, as noted above. A slight digression may help illustrate this point. Time has long been recognized as a competitive weapon by military strategists, as is well documented in works from Sun Tzu (c. 400 B.C.) to the writings of the contemporary American strategist, Col. John R. Boyd. By operating at what Boyd called a faster observe, orient, decide, act (OODA) tempo than an opponent, one could attack the other side's cohesion and ability to make effective battlefield decisions. Sun Tzu had called this idea "shaping your opponent." Often, even a much smaller, more agile (as faster OODA tempo began to be called) force could unhinge and defeat a larger, more ponderous adversary using a new doctrine called "maneuver warfare." Boyd's briefings contained many examples, and his concepts were adopted by the Marine Corps and to lesser degrees by the Army and Air Force.[38]

In the business world, time can also be an effective weapon. As Stalk and Hout concluded, a firm that can inject new offerings into the marketplace more quickly than its competitors, learn more rapidly from the market's reactions, and produce new products and services before its competitors, will gain the ability to "shape the marketplace" – in this case, defining what customers find desirable and establishing the prices they are willing to pay. Stalk and Hout provided many examples and even described the OODA loop model. Time-based competition is truly the business analog of maneuver warfare, which should not be too surprising since Boyd's research rests on the same Zen canon, most famously Sun Tzu and Miyamoto Musashi, that formed part of the cultural heritage of the founders of the TPS.[39]

For manufacturers, lean production simply provides the best way created so far to operate at very high decision-cycle (OODA loop) speed.

Prerequisites

Despite its undeniable advantages, and thousands of pages of descriptions, the TPS is proving extremely difficult to implement. Probably less than 10 percent of U.S. workers are employed by companies that have achieved enough to make a noticeable difference.[40]

Taiichi Ohno himself, who advised companies on implementing the TPS after he retired from Toyota, noticed this and offered the suggestion that: "companies that are doing even moderately well never adopt the TPS. Such companies become very selective in the measures they wish to adopt."[41] The deeper reason, Ohno believed, was that even a modest degree of success retarded the "revolution of consciousness" (a Zen phrase Ohno used often) needed before the TPS could be successfully adopted. People pay lip service to change, and even implement bits and pieces, but the fundamental system never changes.[42]

In Japan, commercial competition is a surrogate for war. The sararimen (from the English "salary men" meaning white-collar workers) regard themselves as modern-day samurai and companies there view their competitors as "stealing the rice out of their children's mouths." The goal is total dominance of the competition and even its destruction, if possible.[43] This is the environment that spawned lean production, and still provides the motivation and discipline necessary to sustain it.

The second prerequisite needed for successful adoption of the TPS appears to be a highly competitive marketplace, and in particular one that rewards the simultaneous attributes of the TPS: lower cost, higher quality, and accelerated delivery span.

A third prerequisite appears to be a company "culture" that rewards the type of initiative and fosters the degree of self-organization needed to operate the system over the long run. In particular, a company must find some way to harvest the savings that lean production provides – that is, to eliminate positions where work is no longer needed – without fomenting a backlash that would quickly bring the system to a halt. Simply put, a functioning implementation of the TPS has institutionalized a way to reward people at all levels of the company for working themselves out of their own jobs. The existence, or vastly more often non-existence, of such a system is the easiest way to tell whether a company has actually implemented the TPS or is just using the buzzwords.

A last prerequisite appears to be more fortuitous: a chief executive who comprehends the data on the TPS, believes that it is the key to survival for his or her company, and designs an organization committed to its implementation. This is probably the single hardest requirement to satisfy. Names like Jack Welch at General Electric, Herb Kelleher at Southwest Airlines, and Michael Dell have become business icons precisely because they are among the very few who have successfully implemented time-based competitive systems.[44] In fact, the greatest danger to implementing lean production may be a CEO who says that he or she is committed to lean production, and spends money installing some of the technology (such as cellular manufacturing and single piece flow), but does not make the people/cultural changes to make it work.

In summary, drawing from the cases where lean production has been successfully implemented, the prerequisites appear to be:

- a deep and widely shared sense of urgency;
- a market environment that is amenable to shaping through rapid decision-cycle speed and compressed delivery spans;
- a culture capable of changing to one that

can support lean production; and
- a knowledgeable CEO with the motivation and leadership skills to catalyze the needed changes.

Without such company and marketplace characteristics, a company would probably be better suited to seek other strategies for competition, or to merge or become acquired while the operation still has market value. It is precisely because they and their marketplace lack these characteristics that companies specializing in defense find it much more difficult to employ the TPS than do commercial enterprises. In fact, the attrition among defense contractors since 1990 has approached levels once only found in real wars. And survivors in the defense sector have evolved alternative competitive tools, in particular the defense power games noted above.

VI. WHY LEAN PRODUCTION IS UNLIKELY TO WORK IN DEFENSE

There are several reasons why defense prime contractors find it more difficult than most to implement true lean production (and thereby realize the benefits in cost, quality, and cycle time).[45]

The primary theoretical reason is that strategies such as mirroring the buyer's organization, specializing in unique technologies, operating behind bureaucratic barriers (e.g., the Federal Acquisition Regulations – FARs), and most especially, engaging in political engineering all act to give the company an aura of protection and ease the sense of urgency. A company that understands it can influence the political system to buy its products sees no need to undertake changes to its comfortable lifestyle that lean production requires. There will be no revolution in consciousness in such an organization.

The second prerequisite is a marketplace that values what lean production delivers, in particular, compression of delivery spans without holding inventory. As noted in the literature, this includes most if not all the true marketplaces (multiple customers and suppliers) in the world. However, given the way the Pentagon develops and procures new defense systems, there does not appear to be any great competitive advantage in compressing delivery spans. Military equipment is already built to order (companies generally don't keep inventories of tanks or fighters), and money is allocated by Congress by fiscal year. Contracts provide for progress payments to offset costs of paying for components and labor as construction proceeds. Although there might be a small cost-of-money advantage to completing an item in six months rather than 12 (i.e., to offset the amounts not covered by progress payments), there does not appear to be any way that a shorter delivery span would take market share away from a competitor – the primary advantage in the commercial world.

The other advantages of a lean system – higher quality and lower cost – would certainly be advantageous for the buying service. But viewed from the standpoint of a contractor, these lose much of their appeal. It would be difficult to convince any defense prime that it will sell additional units by decreasing the defect rate 15 percent. Contractors are already supposed to be doing all in their power to produce "quality" products, so even offering such a deal could be regarded as unethical.

What about reducing costs? From the contractor's standpoint, this was an obvious nonstarter during the cost-plus era since it would have led directly to lower profits. In this modern era of more "commercial practices," that is, fixed-price procurement, the idea would have more appeal. But there are drawbacks. Making significant cost reductions invariably involves reducing the workforce. Over time, a lean system operating in a static market would slowly shrink, thereby losing its ability to both employ political engineering and exploit the revolving door.

The degradation in the effectiveness of political engineering is especially vexing since it is largely played with vendors and subcontractors. A modern weapons program typically derives 60 percent or more of its costs from outside the prime contractor. A lean production facility has noticeably fewer vendors and subs than a traditional mass manufacturer, and it establishes long-term relationships with them. These relationships call for the vendors and subs to likewise adopt lean production (thereby reducing their political clout). Worse, to reduce possible delays in transportation, it encourages them to locate near the main plant, i.e., in the same congressional district, which limits the opportunities for political engineering.

In the commercial world, lean competitors often expand their market shares and so reap the benefits of higher sales and lower costs, which produce substantial increases in profitability and often an overall growth in employment, although per-unit people costs will continue to decline. This advantage is rarely available to defense contractors, since the number of units bought is determined (at least in theory) by military requirements to defeat some postulated combination of threats. Thus, if the Air Force needs a wing of F-16s, it is unlikely that Boeing will be able to capture that business by lowering the cost of the F/A-18.

At one point in the late 1980s, Lockheed offered to build an additional 50 C-5B aircraft at a firm fixed price less than half what the U.S.A.F. was paying for C-17s, and deliver them before the first C-17 would become available. The offer was turned down, even though the Air Force had (and still has) a huge shortfall in its airlift capability, and each C-5B can carry 60 percent more cargo than a C-17. In the commercial world, lower cost and shorter delivery span would likely have been decisive advantages.

In other words, the idea of capturing market share through lean production is largely untenable in the defense world. Lockheed Martin owns 100 percent of the marketplace for F-16s, Boeing has a similar market share for F-15s and F/A-18s, and so on. These programs were monopolies from the moment they entered EMD. From the companies' standpoint, attempting to adopt lean production would risk the operation of their existing lines, upset their labor and management structures, decrease their ability to play the power games that actually sell product for them, and quite likely not increase their sales by a single unit.

Over time, a lean system operating in a static market would slowly shrink...

Adoption of the techniques that lean producers use, typically those that can be grafted into most any existing system – cellular manufacturing is the most common – will lower some costs and could provide advantages in competition for annual buys. However, lean production ultimately rests on time compression, and there is little evidence that the defense marketplace can be shaped by shorter production or development spans. Lean techniques, in other words, may provide useful *tactics* for a specific procurement competition, but lean production is not a viable *strategy* for defense contractors. Such companies would be far better advised to employ practices that have proven effective, particularly front-loading and political engineering, even though these work against implementation of lean production, and increase the cost and development spans of defense hardware.[46]

VII. WHAT CAN BE DONE

It is important, when considering ways to improve the development and production of major weapon systems, to keep in mind several themes that have been covered earlier:

1) The strongest influences on the current system, that is, the factors that most account for the stability of the present MICC, are:

a) lack of market forces to spur innova-

tion and control costs; and equally important;

b) the fact that we fund major weapons programs as much on their political utility (via the power games) as for their effectiveness on the battlefield.

2) The current U.S. military-industrial-congressional complex has evolved since passage of the Defense Production Act in 1950 into the system in place today. Nobody deliberately designed it to be this way.

In the defense marketplace... it is important to keep two real competitors.

3) Companies that did not evolve along with the system did not survive.

4) For many reasons, but primarily the need to play power games and the lack of competition after EMD, defense contractors will find it impossible in most cases to install true lean production, so they will not be able to show the same degree of improvement in cost, quality, and delivery span as in the commercial world.

Ameliorating these problems will require changes throughout the military- industrial-congressional complex. Rarely should the industrial component shoulder the entire blame. Political engineering works, for example, because it benefits members of Congress. One may argue that military spending has less overall economic benefit than other uses of that money – such as funding local infrastructure, paying down the national debt, or returning it to the taxpayers – but for a member of Congress facing reelection, the placement of jobs in his or her district is difficult to turn down, and loss of a program, even one with arguable military utility, could prove embarrassing.

Little is known about how to influence the evolution of very complex systems. In the commercial world, the marketplace appears to be the most effective mechanism for fostering evolution in the direction of better products and services for the consumer. In the defense sector, market forces are limited, but it may still be possible to inject them to a larger degree than is the case today, especially if the government establishes clear policies to do so. That is, when making decisions, the policy should be to move towards the direction of increased competition and market forces, rather than directly towards some other goal such as "efficiency," regardless of how desirable that goal might appear.

Keep more competition

For any particular program, having a large number of competitors does not appear to be the most important factor, although this is an area that could benefit from careful research. In the retail marketplace, for example, the answer does appear to be "the more the better." Japan, for example, during its period of greatest inroad into the United States, harbored *nine* companies that exported automobiles to the United States.[47]

The commercial marketplace, however, represents an aggregate of millions of customers and so can benefit from a multiplicity of competitors. In the defense marketplace, there is only one primary customer capable of paying for the development of major weapon systems. In this environment, it is important to keep two real competitors. But more than two, while it cannot hurt, may not significantly improve program performance. Even in the commercial airliner market, which has perhaps a dozen major customers, the ferocious competition between just Boeing and Airbus has kept prices in the segments where they compete from going up faster than general inflation.

There have also been some spectacular successes in defense. In the mid 1970s, for example, the Air Force kept two competitors producing ammunition for the GAU-8 tank-killing gun on the A-10. The annual buy from each competitor depended on the prices quoted. At the start of the competition, rounds cost $84 each, and analysis suggested that allowing for normal cost growth,

rounds should average around $100. Within five years, however, costs had fallen to $9 each, and this was at a time when the cost for all other ammunition was indeed rising.[48]

Size does have one unfortunate drawback. As with other organisms, the larger ones need to be fed more. In the aerospace business, the industry has announced that the nearly $400 billion currently planned for new fighters (F/A-18E/F, F-22, and JSF) simply isn't enough. Industry representatives are now complaining that if DoD doesn't start planning now for another major program right on the heels of JSF, "a huge part of our industry will die."[49] The Aerospace Industries Association has stated that the American taxpayer owes them an additional $14 billion this year alone, which they have suggested the incoming Bush administration add to the 2001 DoD budget.[50]

Foster new entrants

A more important factor in shaping the evolution of the defense industry is preserving the possibility of new entrants to the defense marketplace. For any form of evolution to work, there must be a field of alternatives from which to select. In evolutionary biology this is expressed in Fischer's Law: the rate of adaptive change is proportional to the genetic variation present. If we want the defense industry to evolve into something different than it is, we must reinforce incentives for new companies to form, perhaps virtually, for established companies in other sectors to enter the defense marketplace, and for poor performers to be selected out. This mechanism cannot work in the current defense environment where each of the two major primes is too big to fail. If either did, the country would be down to one – a pure monopoly – and the major subcontractors on the losing team, Northrop for example, would lose significant revenue that might allow them to return to prime status.[51]

Although it is unlikely that a totally brand new aircraft, armored vehicle, or ship building company will form over the next few years, new entrants could come from companies in related commercial fields. In addition to Northrop Grumman and Raytheon Aircraft, for example, Textron (Cessna and Bell Helicopter) and General Dynamics (Gulfstream) both retain a significant design capability and could bid as prime on certain weapon system programs, especially if teamed with experienced partners, such as an allied aerospace company. They could also serve as a second source for weapon systems where such an arrangement is feasible.

...we must reinforce incentives for new companies to form, perhaps virtually...

There is no reason why competitors for prime contracts should be limited to the hardware manufacturers. For the MC-130H Combat Talon II, for example, since the bulk of the effort involved integrating complex systems into a proven airframe, the system prime contractor was IBM in Owego, NY. In the future, there is no reason why systems integrators such as SAIC, CSC, or EDS could not be the prime contractor for a variety of major weapons systems, buying the platforms from whoever provided the best value.

One recent change that should be reexamined is the government's practice of choosing not the best system, but the management team in which government officials have the most faith.[52] This policy, when strictly observed, makes new entrants virtually impossible. Ironically, by the time the selected weapon is ready for full scale production (often in five to ten years), the original management team that was the basis of selection has long been transferred or retired.

One might also surmise that the government would feel more comfortable with companies whose management structures mirror its own, and which have made skillful use of the revolving door, than with the type of "Kill the competition!" samurai culture that seems to be the most successful in implementing lean production.

The notion of new entrants is not as far fetched as it may sound. Until its design was selected as one of the two finalists for the Advanced Tactical Fighter (ATF), Lockheed had been out of the fighter business for more than 30 years. McDonnell Douglas, which had built the two previous Air Force fighters, was on the team that eventually lost.

...most weapon systems would benefit from preserving (competition) throughout the life of the program.

Keep competition open longer

It does no good to have a vigorous competition up to EMD and then revert to monopoly status for spending the real money. All this practice (which characterizes the majority of U.S. weapon programs) does is reward the more convincing frontloader. At the minimum, competition should be maintained up to the point where the government and the contractors are comfortable with commercial-type (i.e., fixed-price/guaranteed performance) contracts. This point is certainly through EMD and perhaps even to initial operating capability.

However, given the magnitude of savings that competition often produces, most weapon systems would benefit from preserving it throughout the life of the program. As noted previously, these benefits often include costs reduced by 25 percent, defect rates by 90 percent, and much more rapid incorporation of new features, technologies, and upgrades. It does not take a very large production run for these advantages to amortize the cost of developing a competitor system. The more rapid delivery of effective and supportable combat systems to troops in the field could be considered a bonus.

The argument against preserving competition this long is cost: if the United States can barely afford the $20 billion to develop one advanced tactical fighter, the F-22, how could it possibly afford $40 billion to develop two? Part of the answer is that with competition, development would likely be much more efficient and so the total bill for two would certainly be less than $40 billion.

The other part of the answer is that in a competitive environment, companies have an incentive to reduce production costs. Although it is impossible to say beforehand how much savings could result from competition, cost reductions of 20 percent to 25 percent are not unusual in the commercial world. However, since production costs over the life of a program typically amount to five or more times R&D costs, only a 25 percent reduction in production costs would be needed to offset the additional burden of developing a second weapon system, depending on how many units are finally bought and how much effect competition has on reducing the bill for the other aircraft.[53]

This magnitude of reduction has been seen in those few cases where a military item is comparable to a commercial product. In the C-130/Boeing 737 case noted above, the $4 billion (200 aircraft at a delta of $20 million each) of cost growth in the military aircraft compared to its commercial counterpart would have more than paid for developing an entirely new aircraft that better met the needs of the modern world.[54] This aircraft could have competed with the C-130J for the tactical airlift mission buy every year.

While it is too late to develop a second advanced tactical fighter, there is no legitimate reason for choosing a single contractor for a program as large as the JSF. The annual buy could be divided between the competitors based on performance, delivery span, and cost. This should be true competition, not a partitioning of the program into two smaller monopolies. Giving Boeing, for example, sole rights to the Navy variant and Lockheed Martin the U.S.A.F. and U.S. Marine Corps versions eliminates competition just as surely as awarding the entire program to one or the other. Modern logistics management (a type of "enterprise resource planning," or ERP) systems can overcome the obstacles of adding one more type of weapon to the fleet, as

they are routinely doing for airlines.

If a weapons program reaches the point where there can be no competing source for the same capability, this is probably a clear signal that it should not be bought at all. Under these conditions, it cannot be fielded in any quantity that would have decisive effect on the battlefield, it will prove impossible to contain cost and requirements growth, and the pressure to keep it alive will overwhelm our political system. Once operational, the regional commanders in chief will be required to employ it in some role, and will have to change tactics and strategy to ensure that none of the golden BBs are lost. Ultimately, it will suck in such enormous resources that the Pentagon will not be able to procure enough systems with real warfighting utility, or even to maintain adequately the forces it now has. All these effects can be seen today with the B-2 and will be seen again with the F-22.

If the United States cannot afford two competing systems, it certainly cannot afford one.

VIII. SUMMARY: COMPETITION CAN PROBABLY BE RESTORED

Lean production works in marketplaces that can be shaped by shorter development and production spans, lower costs, and higher quality. While these would be valuable to military as well as commercial customers, the reality is that political factors, such as front-loading and political engineering, have far more effect. This is not to imply that the techniques of lean production are irrelevant for defense programs, just that they cannot be implemented to the same degree as in the highly competitive and less political commercial sector. During a program's life, the longer that competition is preserved, and the more weight that the three factors of time, cost, and quality carry in deciding the winner, the more useful lean techniques will prove in reducing the cost of that system.

The arguments in the immediately preceding sections outline a difficult process, but one that does not threaten the underlying political realities of defense acquisition. That is, the Pentagon could keep Boeing and Lockheed Martin in competition for periodic JSF buys using existing contractual types and the current planning, programming, and budgeting system (PPBS) and congressional authorization and allocation processes. If fact, it might even prove easier, since neither of the primes would have to lose a program permanently.

For other programs, if more competition is desired, the government could offer incentives for systems integrators or near-primes to make the investments required to enter the market. Such incentives could include expanded tax credits for bid and proposal efforts, and relaxation of "Buy America" policies so that U.S. systems integrators could more easily team with offshore manufacturers.

What we do not know is whether we can restore enough competition to simulate a commercial marketplace and so create an environment conducive to true lean production. From those few instances where it has been seriously tried, such a possibility seems reasonable, although we should expect the details to vary from program to program. Unlike the real marketplace, however, it will be difficult to eliminate one of the two competitors, for then the program would return to the true monopoly status that most large programs enjoy today. That is, competitors will still be protected from elimination, which is the penalty extracted by the real marketplace for falling behind the competition in cost, quality, or delivery span. The less energetic competitor may also try to use power games to convert from real competition to a gentleman's version, where nobody gets hurt and certainly nobody gets eliminated.

This recalls to mind the other requirement for

employing lean production – and thereby significantly reducing cost, defect rate, and development span: a market that rewards improvement in these areas. The present U.S. political system, as noted in the sections on power games, rewards other attributes much more strongly. Fixing these problems would require significant changes in law and perhaps even in the Constitution itself.

...the problem of fostering competition and new entrants may be simplified if the weapons themselves are simplified.

As covered earlier, the three most common power games are front-loading (to get programs started), political engineering (to keep them funded, independent of changing requirements), and the revolving door (to weaken the resolve of government employees to make difficult decisions). Since front-loading hides in the legitimate uncertainty inherent in any new program, and since political engineering dwells at the heart of the U.S. representative democratic system, these two power tools will likely always be available in some form. They are simply too difficult to attack directly.[55]

It might be possible, however, to reduce the most pernicious effects of the revolving door.

Investigate whether there are ways to close the revolving door

We need to find some way to close, or at least slow, the revolving door. As noted previously, this gets into an area of individual liberties and runs into the problem of defining "defense contractor." But the fact is that so long as large defense contractors can influence the actions of government officials through the hope or expectation of lucrative future employment, then the United States truly is basing its national security around the convenience of the contractors, not the troops in the field or the people.

In the earlier discussion of this subject, it was suggested that restoring competition, especially keeping the number of competitors well above two, might dilute the influence of contractors on buyers. Others have suggested an outright ban on employment, although that would require a bureaucracy to write the rules and interpret them. Who, for example, is a defense contractor? Are we talking just primes? Are consultants included? Could a company that does not meet the definition of "defense contractor" today become one in the future? If so, do the ex-government employees who work for it have to leave?

Any action to reduce the influence of contractors on government employees would require Congress to write legislation that gives unambiguous answers to questions such as these. Once "defense contractor" is defined, Congress could require ex-government employees to waive their government pensions, or impose a significant waiting period before such an employee could be hired either directly, as a consultant, or through a third party.[56]

Of course, the problem would be simple if there were only one defense prime contractor – a U.S. Aerospace and Defense Company – and former government employees could simply be forbidden to work for it, even indirectly. Although it might be possible politically to create such a company, and might not even be that difficult if Congress voted enough money to ease the birth pangs, the U.S. government should not be so quick to forgo forever the benefits of innovation and competition.

Ultimately, industry will mirror weapon systems

To be realistic, as long as the services insist on weapons to counter Cold War-era threats, the government will be buying ever more complex and expensive aircraft, ships, and fighting vehicles. Developing and building such behemoths will probably require contractors in its own image, that is, organizations capable of managing multi-year, multi-billion dollar contracts. Such organizations will employ the same tools of lobbying, front-loading, and political engineering

available to all companies whose primary customer is the government.

Although some may point to Airbus as an example of how a relatively small, virtual organization can carry out enormous projects, the fact is that all the technical work was performed by its underlying national aerospace companies, which were monopolies for all practical purposes in their own countries. Three of those companies, in France, Spain, and Germany, have consolidated into the European Aeronautic Defence and Space Company (EADS). Airbus itself is in the process of transforming into an integrated company, owned by EADS and BAE Systems, "destined to consolidate the Airbus resources and know-how in the locations around Europe into a single entity."[57] One should note that there were not two competing Airbuses in Europe.

So the problem of fostering competition and new entrants may be simplified if the weapons themselves are simplified. If, in fact, the world is moving towards an asymmetric "fourth generation of warfare," as typified by Vietnam, Somalia, the recent Middle East (excluding Desert Storm), terrorism, and counter-narcotics, then perhaps the era of the mega-prime will naturally come to an end.[58]

ENDNOTES

[1] Col. Warden was the Director of Project CHECKMATE at HQ USAF in late 1990 and was one of the chief architects of the airpower campaign in the Gulf War. He is also the creator of the strategic airpower doctrine known as "parallel war."

[2] Programmed cost reductions, that is, from the original bid and not including learning curve effects, must average $62 million per aircraft. Average unit cost of the F-15E was $46 million. See NSIAD-00-178, "Recent F-22 Cost Estimates Exceeded Congressional Limitation," dated August 2000. Available on the GAO web site.

[3] F. C. Spinney, *Defense Death Spiral*, available on *http://www.d-n-i.net*.

[4] Although less studied than the production system, the Toyota Development System delivers results equally as remarkable. Interested readers should consult "The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster," by Allen Ward, Jeffrey K. Liker, John J. Cristiano, and Durward K. Sobek II, *Sloan Management Review*, Spring 1995, 43-61.

[5] Robert Wall And David A. Fulghum, "Fighting To Stay In the Big League," *Aviation Week and Space Technology*, November 20, 2000.

[6] For a superb history of Grumman aircraft and their contributions to national defense, please visit *http://www.grummanpark.org*

[7] John Diamond, "Analysts, auditors worry about impact of defense mergers," October 18, 1998, The Associated Press. Savings claims from defense restructuring have also been investigated by the GAO. See, for example, "Defense Industry: Restructuring Costs Paid, Savings Realized, and Means to Ensure Benefits," NSIAD-99-22, 1 Dec 1998.

[8] *ibid*.

[9] Herbert L. Fenster, "Reforming The Management Of The National Defense: Can The National Defense Afford Congress?" Address to the American Bar Association, Friday, February 3, 1989. Available at *http://www.d-n-i.net*.

[10] The Constitution does allow for a standing army but only permits Congress to fund it for a period of two years. There has been considerable debate over the last 200 years over exactly what this means. Until the Cold War, the standing army was so small that constitutional issues could be largely ignored.

[11] Robert Wall, "Fix Technology Program," *Aviation Week and Space Technology*, October 16, 2000.

[12] *ibid*.

[13] David C. Gompert and Irving Lachow, "Transforming U.S. Forces: Lessons from the Wider Revolution," The RAND Corporation, IP-193, 2000.

[14] Anthony L. Velocci, Jr., "Rockwell Collins Granted Autonomy," *Aviation Week and Space Technology*, December 18, 2000. I cannot comment on the accuracy of Collins' claims, which approach those demonstrated in the automobile and other commercial sectors. It should be noted that Collins' business is 62 percent commercial, and it may be easier to mix lines in the component business than it has proven in aircraft.

[15] "Lockheed to Cut 675 More Jobs," *Atlanta Journal and Constitution*, January 4, 2001. According to the site manager, "The reality is that we cannot meet our cost savings imperatives and maintain the fabrication operations in-house." Fabrication was where most of the Marietta, Georgia plant's "lean" efforts had been concentrated and where it claimed the greatest success. The plant's lean accomplishments had merited a cover story less than 18 months before the layoffs were announced: "Lean Thinking Spurs Culture Shift at LMAS," by Stanley W. Kandebo, *Aviation Week and Space Technology*, July 12, 1999.

[16] The classics in this area, in addition to *The Wealth of Nations*, certainly include Frederich Hayak's *The Fatal Conceit* and Milton Friedman's *Free to Choose*. Both are widely available.

[17] Hayak's book, subtitled "The Errors of Socialism," explicitly considers the limitations of non-market economies and the advantages of the marketplace in evolving more efficient processes.

[18] The actual prices airlines pay for aircraft often differs from what Boeing shows on its web site. Depending on competitive factors and the size of the buy, discounts of up to 25 percent have been reported. Lockheed Martin's prices for international C-130J customers are author's estimates based on conversations with persons familiar with the global market for military aircraft.

[19] The RAF was the launch customer for the C-130J, ordering 25 aircraft in 1995 to fill approximately half their requirement. For the "second tranch," however, the RAF recently selected the A400M, augmented by 4 C-17s in the near term. Boeing has offered the C-17 at $150 million each for buys of 15 per year.

[20] Anne Marie Squeo, "Raytheon Struggles To Find Bidder To Pay $4 Billion For Aircraft Unit," *The Wall Street Journal*, October 18, 2000.

[21] The term "front-loading," along with its sister "power game" political engineering, was popularized by Pentagon analyst Franklin C. (Chuck) Spinney in his seminal briefing "Defense Facts of Life." Interested readers may obtain this briefing, and its updated companion, "Defense Death Spiral," from Defense and the National Interest, *http://www.d-n-i.net*.

[22] For an elaboration, see *Defense Power Games*, 1990, rev. 1998, by Franklin C. Spinney, originally published by the Fund for Constitutional Government and available at *http://www.d-n-i.net.*

[23] This statement was made by Maj. Gen. Claude Bolton, the Program Executive Officer for Fighter and Bomber Programs in the Office of the Assistant Secretary of the Air Force for Acquisition, in an interview with *Jane's Defense Weekly*, August 9, 2000. In this interview, Maj. Gen. Bolton also said that we could not have won the Gulf War if we had still been flying the F-4 instead of the F-15. Such sentiments are typical of those who believe that hardware, not people, and certainly not the U.S. Army, Navy, or Marine Corps, win wars.

[24] As of the time of this writing, the F-22 program (R&D and procurement) is estimated to cost $62 billion for 341 aircraft, or about $182 million per copy. If the buy were to exceed 341, without changes to the aircraft or further cost overruns, the unit cost would be less. For details on the cost risk to the F-22 program, see any of the recent GAO reports on the subject, for example, NSIAD-00-178 cited above.

[25] According to the Federal Election Commission the Lockheed Martin Employees PAC disbursed $1,063,289 to political candidates from January 1, 1999 through November 22, 2000.

[26] A point developed at length by F. C. Spinney in *Defense Power Games*.

[27] This incredible episode is well documented. See, for example, Jim Mann, "A Government By The People, For The Military-Industrial Complex," *Los Angeles Times*, September 27, 2000.

[28] Col. Warden (see endnote 1) expressed his preferences and rationale for smaller but more frequent programs in "Apocryphal Now: The Myth of the Hollow Military," by Gregg Easterbrook, *The New Republic*, September 11, 2000.

[29] For a thorough analysis of the merits of the F-22 compared to the F-15, see E. E. Riccioni, "The F-22, Fact vs. Fiction," available at *http://www.pogo.org*. Irrelevance stems from the fact that the longer a program takes to develop, the more time potential adversaries have to invent ways to counter or avoid it.

[30] Probably the most comprehensive single reference for the effects of time-based competition in business is George Stalk and Tom Hout, *Competing Against Time*, Free Press, 1990.

[31] The original data that demonstrated the efficacy of the Toyota Production System came from the International Motor Vehicle Project performed in the mid-1980s by MIT. These data are summarized in *The Machine that Changed the World*, by James P. Womack, Daniel Roos, and Daniel Jones, Rawson Assoc. 1990, PB Harpercollins 1991 (available through online retailers). Jones and his co-authors were participants in the study.

[32] Stalk and Hout, *op. cit.*, describe several case studies of the effects of faster decision cycle time. Interested readers might also consult any publications by Tom Peters beginning with *Thriving on Chaos*.

[33] For a recent article in the trade press discussing the difficulty of implementing lean production, see John H. Sheridan, "Growing With Lean," *Industryweek*, October 2, 2000.

[34] The basic idea behind a complex adaptive systems (CAS) approach to management is to recognize that groups of living organisms (including homo sapiens) have a tendency to self-organize. Under proper leadership, groups can often be induced to self-organize in unpredictable ways that are actually more effective than a top-down hierarchy in accomplishing the organization's purposes. Hayak advanced a similar notion about the economy as a whole in *The Fatal Conceit*. There are many web sites that explore this concept, although one might begin with the Mecca of the CAS approach, the Santa Fe Institute, *http://www.santafe.edu.* Interested readers should also spend time with "Organic Design for Command and Control," by the late Col. John R. Boyd, available at *http://www.belisarius.com*. Boyd addressed the problem of leadership in high performance organizations and advanced many of the ideas later incorporated into the CAS concept.

[35] Taiichi Ohno's book, *Toyota Production System*, is succinct and highly condensed, in the style of Sun Tzu's *Art of War*. Like its famous predecessor, it is at essence a distillation of strategy and it should be read the same way as *The Art of War*, one sentence at a time, several times. Yasuhiro Monden's book of the same title goes into much more detail on the implementation of the system. Shingeo Shingo was a practicing industrial engineer and his books involve the most detail of all (becoming in places very difficult for

the non-engineer to follow). All these books are available (as of January 2001) at online retailers.

[36] George Stalk and Thomas M. Hout, *Competing Against Time*, Free Press, 1990.

[37] Roger W. Schmenner, "The Merit of Making Things Fast," *Sloan Management Review*, Fall 1988.

[38] Boyd's magnum opus, "Patterns of Conflict," was never published. Excerpts appear at *http://www.belisarius.com*. The USMC incorporated many of Boyd's ideas into their top-level doctrine publication, MCDP 1, *Warfighting*, available online at *http://www.doctrine.quantico.usmc.mil.*

[39] Miyamoto Musashi wrote *A Book of Five Rings* (also known by similar translations) in about 1645. Although ostensibly a how-to manual for slicing and dicing opponents, Chapters 3 and 4 illustrate some of the most subtle and effective strategic patterns ever devised (which is reasonable because in his profession, losers rarely got a second chance). In particular, Musashi insists on preparing an opponent mentally and morally before risking a decisive attack. Several translations of Musashi are available.

[40] This estimate comes from lean guru George Koenigsaecker, in Sheridan's article cited in footnote 30.

[41] When Taiichi Ohno left Toyota (was essentially fired, an all too common occurrence among corporate messiahs), he joined the "New Production Research Society" of Japan, which was a type of consulting organization dedicated to spreading the system he had largely invented. One should note the evident frustration in his comment.

[42] A point also noted by Gompert and Lachow of RAND, *op. cit.*

[43] "The Outsider, His Business and His Billions: The New Imperialists, Larry Ellison, Oracle Unto Himself," *Washington Post*, October 30, 2000, p. A1. Although almost a caricature of the Japanese sarariman as samurai, it is still the dominant business culture in many companies in Japan.

[44] General Electric Chairman Jack Welch and his counterpart at Southwest Airlines, Herb Kelleher, explored many of these ideas in their famous interview for Fortune Magazine on January 11, 1999. A summary is available through the Fortune web site. Interested readers might also peruse the various Annual Reports on GE's web site.

[45] Two of the founders of the lean movement, James Womak and David Fitzpatrick, characterized lean in aerospace as a buzzword sprayed "one molecule deep over an existing industry designed for an age now departed." ("An Industry That Can't Afford Its Future," *Aviation Week and Space Technology*, February 22, 1999.)

[46] In addition to the work of Mr. Spinney, previously cited, this conclusion was recently upheld by the General Accounting Office in "Major Management Challenges and Program Risks: Department of Defense" (GAO-01-244, January 2001), available at the GAO web site.

[47] They were: Honda, Toyota, Nissan, Mitsubishi, Isuzu, Mazda, Daihatsu, Subaru, and Suzuki. Michael Porter convincingly advances the "competition stimulates competitiveness" argument in *The Competitive Advantage of Nations*, Free Press, 11th printing, June 1998.

[48] These data were provided by the program manager, Col. Bob Dilger, USAF, Ret.

[49] John M. Donnelly, "Aerospace Boss: Will Disaster Follow JSF?" *Defense Week*, October 16, 2000.

[50] Jim Matthews, "AIA Details Proposals for Big Defense Hikes," Aviationnow.com, January 3, 2001.

[51] Robert Wall And David A. Fulghum, "Fighting To Stay In the Big League," *Aviation Week and Space Technology*, November 20, 2000. As this was written, Northrop Grumman announced its purchase of Litton Industries.

[52] David A. Fulghum, "Skunk Works Pushed To Improve JSF Effort," *Aviation Week and Space Technology*, October 2, 2000.

[53] The F-22 is something of an anomaly, since its procurement budget is only about twice its R&D bill. This largely reflects the cutback in program size from the original 648 to the current (January 2001) 341.

[54] The C-130 was designed in the early 1950s for high sorties rates, short/unimproved fields, and relatively short ranges to support a highly intense conflict against the Soviet Union in Europe. Today's missions tend to be much longer – United States to Africa or South America, for example – which would suggest a faster, longer range aircraft with a wider body and heavier payload but still retaining the C-130's ruggedness and short/rough field capabilities. The Airbus A400M meets many of these requirements, which suggests that it could capture significant market share if costs can be controlled. Advances in technology since 1950 should also allow rapid development of a competing aircraft by U.S. industry. Boeing reports, for example, that development for the 777, which weighs over three times as much as the C-130J (MTGW), cost around $4 billion and took less than 6 years.

[55] Changes to our political system are beyond the scope of a paper on industrial policy. For a set of recommendations that could restrict front-loading and political engineering but would not require amending the Constitution, see Section VI, Reform: Back to Fundamentals, in Spinney's "De-

fense Power Games."

[56] A suggestion often made by noted defense commentator and decorated Vietnam veteran, Col.OL David Hackworth.

[57] Quoted from the Airbus Website, *http://www.airbus.com*, on January 31, 2001.

[58] There is an excellent section on "fourth generation warfare," including the paper that coined the term, at *http://www.d-n-i.net.*

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