Postfordism in the US Arms Industry: Toward 'Agile Manufacturing'

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Introduction[1]

Since the late 1980s, the US arms industry has been characterized by far-reaching changes in technology, technique and organizational structure. Shaped by the material requirements of the so-called 'military-technical revolution', as well as by the discourses of 'flexibility' and 'globalization', during the 1990s postfordist production techniques began to displace the set of manufacturing techniques that had long been considered 'best practice' in the American arms industry. As a result, a new arms production paradigm – now commonly referred to as 'agile manufacturing' – has coalesced. This new paradigm is still is still in embryonic form, of course, and it is likely to evolve in ways that cannot be precisely predetermined. Even at this juncture, however, there is a clear sense that arms production is being reconstituted around a radically new industrial paradigm involving the use of computer-driven flexible machine tools, 'lean production' processes, and rapidly re-configurable 'virtual enterprises' to undertake low-rate/low-volume production of increasingly 'knowledge-intensive' high-technology weapons. As it evolves and diffuses through the US armaments industry, this new paradigm is profoundly transforming the nature and logic of armaments production. Indeed, so profound are these changes that the transition to agile arms production can be said to constitute nothing less than a 'quiet revolution', marking the end of one era in America's military-industrial history and the beginning of another.

This paper seeks to illuminate this process of military-industrial transformation. It argues that two powerful motive forces can be identified behind this phenomenon. The first is practical, deriving from both the need to field the kind of increasingly knowledge-intensive weapons deemed necessary to American military superiority in the late twentieth century and the need to contain costs. The second is discursive, having to do with the influence that the ideals of 'precision warfare' and 'postfordist production' have gained over the collective imagination of America's managerial, military and military-industrial elites. At one level, the effects of these two forces are difficult to disentangle as the prevailing understanding of the nature of the 'material' requirement for victory in war is powerfully shaped by an ideal that emphasises the importance of 'precision'. Indeed, it is important to recognise that neither material nor discursive forces have absolute primacy in the shaping of contemporary US military-industrial policy; both are playing a prominent role in reshaping patterns of military (product and process) innovation. Nevertheless, it is crucial to our understanding of the development and diffusion of the agile manufacturing paradigm to develop

[1] An earlier and partial version of this paper was presented to the Faculty of Economics and Social Science, University of the West of England, 23 October 1994. A number of those who attended that session contributed useful comments and suggestions for which I am most grateful.

some sense of the way in which these forces are acting and interacting to transform arms production during the contemporary period. Thus, this paper attempts to illuminate this process of military-industrial transition by tracing the diffusion of 'agile' production techniques through the crucially important US military aerospace industry. Recognising that the terrain explored is far too complex to be mapped properly within the limits of this paper, my goal is not to provide a comprehensive account of the evolution of the American military aerospace industry during the current era. Rather, it is to chart the way in which a key sub-sector of the arms industry is experiencing the crossing of America's third military-industrial divide. Although it would be preferable to discuss the motive forces driving this transition separately, the way in which these forces interact with one another means that an integrated sketch is all that is possible.

This paper proceeds in three parts. In the first section, I discuss the effects of the 'military-technical revolution' on the military-industrial environment in the United States. I then examine the state's response to this phenomenon, focusing on both the US government's articulation of a new vision of arms production – 'agile manufacturing' – and on its efforts to encourage the realisation of this new vision through a number of key policy initiatives. The paper concludes with some general observations regarding the nature of the US arms industry's transition to agile manufacturing.

The Triggering Effects of the 'Military-Technical Revolution'

Although the conventional wisdom states that military industrial restructuring is driven primarily by the contraction in the global arms market associated with the end of the Cold War, in the late twentieth century there are other forces at work reshaping the arms industry. One of these is the so-called 'military-technical revolution' (MTR) that is currently transforming the ideas, instruments and institutions of warfare in the United States.[2] At the battlefield or war-fighting level, the MTR

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[2]A representative sample of the literature on the MTR includes: Eric H. Arnett, 'Welcome to Hyperwar', *The Bulletin of the Atomic Scientists*, 48:7 (7 September 1992), pp. 14-21; John Arquilla and David Ronfeldt, 'Cyberwar is Coming!' *Comparative Strategy*, 12:2 (1993); Alan D. Campden (ed.), *The First Information War* (Fairfax, VA: AFCEA International Press, 1992); Dan Gouré, 'Is there a Military-Technical Revolution in America's Future?' *The Washington Quarterly*, 16:4 (Autumn 1993), pp. 175-192; Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey: Summary Report* (Washington, DC: USGPO, 1993); Eliot A. Cohen, 'A Revolution in Warfare', *Foreign Affairs*, 75:2 (March/April 1996); Frank Kendall, 'Exploiting the MTR', *Strategic Review*, 20:2 (1992); Michael J. Mazarr, *et al*., *The Military Technical Revolution: A Structural Framework* (Washington, DC: CISS, 1993); L. Benjamin Ederington and Michael J. Mazarr, *Turning Point: The Gulf War and US Military Strategy* (Boulder, CO: Westview Press, 1994); Gary Stix, 'Fighting Future Wars', *Scientific American*, 273:6 (December 1995); Martin Libicki, 'What is Information Warfare?' National Defense University ACIS Paper 3, August 1995; Stuart E. Johnson and Martin C. Libicki (eds.), *Dominant Battlespace Knowledge: The Winning Edge* (Washington, DC: NDU Press, 1995); Richard

involves the use of microelectronics, precision munitions, stealth technology, near real-time sensing capabilities, and ever more advanced C^3I to generate quantum increases in 'visibility' (the ability to grasp the battlefield), 'lethality' (the ability to destroy or incapacitate the enemy on the battlefield), 'flexibility' (the ability to respond to developments on the battlefield) and 'concealability' (the ability to prevent an enemy from observing one's forces on the battlefield). In one sense, of course, this revolution can be interpreted as the natural outcome of a process that began during the Second World War. This is so not only because technology has increasingly dominated weapons' development and production throughout the entire period since 1945, but because, as Mary Kaldor argues, technological innovation during this era was largely a matter of exaggerating and improving the performance characteristics of the weapons systems that had proven decisive during the War.[3] But there is something clearly revolutionary about recent changes in military technology and technique. At a very general level, this is probably due to the fact that, as Soviet military theorists predicted in the 1970s, incremental changes in the means and methods of combat have exerted a progressively more profound effect on the character of warfare, and are now culminating in a *qualitative* transformation in the nature of warfighting.[4] On another level, however, the emerging mode of warfare is increasingly viewed as revolutionary because military technologies are more and more frequently breaking out of technological trajectories established during the Second World War as the search for radically new combinations of generic technologies becomes a primary determinant of the structure of military demand. Whatever the case, there is now a general consensus that the mode of warfare has evolved beyond Industrialised Total Warfare, and that the 'Military After Next' will be organised around instruments, ideas and institutions radically different from those that dominated the Second World War.[5]

J. Dunn III, *From Gettysburg to the Gulf and Beyond: Coping with Revolutionary Technological Change in Land Warfare* (Washington, DC: Institute for National Strategic Studies, 1992); David Shukman, *Tomorrow's War: The Threat of High-Technology Weapons* (New York: Harcourt Brace and Company, 1996); and Manuel DeLanda, *War in the Age of the Intelligent Machine* (New York: Zone Books, 1991).

[3]Mary Kaldor, *The Baroque Arsenal* (New York: Hill and Wang, 1981).

[4]See, 'The Revolution in Military Affairs', *Soviet Military Encyclopaedia*, vol. 7 (Moscow: Voyenizdat, 1979), pp. 80-82.

[5]The phrase 'the Military After Next' is from Paul Bracken, 'The Military After Next', *The Washington Quarterly*, 16:3 (Autumn 1993), pp. 157-174.

The Dynamics of Military Technology in the Late Modern Era

During the era of Industrialised Total Warfare, the means of destruction were essentially electro-mechanical in nature, reflecting the technological 'state-of-the-art' during the First and Second Industrial Revolutions. The instruments of warfare included enabling technologies such as steel, steam, and the internal combustion engine, as well as dedicated military technologies such as rifles, artillery and tanks. With the application of the technologies of the Third Industrial Revolution to military purposes, however, these instruments of warfare are increasingly being supplemented (and supplanted) by revolutionary advances in electronics, artificial intelligence and computing, C^3I systems, and advanced materials. As in the civil sector, these technologies are exerting truly revolutionary effects. Indeed, they have already begun to transform the battlefield by vastly increasing single-shot kill ratios, providing near real-time command and control, and creating an ever more transparent 'battlespace'.[6] As these knowledge-intensive military technologies continue to evolve, some argue that, in the not too distant future, the fundamental technical bases of warfare will be transformed, and that 'aircraft carriers, tanks, fighters and bombers will cease to have a primary role in the postmodern theatre of war'.[7] In this scenario, the battlefield of the twenty-first century will be dominated, not by massed troops and armour, but by:

> networks of intelligent mines and unpiloted drones that can perform reconnaissance and launch or plant weapons. Highly dispersed special forces may scout for targets and evaluate battle damage. Remotely fired missiles may become the main instruments for destroying enemy targets.[8]

For the moment, of course, such scenarios remain the stuff of futuristic treatises;[9] warfare today continues to be dominated by 'baroque' versions of the military technologies that achieved preeminence during the Second World War. Indeed, many of today's most advanced weapons

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[6]See Martin Libicki, 'The Emerging Primacy of Information', *Orbis*, 40:2 (Spring 1996), pp. 261-274.

[7]Stix, 'Fighting Future Wars', p. 94.

[8]Ibid., p. 92. For a discussion of this futuristic scenario see Arnett, 'Welcome to Hyperwar', pp. 14-21; Arquilla and Ronfeldt, 'Cyberwar is Coming!'; Libicki, 'What is Information Warfare?'; *Idem*., *the Mesh and the Net: Speculations on Armed Conflict in a Time of Free Silicon*, available on the WWW at http://www.ndu.edu/ndu/inss/macnair/mcnair28/m028cont.html; Stuart E. Johnson and Martin C. Libicki (eds.), *Dominant Battlespace Knowledge: The Winning Edge* (Washington, DC: NDU Press, 1995); Shukman, *Tomorrow's War*, esp. Ch. 8; and Alvin and Heidi Toffler, *War and Anti-War: Survival at the Dawn of the 21st Century* (New York: Little, Brown and Company, 1993).

[9]Although it should be noted that the US Army has completed at least one study that concludes that the next century's core weapon 'may well be the unmanned system'. *Star 21: Strategic Technologies for the Army of the 21st Century* (Washington, DC: National Academy Press, 1992).

systems are the culmination of a long process of more or less linear 'trend innovation', which Kaldor describes as 'perpetual improvements to weapons that fall within established traditions of the armed services and the armourers'.[10] But the constant, continuing press of technological innovation is increasingly yielding a plethora of military technologies that 'break out' of existing technological trajectories, either as a result of the development of radically new technologies or as previously discrete generic technologies are dynamically recombined in novel ways.

Simply stated, then, the onset of the so-called 'military-technical revolution' has given rise to a new 'great desideratum' in American military circles: 'knowledge-intensive' weaponry. This ideal has come to exercise enormous influence within the American military, generating a dynamic of 'perpetual innovation' that is increasingly forcing arms producers to seek an enhanced capacity to upgrade existing weapons systems, to develop radically new weapons technologies (by combining generic technologies in new and innovative ways), and to reduce 'lab-to-field' cycles so that new technologies are not obsolete before they are deployed. It is also accelerating the pace of technological innovation. Military innovation, of course, has always been an important element of interstate rivalry, and the phenomenon of perpetual innovation can be traced back at least to the 'invention of invention' in the nineteenth century.[11] What distinguishes both the emerging mode of warfare and its military-industrial correlates is that as we approach the twenty-first century the capacity to develop, produce and field ever more innovative and 'knowledge-intensive' weaponry is becoming *the* primary determinant of military power and victory in war. This differs from the preceding era, during which the capacity for technological innovation, while important, was less decisive than the capacity for social and economic mobilisation.

The Effects of the MTR on the Military-Industrial Environment

After the Second World War, market conditions in the civil sector were such that manufacturers were able to organise production around specialised machine tools and rigid and mechanically-guided production lines employing relatively unskilled labour. This system was sustained by an interlocking framework of state, market and institutional control systems that stabilised and standardised demand, unleashing the full productive potential of the fordist paradigm. This fusion of the fordist production paradigm with an appropriate regulatory framework generated unprecedented economic growth during the post-War era. Indeed, so great was the economic

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[10]Kaldor, *Baroque Arsenal*, p. 4.

[11]See Martin van Creveld, *Technology and War* (New York: Free Press, 1989), ch. 15.

expansion initiated by this growth model that the period is often referred to as the 'golden age of capitalism'.[12]

In the arms sector, on the other hand, conditions could scarcely have been more different. Where commercial firms serviced a market that encouraged the standardisation of products and parts, the pursuit of economies of scale, the mechanisation of the manufacturing process, and the lowering of product prices, arms manufacturers had to produce for a monopsonist state that demanded relatively small numbers of specialised, increasingly 'baroque', performance-maximising weapons.[13] Cold War rivalry and the system of perpetual military innovation it fostered worked against the implementation of commercial-style fordism in several ways. First, it blocked the kind of standardisation of demand that allowed the widespread use of specialised production machinery in the civil sector. The emphasis on 'technological superiority' meant that designs had to be updated and incorporate the latest technological advances. This worked against the kind of dedicated mechanisation increasingly common in the commercial sector. Second, perpetual innovation and the pursuit of 'technological superiority' worked against product simplification, giving rise to increasingly complex (baroque) technologies that were not particularly amenable to fordist production practices. Finally, in the aftermath of World War Two, levels of demand dropped dramatically, and never again reached levels that could be called 'mass'. While the military often procured large quantities of specific types of weapons, demand never reached the 'mass' proportions that were common in the civil sector.[14] This precluded making the kinds of investment in advanced, dedicated machinery that had enabled commercial firms to continually increase productivity through the 1960s. It also encouraged the development and diffusion of flexible manufacturing systems, as well as an increased dependence on skilled labour.[15] As the Cold War progressed and the tendency toward baroque technology intensified, these differences in the mode of regulation were

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[12]Michael DeVroey, 'A Regulation Approach Interpretation of the Contemporary Crisis', *Capital & Class*, 23 (1984), p. 54.

[13]Kaldor, *The Baroque Arsenal*.

[14]In the 1950s, the US procured approximately 2,000 fighter aircraft per year; in the 1960s, about 600; and in the 1970s, approximately 300. These numbers (which include several different models in each year) are substantially lower than those of, say, the automobile industry, which typically produced tens of thousands of nearly identical models in any given year. Jacques Gansler, *Affording Defense* (Cambridge, MA: MIT Press, 1989), p. 170.

[15]Jacques Gansler, *The Defense Industry* (Cambridge, MA: MIT Press, 1980), pp. 50-54.

exacerbated, widening the breach between commercial and military variants of fordism, though never severing the material and discursive links connecting them.[16]

Against this backdrop, the onset of the MTR triggered the terminal decline of military-fordism. By the late 1970s, the disjuncture between patterns of military demand and the logic of the prevailing arms production paradigm had begun to manifest itself as a growing inability to produce affordable high-technology weapons systems.[17] At first, these tensions between the military-fordist production paradigm and the technical demand of the prevailing mode of warfare had been problematic, but manageable. During the late 1980s, the quantum leap in the knowledge-intensity and technological density of warfare associated with the military-technical revolution, coupled with the reduction in military spending associated with the end of the Cold War, intensified these tensions to the point where they reached crisis proportions. Indeed, even before the end of the Cold War it was clear to many in both industry and government that change in the technical bases of warfare, coupled with the transformation of the global security environment, had signalled the terminal decline of the existing arms production paradigm.[18]

From the point of view of the state, the exhaustion of the military-fordist paradigm manifested itself first and foremost in terms of a radical inability of US arms producers to undertake the kind of low-rate/low-volume production of technologically-dense goods required by knowledge-intensive

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[16]Ann Markusen has suggested that as a result of this divergence in demand patterns following World War Two, 'the military-industrial complex became a pioneer in post-Fordist production methods'. This, however, is questionable on at least two grounds. First, most scholars agree that the roots of postfordist production can be traced to incremental innovation introduced in post-war Japanese industry and only introduced to the US much later (and then via civil industry). See Martin Kenney and Richard Florida, *Beyond Mass Production: The Japanese System and its Transfer to the US* (Oxford: Oxford University, 1993). Second, it is also incorrect to claim that the US arms industry during this era was anything other than fordist at a deep paradigmatic level. To be certain, faced with changes in the nature of demand during the Cold War period US arms firms continued to evolve along the trajectory first established during the war – i.e., they became more flexible. But this did not mean that they transcended the basic logic of fordism. US arms producers remained firmly in grip of the fordist paradigm, purposively seeking to extend the logic of fordism into small batch production and never severing the link between rate/volume of production and unit costs that was the hallmark of fordism. Rather, it meant that they continued to implement fordist principles in a particular institutional and technological milieu.

[17]Gansler, *Affording Defense*, pp. 170-171.

[18]For a clear indication of this see US Department of Commerce, *Findings of the US Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Washington, DC: National Technical Information Service, 1989).

warfare. Under military-fordism, there was a clear correlation between rate/volume of production and unit costs: the more units produced, and the more rapidly they were manufactured, the lower were individual unit prices. Conversely, shorter production runs tended to result in higher unit prices as the cost of development and tooling was amortised over fewer units of output. This was not terribly problematic during World War Two, when levels of demand were roughly comparable to those prevailing in the commercial marketplace. Following the war, however, sharp reductions in the levels of absolute demand, coupled with the rising technological-density and complexity of weaponry, began to drive costs upward. Almost invariably, this meant that with each successive generation of weapons fewer and fewer units could be purchased.[19] As a result, unit prices were driven up still further, setting off the escalatory spiral that subsequently came to be known as 'structural disarmament'. Primarily as a result of the MTR, by the late 1980s this situation had become much worse, and it was generally acknowledged in US military-industrial circles that the tendency toward structural disarmament, which was rooted in the very nature of military-fordism, had reached crisis proportions.[20]

The onset of the MTR, then, created an unbridgeable gap between the nature of military demand on the one hand and the logic and best-practices of military-fordism on the other. This initiated a crisis in US military-industrial circles as government fears of structural disarmament converged with industry fears of declining profits and bankruptcy to initiate a period of profound intellectual ferment and practical experimentation related to arms manufacturing. Out of this process, a new set of military-industrial desiderata emerged during the late 1980s and early 1990, key elements of which include:

C cost-efficient low-rate/low-volume production: A key part of the military's vision of the arms industry of the future is a capacity to produce limited numbers of knowledge-intensive weaponry at affordable costs (with costs defined not only in terms of initial purchase prices, but overall life-cycle expenses as well).

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[19]This was compounded by the shift away from military use of standard commodities produced in commercial production facilities. As Ann Markusen has noted, in World War One 80 percent of Army equipment came off standard commercial production lines. During World War Two, this percentage dropped below 50 percent. By the 1960s, however, 'the share of military demand met by specialized equipment made in special facilities had escalated to 90% . . .' Ann Markusen, 'The Military-Industrial Divide', p. 399.

[20]Thomas A. Callaghan, *Pooling Allied and American Resources to Produce a Credible, Collective Conventional Deterrent*, a report prepared for the US Department of Defense, MDA903-84-C-0274, August 1988, p. 57.

- a capacity for rapid technology realisation and insertion: As the MTR accelerates, the arms industry of the future must be able to develop and insert advanced technologies rapidly. This involves not simply developing and producing new platforms in a timely fashion, but also a capacity for quickly inserting leading-edge subsystems into ongoing production programmes.
- a capacity for rapid prototyping: In a military-technical environment where not every new technology can be put into quantity production, technology-demonstrators, technology integration demonstrators, production retrofit demonstrators, and operational prototypes will play an increasingly important role in US acquisition strategy. In such an environment, the capacity to rapidly and cost-efficiently develop and produce prototypes will be crucially important to maintaining a technological edge.[21]
- a capacity to draw on the broader civil technology and industrial base: As the commercial sector has taken the lead in technological dynamism, there has been a recognition that continued American military-technical superiority requires the creation of a unified national technology and industrial base.[22]

For arms firms, then, the military-technical revolution and the associated quantum leap in the knowledge-intensity of weaponry has initiated a clear rupture with the industrial best-practices of the post-War era. Whereas during the Cold War the tensions between military demand and the logic of the arms production paradigm were manageable (if only at great expense), since the onset of the MTR they have reached crisis proportions. This has generated pressures to adapt manufacturing processes, business practices and intra- and inter-firm relations in order to enhance flexibility and innovative capacity, the goal being affordable low-rate/low-volume production of knowledge-intensive weaponry. In recent years, this process has culminated in the adoption by arms producers of those 'postfordist' manufacturing practices that are widely perceived to underpin the technological vitality of the global electronics and automobile industries.[23]

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[21]Prototypes can be used for a range of purposes, including: reducing technological uncertainty; identifying design flaws prior to production; testing systems integration; exploring various ways of accomplishing a mission; helping select a prime contractor; and testing the 'soldier/system interface'. See US Congress, Office of Technology Assessment, *Building Future Security*, pp. 51-75, but esp. p. 52.

[22]Regarding this aspect of the evolving military-industrial vision see US Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration: Technologies, Processes and Practices*.

[23]These will be discussed in some detail below. Descriptions of the transformations of the global electronics and automobile industries include David Angel, *Restructuring for Innovation: The Remaking of*

The Pentagon and the Evolution of 'Agile Manufacturing'

Pressured by the demands of an accelerating military-technical revolution to restructure and modernize, and inspired by the successful application of 'postfordist' production techniques in the US automotive and electronics sectors,[24] over the last decade or so American arms producers have simultaneously undertaken innovations in product technologies, development and manufacturing processes, and corporate structure. As a result, the (essentially fordist) production paradigm around which US arms manufacturing has been organized since the Second World War has entered into a period of terminal decline, and the defining features of a new arms production paradigm are now becoming visible across the American military-industrial landscape. Conditioned to a significant degree by the example of the Japanese and American automobile industries, this emerging paradigm is based on four principles. The first is the pursuit of flexibility, which involves efforts to adopt new technologies and techniques in order to de-couple rate and volume of production from unit cost. The second is the pursuit of accelerated technological innovation through the adoption of a variety of practices intended to shorten design-to-field times and encourage the dynamic re-combination of previously discrete technologies in new and innovative ways. The third organizing principle is the pursuit of 'leanness' through the relentless elimination of waste and inefficiency at every stage of the production cycle. The final principle is 'agility', defined as the ability to create electronically-integrated virtual enterprises (comprising civil and military firms) quickly and painlessly to respond effectively to constantly evolving demand patterns. This new paradigm can be conceptualized as *agile manufacturing* – a term that has been advanced in various military-industrial circles to refer to the adaptation of postfordist production techniques to the military-industrial environment of the late twentieth century.[25] Since the early 1990s, agile manufacturing has become *the* paradigmatic vision of what the future arms industry should look like, and has thus played a crucial role in the contemporary restructuring of the US defence industrial base.

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the US Semiconductor Industry (New York: Guildford Press, 1994); Martin Kenney and Richard Florida, *Beyond Mass Production: The Japanese System and its Transfer to the US* (Oxford: Oxford University Press, 1993); and Kurt Hoffman and Raphael Kaplinsky, *Driving Force: The Global Restructuring of Technology, Labour and Investment in the Automobile and Components Industries* (Boulder, CO: Westview, 1988).

[24]Elements of the postfordist production paradigm include concurrent engineering, flexible manufacturing systems, and just-in-time inventory practices. The central innovation of this new cluster of best-practices, however, is its emphasis on flexible volume production. For a good overview see, Ash Amin, *Post-Fordism: A Reader* (Oxford: Blackwell Publishers, 1994).

[25]The term 'agile manufacturing' was first developed in a DoD-sponsored study undertaken by the Iaccoca Institute at Lehigh University. See Roger N. Nagel and Rick Dove, *21st Century Manufacturing Enterprise Strategy*, vols. 1 and 2 (Bethlehem, PA: Iaccoca Institute, Lehigh University, 1991).

This section also makes the argument that while the pursuit of perpetual innovation has become the defining characteristic of the contemporary arms industry, *affordability* has become an important secondary consideration. During the military-fordist era, production engineers and industrial managers never managed to sever the connection between rate/volume of production and unit cost, despite innovations such as N/C machine tools and other flexibility enhancing innovations. As a result, as the volume of military orders has declined (due to the passing of Industrialised Total Warfare, the decline of military-keynesianism and the end of the Cold War), and as the technological density of weaponry has increased, by the late 1970s unit costs were rising so fast that many feared the United States was on course toward structural disarmament. Faced with this prospect, during the 1980s state and industrial officials began searching for new ways of manufacturing arms. At first, they turned their attention toward the Japanese model of production, which was universally regarded as having solved many of the problems facing the US arms industry.[26] Later, they began to look at the 'lean manufacturing' model that was widely perceived to have reversed the sagging fortunes of America's automotive firms. While the new vision of arms production that emerged out of this period of intellectual ferment ultimately transcended the (initially civilian) lean production paradigm, it is clear that this latest cluster of 'modern methods' has exercised a powerful conditioning influence on the contemporary military-industrial restructuring process.

The US Government and the Evolution of Agile Arms Production

The complex edifice of promotion and support underpinning the diffusion of postfordist production techniques through the arms industry began taking shape in the early 1990s with the launching of the Lean Aircraft Initiative (LAI).[27] The LAI's primary mandate was (and is) to encourage military aerospace companies to begin adopting the postfordist lean production techniques that are widely perceived to have revived America's automotive industry during the 1980s. The goal underpinning this initiative has been twofold: to create the capacity for low-volume/low-rate production of military products at reasonable prices; and to shorten weapons system development time and increase the pace at which technological improvements can be incorporated into new systems. The

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[26]See, for example, US Department of Commerce, *Findings of the US Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Washington, DC: National Technical Information Service, 1989).

[27]The term 'lean production' was coined by MIT's International Motor Vehicle program in its 1991 report *The Machine That Changed the World*. Although there are differences between lean and agile production (especially with respect to the desired characteristics of the supplier chain), broadly speaking, agile manufacturing can be said to encompass and build upon lean production. Thus, the LAI can be said to be an integral part of the US government's effort to develop and promote agile arms production.

initiative has its roots in the realization in military-industrial circles that America's ability to develop and incorporate advanced, and increasingly knowledge-intensive, technologies at affordable prices required a fundamental change in the nature of the arms production system.

The LAI began in earnest in 1992 when the US Air Force's Aeronautical Systems Center (AF/ASC) requested that Massachusetts Institute of Technology (MIT) conduct an initial 'quick-look' evaluation of the applicability of lean production practices in the military aircraft industry. MIT, which had earlier identified such postfordist practices as the single most important factor behind the Japanese automobile industry's competitive edge over its American counterpart, conducted an initial assessment of the military aerospace industry, and concluded that the application of lean manufacturing techniques to the manufacture of military aircraft could be expected to result in a number of benefits, including:

- fifty percent reductions in factory labour, factory space and engineering effort;
- ninety percent reductions in in-process inventory;
- sixty-six percent reductions in the number of defects;
- eighty-seven percent reductions in suppliers and subcontractors; and
- fifty to sixty-six percent reductions in aircraft development times.

The assessment also concluded that adopting lean production techniques would improve the 'ability of US industry to rapidly develop prototypes and implement product improvements quickly in response to changes in threat and need'.[28]

As a result of this positive initial evaluation, in August 1993 the AF/ASC launched a more comprehensive three-year programme intended to identify and study lean production practices and to promote their diffusion through the military aerospace industry. Under this initiative, the US Air Force's Wright Labs began collaborating with about twenty military aerospace firms (distributed across the three main sub-sectors: airframes, avionics and propulsion) to build and extend the lean production paradigm through an organized programme of research, information-sharing, and pilot projects.[29] The LAI is organized under the auspices of MIT's Center for Technology, Policy and

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[28]'Valuable Lessons Home to Roost', *Jane's Defence Weekly*, 23:20 (20 May 1995), p. 45.

[29]As of April 1995, participating firms included: AIL Systems, Allied Signal, Boeing Defense and Space Group, Fairchild, GE Aircraft Engines, Hughes Radar Systems, Litton, Lockheed Aeronautical Systems

Industrial Development (CTPID), which acts as a research 'hub' and clearing house. Funding is provided by both the government (US $950,000 per year) and the participating firms (US $75,000 per year per firm). 'The whole effort is overseen by an advisory board made up of senior officials from the aerospace industry, government and national labour unions'.[30]

During its initial stages, the LAI focused on evaluating the degree to which lean production practices had diffused through the US military aerospace industry. Subsequently and more recently, however, it has 'sought to identify existing high-performance practices, within and outside the aerospace community, emphasizing those that can bring major reductions in both cost and cycle time'.[31] To this end, the project has used integrated research teams (involving government, industry and labour) to conduct surveys and case studies of relevant industrial organisations. In its final year, the LAI is concentrating on developing a 'Lean Enterprise Model' (LEM) to aid in the implementation of postfordist production practices throughout the US military aerospace industry.

Although the project will not be completed until late 1996, several government initiatives have already resulted from LAI research. For example, the USAF has actively encouraged lean manufacturing techniques for the F-22 fighter, JDAM (Join Direct Attack Munition), and C-17 transport aircraft programmes. It has also launched two dedicated pathfinder projects, one in connection with the JAST next-generation Air Force/Navy strike aircraft programme (involving seven demonstration projects to pilot the introduction of lean manufacturing techniques), and the other a project related to postfordist 'modular factories'.[32]

A second, and somewhat more comprehensive initiative for the promotion of postfordist techniques was also launched in 1991 when the US Department of Defense sponsored a study by an industry-led

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Company, Martin Marietta (subsequently merged with Lockheed), McDonnell Douglas, Northrop Grumman, Pratt & Whitney, Rockwell North American Aircraft, Sundstrand, Texas Instruments, Textron Defense Systems, TRW, and Westinghouse Electronic Systems Group.

[30]Mark Hewish and Pamela Pohling-Brown, 'Making Change a Positive Force: Revolution in US Aircraft Factories', *International Defence Review* 28:4 (1 April 1995), p. 30.

[31]Stanley I. Weiss, Earll M. Murman and Daniel Roos, 'The Air Force and Industry Think Lean', *Aerospace America* (May 1996), p. 2/9.

[32]Hewish and Pohling-Brown, 'Making Change a Positive Force: Revolution in US Aircraft Factories', p. 31.

group to investigate the future of arms production.[33] This study, conducted at Lehigh University's Iacocca Institute, coined the term 'agile manufacturing' to describe its vision of America's military-industrial future. As described in the study report *21st Century Manufacturing Enterprise Strategy*,[34] agile manufacturing is a new postfordist production paradigm that is intended to enable the arms industry 'to thrive in an environment of continuous and unanticipated change'.[35] Achieving such agility in arms manufacturing requires integrating computer-driven production technologies with the skill base of a knowledgeable workforce using postfordist management structures. It includes elements of both 'flexible' and 'lean' postfordist manufacturing techniques, but it is not synonymous with these approaches. Simply stated, whereas flexible production focuses on process adaptability, and lean production aims at reducing cost and shortening design-to-field times through the use of advanced techniques and technologies, agile production is intended to enhance technology development through the use of rapidly reconfigurable, computer-networked cooperative ventures capable of meeting the changing requirements of knowledge-intensive warfare. In other words, agile manufacturing encompasses the basic postfordist objectives of severing volume/rate of production and cost, reducing waste, and shortening design-to-field cycles, but also emphasizes the rapid creation of 'virtual enterprise' – groups of vertically and/or horizontally linked companies that come together via computer networks to fill a specific demand. It is based on the recognition that while programmable automated machine tools and flexible manufacturing techniques are important elements of the new industrial paradigm, they are only part of the picture. True agility requires that the 'entire supply chain . . . be engineered and managed so that manufacturers can work concurrently with their strategic partners, suppliers and customers to reduce costs and improve product design and performance'.[36] Whereas in the automotive industry the tendency has been to organize the supplier chain around semi-permanent 'extended enterprise' (supplier-assembler

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[33]DoD's Manufacturing Technology Program, now part of the Manufacturing Science and Technology Program, sponsored the original research that led to the vision of agile manufacturing.

[34]See Nagel and Dove, *21st Century Manufacturing Enterprise Strategy*, vols. 1 and 2.

[35]Mike McGrath, *Agile Manufacturing Program*, document available on the WWW at www.arpa.mil/sisto/overview/agile.html.

[36]Tim Farrell, *Agile Manufacturing*, document available on the WWW at http://www.niit.org/sha/amfg/amfg.html.

partnerships lasting 20+ years), in the arms industry the vision that has emerged emphasizes the creation of short-term horizontal and vertical teaming arrangements via computer networks.[37]

A key element of the agile manufacturing vision is the creation of an integrated national technology and industrial base (NTIB) comprising agile commercial and military firms, linked by computer networks, that can be assembled quickly to form a virtual enterprise capable of rapid and cost-efficient product realisation.[38] As arms production has become less and less vertically-integrated,[39] and as production has come to be based on complex 'webs' of suppliers,[40] assemblers and strategic partners, military-industrial planners and industry executives have come to recognize that there are considerable benefits to including both commercial and military firms in the pool of potential project participants. Although significant cost-savings may derive from including commercial firms in the potential supplier chain (the commercial supplier of a particular technology may be the most cost-efficient), the real military benefit of an integrated NTIB lies in the enhanced access to leading-edge technology that this would afford arms producers. An additional benefit, and one not to be underestimated, would be an expansion of the military supplier base. Over the past few decades, the regulatory burdens associated with defence contracting have driven many of the crucial sub-tier suppliers (usually small- and medium-sized enterprises) out of the arms industry.[41] This has been

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[37]Daniel Whitney, *et al.*, *Agile Pathfinders in the Aircraft and Automobile Industries – a Progress Report*, 1995, document available on the WWW at http://web.mit.edu/ctpid/www/agile/atlanta.html.

[38]For statements of this vision see US Department of Defense, *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology* (Washington, DC: USGPO, 1995); Jeff Bingaman, Jacques Gansler and Robert Kupperman, *Integrating Commercial and Military Technologies for National Strength* (Washington, DC: CSIS, 1991), esp. Chapter 1, 'The Logic of Integration'; Lewis Branscombe, 'Dual-Use Technology: Optimizing Economic and Security Interests through National Technology Policy', distinguished Honeywell W.R. Sweat Lecture on Technology Leadership, University of Minnesota, Minneapolis, 18 May 1989; Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington, DC: USDOD, Office of the Undersecretary of Defense (Acquisition), 1989), A-13 to A-18; Nagel and Dove, *21st Century Manufacturing Enterprise Strategy*, vols. 1 and 2.

[39]One indication of this trend is the rise in the subcontracted content of major Department of Defense acquisitions. These have increased from 9 percent in 1950, to 41 percent in 1980 to 53 percent in 1990. See *Agile Aerospace Manufacturing Research Center*, document available on the WWW at http://arrirs02.uta/aamrc /aamrchp.html.

[40]A 'web' is defined as those firms (primes, sub-contractors and suppliers) that comprise the supplier chain.

[41]Numerous studies have noted this exodus of subtier firms from the defence supplier base, including most notably, James Blackwell, *Deterrence in Decay, Report of the CSIS Defense Industrial Base Project*

a source of concern in military-industrial circles, not only because it threatens the viability and 'surge capacity' of the US arms industry, but because it increases US dependence on foreign sources as well.[42] Creating an integrated NTIB comprising agile firms capable of servicing commercial and military markets with equal facility would assure the continued existence of a robust arms industry at the level of prime contractors, sub-contractors and suppliers.

Inspired by this vision, the US government has recently begun to dismantle many of the regulatory barriers to civil-military integration. There is a growing realisation, however, that a truly integrated NTIB will require more than simply removing the regulatory barriers dividing the CTIB and DTIB. While this is an important precondition for integration, the development of an intrinsically 'dual-use' technology and industrial base will require the recomposition of the entire US technology and industrial base into agile firms capable of rapidly forming virtual enterprises in response to constantly evolving commercial and military demand patterns. In essence, the goal is to transcend the distinction between commercial and military firms by creating a single, generic category of industrial enterprise that can be readily incorporated into an industrial web producing either commercial or military goods.[43]

Thus, in a very real sense the agile manufacturing vision can be said to represent a military-inspired derivative of the postfordist production methods. It is clearly rooted in the basic logic of postfordist production, emphasising flexibility, quality and responsiveness. But it goes beyond this paradigm to include a new vision of inter-firm relations, one based on the rapid creation and dissolution of virtual enterprises comprising generic firms (i.e., firms that are neither civil nor military in the traditional sense) that can service the commercial or defence markets with equal ease. While deriving from the military-industrial desiderata generated by the military-technical revolution, this

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(Washington, DC: CSIS, 1989); and Norman Augustine, *Lifeline in Danger: An Assessment of the United States Defense Industrial Base* (Arlington, VA: Aerospace Education Foundation, 1988).

[42]Bingaman, *et al*., *Integrating Commercial and Military Technologies for National Strength*, p. 6.

[43]It is important to note that the agile manufacturing vision effectively supersedes earlier visions of 'dual use' and 'conversion'. Dual use (which originally focused on increasing the ability of defence firms to incorporate commercial product and process technologies), and conversion (which originally focused on redirecting arms production to commercial applications) have both given way to a vision of a fully integrated NTIB comprising agile firms that can be brought together readily to form virtual enterprises to meet either commercial or military demands. Regarding the changing vision of conversion, see Richard Burnett, 'Weapons Technology Aims at New Target', *The Orlando Sentinel*, 17 June 1996, p. 15.

vision is not restricted to the arms industry; for, if the agile vision is to be realized, civil industry also has to be transformed. Thus, the emergence of this new vision of production has had an important 'knock-on' effect: it has triggered a new phase in the restructuring of the commercial technology and industrial base. Increasingly, commercial industry sees agile manufacturing as its hope for future competitiveness in a world of fast-paced technical change and intensified global competition.[44]

Since the publication of *21st Manufacturing Enterprise Strategy*, the vision of agile arms production developed at the Iaccoca Institute has come to enjoy great currency in both government and industry circles. Building on this vision, the US government has initiated a number of research programmes aimed at infusing an agile manufacturing capability into the defence industrial base. *Inter alia*, these include the Manufacturing Automation and Design Environment (MADE) programme, the Affordable Multi-Missile Manufacturing (AM^3) programme, the Technologies Enabling Agile Manufacturing (TEAM) programme, and the Electronic Commerce Resource Center (ECRC) programme. The most important of these have been implemented under the auspices of the joint Advanced Research Projects Agency/National Science Foundation (ARPA/NSF) Agile Manufacturing Initiative (AMI). Initiated in 1993, the AMI's mandate is to 'develop, demonstrate and evaluate the advanced design, manufacturing and business transaction processes described in the *21st Century Manufacturing Enterprise Strategy* report',[45] thus encouraging and facilitating the implementation of agile manufacturing through the arms industry and the broader technology and industrial base upon which the arms industry relies.

The Agile Manufacturing Initiative operates through a series of working groups, fora and research institutes focusing on particular topics. These act as catalysts for change in the arms industry by providing greater definition of the vision of agile manufacturing, identifying impediments to the diffusion of the emerging paradigm, and validating/demonstrating the effectiveness of particular techniques. The AMI has so far established six subsidiary projects:

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[44]For a discussion of agility as a vision for the future of America's commercial sector see Steve Goldman, Roger Nagel and Kenneth Preiss, *Agile Competitors and Virtual Organizations* (New York: Van Nostrand Reinhold, 1995).

[45]ARPA, 'Agile Manufacturing', document available on the WWW at http://www.sei.cmu.edu/arpa/agile-mfg.html.

- *The Agility Forum (formerly the Agile Manufacturing Enterprise Forum)*: This is an industry forum which is responsible for developing and refining the overall vision of agile manufacturing first articulated in the Iacocca Institute study. Its responsibilities include defining agile business practices, identifying technology needs, recommending pilot programmes and demonstrations, and generally promoting industry awareness and training activities. 'In addition to its outreach and dissemination activities, the Forum is committed to producing an evolving, integrated, system-level model of agility out of knowledge being generated by more than 30 government- and industry-funded research, development and pilot projects as well as by the Forum's own programs and activities; and it is committed to producing agile business practice 'toolkits' that companies can use to deploy agility in their organization and assess its impact'.[46]

- *Agile Manufacturing Research Institutes (AMRIs)*: The purpose of the AMRI 'is to develop an understanding of agile manufacturing enterprise and system performance based on quantitative data; to structure a program of research to meet industry-defined needs; and to move emerging technology which has a potential for impacting agile manufacturing into the next stage of functional prototyping or proof-of-concept test beds'.[47] Several AMRIs have been established, including the Aerospace Agile Manufacturing Research Center, the Machine Tool Agile Manufacturing Research Institute, and the Electronics Agile Manufacturing Research Institute.

- *Agile Manufacturing Network Projects*: The purpose of this programme is to develop a prototype of the national information infrastructure necessary to support a distributed technology and industrial base, and to facilitate electronic commerce and electronic data interchange. Existing projects include the Advanced Collaborative Open Resource Network (ACORN), the Agile Manufacturing Information Infrastructure, the CAMnet Prototype projects and the PartNet project.

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[46]Steven L. Goldman, *Agility Overview*, document available on the WWW at http://absu.amef.lehigh.edu /agility.html.

[47]*Agile Manufacturing Program Solicitation*, document available on the WWW at http://elib.cme.nist.gove /edl/html/agile/agile.rfp.txt.

C *Agile Business Practice Projects*: These projects are intended to test, validate and demonstrate innovative business practices that focus on enabling the rapid formation and dissolution of virtual enterprises. The projects deal with issues such as labour organisation, decision support, and virtual enterprise management. Ongoing projects include the Agile Web Pilot Program, the Labor Infrastructure for Agile High Performance Transformations project, the Supply Chain IPPD Pilot Project, and the Strategic Planning and Operating Tools for Agile Enterprise project.

C *Enabling Technology Development and Demonstration Projects*: The purpose of this programme is to facilitate the development and demonstrate the utility of a range of technologies necessary to agile manufacturing. Projects include the Agile Manufacturing Decision Support Systems project, the Decision Support System for the Management of Agile Supply Chains, and the Virtual Enterprise Engineering Environment project.

C *Agile Manufacturing Pilot and Pathfinder Demonstration Projects*: These projects are intended to demonstrate the applicability and utility of agile manufacturing techniques and enabling technologies. 'The primary focus is on networked interfaces with suppliers and customers for product development and electronic commerce, and on business methods for virtual companies'.[48] Agile Manufacturing Pilot Projects include the Agile Infrastructure for Manufacturing Systems (AIMS) project; Agile Manufacturing Pathfinder Projects include the MIT/Lehigh Fast and Flexible Communication in the Aerospace Industry project.[49]

In addition to launching the LAI, AMI and other industrial transformation initiatives, the US government has taken a number of steps to remove the regulatory impediments to agile production and the creation of a unified national technology and industrial base. Until quite recently, of course, many elements of the military acquisition process (even as reformed during the 1980s) worked against the diffusion of postfordist production techniques. The Competition in Contracting Act (CICA), for example, has had a powerful dampening effect on process innovation and the ability of arms producers to adapt their organizational structures to the changing commercial environment.

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[48]ARPA, *Agile Manufacturing*, document available on the WWW at http://www.sei.cmu.edu/arpa/agile-mfg.html.

[49] 'Agile Manufacturing: Lean Manufacturing's Virtual Cousin', *International Defence Review* 28:3, p. 32.

Initially put in place in 1984, the CICA is a Federal statute which requires 'full and open competition' in all US government procurement programmes. While conceived as a means of creating competitive market conditions (and thus reducing prices) in previously non-competitive markets, CICA has in many ways served to slow the proliferation of postfordist techniques which might substantially improve efficiency and productivity in the defence sector. In particular, the requirement that contracts for components and subsystems be tendered on a competitive basis means that the development of the type of long-term relationships at the heart of many new corporate governance structures (particularly solar complexes) is significantly inhibited. In turn, this limits the extent to which concurrent engineering, just-in-time manufacturing and TQM (all of which are at least partly dependent on these new organisational structures) can be implemented.

Dual\second sourcing practices involving transfers of proprietary technologies, while also rooted in an entirely reasonable impulse to control defence costs, have had similar effects on the proliferation of postfordist manufacturing techniques.[50] In such a situation developers not only run the risk of not being awarded the production contract (which they may be counting on to subsidize development), but of having to transfer technical data and design/development information to competitors. As a result, they are necessarily discouraged from incorporating proprietary production technologies or management techniques in their design proposals.

Other regulatory impediments include budget instability, which makes it difficult to employ efficient production planning and control techniques; the nature of military contracts, which stipulate that only approved production processes can be used; and the criminalisation of non-compliance, which further reduces flexibility, responsiveness and risk-taking by forcing managers to fulfil strictly regulatory requirements.[51]

Beyond these direct impediments to the diffusion of postfordist production practices, the regulatory framework governing arms procurement has also impeded the realisation of the agile manufacturing

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[50]Dual sourcing refers to simultaneous production from two sources, typically involving the transfer of technology from the developer to an alternative producer. In such a situation, production is split between two firms, with the larger order going to the lower cost producer. Second sourcing, on the other hand, is similar except that the entire production contract is 're-competed' periodically with the low-cost bidder awarded the entire production contract. See Jim Leitzel, 'Competition in Procurement', *Policy Sciences* 25 (1992), pp. 43-56.

[51]See William E. Kovacic, 'Regulatory Controls as Barriers to Entry in Government Procurement,' *Policy Sciences*, 25:1 (February 1992), pp. 36-37.

vision in that it effectively segregated the defence technology and industrial base from its commercial counterpart, thus blocking the evolution of the kind of unified NTIB required for agile arms production. The regulatory sources of segregation have been well documented in previous studies and need only be discussed briefly here.[52] Suffice it to say that during the Cold War factors such as unique accounting requirements, military specifications and standards, state control of technical data rights, and byzantine public contracting procedures meant that, 'in many companies, defence products are designed, developed, produced and supported in isolated plants or independent division; and many other companies either maintain separate research facilities for defence and commercial work or simply refuse to accept DoD research contracts'.[53] This led to the evolution of two discrete and isolated technology and industrial bases in the US: one exclusively commercial, the other primarily military.[54] While this may have made sense even as recently as 15 years ago – when 'DOD set a standard of technological performance that few commercial firms could match' – in makes little sense today, when 'the pace of innovation and the standard of performance are set in the commercial sector in response to an intensely competitive international business environment'.[55]

Viewed against this backdrop, it is clear that the American government's ability to realize its vision of an agile arms industry is largely dependent on its ability to eliminate or reduce the barriers

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[52]See, for example, US Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration: Technologies, Processes and Practices*, OTA-ISS-611 (Washington, DC: USGPO, 1994); Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington, DC: USGPO, 1989); US Congress, *Streamlining Defense Acquisition Laws: Report of the Acquisition Law Advisory Panel to the United States Congress*, January 1993; US Department of Defense, Office of the Undersecretary of Defense for Acquisition, *Report of the Defense Science Board Task Force on Defense Acquisition Reform* (Washington, DC: USGPO, 1993); Debra van Opstal, *Integrating Civilian and Military Technologies: An Industry Survey* (Washington, DC: Center for Strategic and International Studies, 1993); and Jeff Bingaman, Jacques Gansler, and Robert Kupperman, *Integrating Commercial and Military Technologies for National Strength* (Washington, DC: Center for Strategic and International Studies, 1991).

[53]Jacques Gansler, 'The Future of the Defence Firm: Integrating Civil and Military Technologies, in Andrew Latham and Nick Hooper (eds.), *The Future of the Defence Firm: New Challenges, New Directions* (Dordrecht: Kluwer Academic Publishers, 1995), p. 93.

[54]For a countervailing view see Maryellen R. Kelley and Todd A. Watkins, 'In from the Cold: Prospects for Conversion of the Defense Industrial Base', *Science*, 268 (28 April 1995); and *idem*., 'The Myth of the Specialized military Contractor', *Technology Review* (April 1995).

[55]See especially Jeff Bingaman, *et al*., *Integrating Commercial and Military Technologies for National Strength*, Chapter 1.

separating the commercial and defence technology and industrial bases; for only if these barriers are lowered will it be possible to create the kind of unified technology and industrial base that state and industry officials perceive as being necessary to the future of American arms production. To date, the government has taken a number of steps in the direction of creating such a regulatory framework. Two of these stand out as being particularly important.[56] The first was the passing of the 1994 Federal Acquisition Streamlining Act (FASA) which specifically addressed the purchase of commercial items and services, provided a clearer definition of commercial items and services, eliminated the requirement for cost and pricing data on commercial items, and made it more difficult for the government to acquire rights in technical data for items developed with private funds.[57]

The second significant initiative in this regard involved a significant reduction in the use of military specifications and standards (milspecs) in the defence acquisition process. Milspecs, as a number of government and academic reports have concluded,[58] have long constituted one of the key impediments to the integration of the commercial and defense technology and industrial bases in that they deter many successful commercial firms from undertaking military business. Thus, any movement toward lowering the barriers between the commercial and military technology and industrial bases will require a prior reduction in the use of milspecs.[59] It will also involve 'fundamentally altering the incentive structure to promote greater use of commercial goods'.[60]

In June 1994, Secretary of Defense William Perry took a decisive step in this direction when he circulated a memorandum directing the Department of Defense to implement changes in the use of military specifications and standards.[61] This memorandum directed military procurement executives

[56]For an overview of these initiatives see US Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration: Technologies, Processes and Practices*, pp. 64-66.

[57]US Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration*, p. 51.

[58]See especially Jeff Bingaman, *et al*., *Integrating Commercial and Military Technologies for National Strength*.

[59]Process Action Team for Specifications and Standards, *Final Report: Briefing*, 19 November 1993.

[60]US Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration*, p. 84.

[61]See Secretary of Defense William J. Perry, *Memorandum for Secretaries of Military Departments, Subject: Specifications and Standards – A New Way of Doing Business*, 29 June 1994.

'to use performance and commercial specifications and standards instead of military specification and standards, unless no practical alternative exists to meet the user's needs'.[62] To be certain, even before 1994, DoD had begun the process of shifting to commercial standards, and by 1993 'had increased the number of adopted non-governmental (i.e., commercial standards from 3,279 to 5,617 [a 51 percent increase])'.[63] Until the Secretary issued his 1994 memorandum, however, progress had been slow and piecemeal, impeded by a bureaucratic infrastructure not convinced that senior officials were serious about altering the procurement environment so profoundly. Since 1994, however, all this has changed. The Secretary's memorandum has signalled the commitment of senior levels of DoD to procurement reform and the shift to commercial standards. Now, there is a clear presumption that commercial standards will be used *except* in carefully delimited circumstances. While the process of integrating the civil and military specifications and standards around the commercial norm is far from complete, it is clear that the process is well underway.[64]

While they mark the beginning of a transformation of the regulatory framework governing arms production, these regulatory and acquisition reform initiatives have thus far failed to create the type of unified technology and industrial base essential to the realisation of agile manufacturing. Indeed, as one OTA report put it, 'in the face of persistent obstacles to commercial purchasing, these executive and legislative branch efforts have had only marginal success in increasing [commercial-military integration]' . . . The process of integration is in its infancy, however, and while the final outcome is difficult to predict precisely, it is clear that the first tentative steps have been taken toward restructuring the regulatory framework in order to realize the state's vision of agile manufacturing.

Conclusions

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[62]*Ibid*.

[63]Department of Defense, Office of the Assistant Secretary of Defense (Public Affairs), *New Release*, 'DoD's Acquisition Reform Recommendations to the 800 Panel Report', 28 October 1993.

[64]The process of shifting to commercial specification has been parallelled by the adoption of (commercial) American National Standards Institute/American Society for Quality Control and International Organization of Standardization quality standards in place of military MIL-Q-9858A and MIL-I-45208A standards. See Under Secretary of Defense, John M. Deutch, *Memorandum for Secretaries of the Military Departments and Directors of Defense Agencies on the Use of Commercial Quality system Standards in the Department of Defense (DOD)*, 14 February 1994.

Many of the findings reported in this paper concerning the diffusion of postfordist production technologies and techniques should be regarded as preliminary and, therefore, more indicative of evolutionary tendencies rather than a completed transformation. Nevertheless, based on this broad survey of military-industrial restructuring, four general observations can be made concerning the transition to agile manufacturing. First, the process of experimentation and *bricolage* that characterizes the current stage of the transformation of arms production is being driven by the need to develop the means to sustain high-quality/low-cost production under conditions of rapidly changing patterns of military demand. The problems experienced by US arms producers in the 1970s and 1980s derived not from a shortage of innovative capacity, but from tendentially rising costs that posed a serious threat to their long-term commercial viability. These production problems arose in part from a fundamental tension between the nature of military-fordism (which created an inversely proportional relationship between rate/volume of production and unit costs) and the emergent military-technical revolution (which involved a shift away from the mass production of simple weapons to an emphasis on smaller numbers of increasingly 'baroque' armaments). Beginning in the 1990s, American arms producers began to realize that if they were to maintain their economic viability and technological competitiveness in the context of a changing regulatory framework, they would have to find ways of severing the military-fordist connection between volume and cost, thus achieving affordable low-rate production.

But if the pursuit of affordability is clearly a powerful motive in the current restructuring of arms production, the adoption of agile manufacturing techniques is also being driven by a desire to maintain and enhance the technological vitality of the arms industry. Under conditions of 'perpetual innovation', extending the technological frontier requires a shift away from an exclusive emphasis on developing radical new technologies in the lab and toward a more balanced approach that involves both breakthrough innovations and incremental product and process innovation. Thus, much of the attention of US arms firms seeking to remain at the technological frontier is now focused on 'not only the ability to invent new products and technologies [in the R&D lab] but also the ability to upgrade and improve those products and manufacture them as efficiently as possible'.[65] As Japanese (and more recently American) automobile and electronics firms have demonstrated, such incremental product and process innovations can be a powerful source of technological dynamism and commercial success. American arms producers are hoping that by introducing agile

[65]Kenney and Florida, *Beyond Mass Production*, p. 16.

production they can blur the distinctions between the factory floor and the R&D lab, with the result that product and process innovation will be intensified while design-to-field cycles are shortened.

Agile manufacturing is also intended to enhance the technological capacity of the US arms industry by breaking down the barriers separating the civil and military technology and industrial bases. A key element of the agile manufacturing vision is the creation of a unified national technology and industrial base comprising agile firms and virtual enterprises capable of servicing the military and commercial markets with equal facility. Thus, the current restructuring must be seen as extending beyond the existing arms industry to encompass the civil manufacturing base as well. Indeed, in the long-run, agile manufacturing will necessarily involve a blurring of the practical and conceptual lines separating military and civil firms. If the agile manufacturing vision is realized, in the next century there will no longer be distinctive firms servicing segregated markets, only inherently agile 'generic' firms capable of rapidly forming virtual enterprises to produce increasingly knowledge intensive commercial or military goods to order.

A second general conclusion that can be drawn from the literature dealing with the shift to lean production is that the process of military-industrial transformation in the US is clearly conditioned by civilian best-practices. Faced with changes in both the nature of military technology and the regulatory framework governing arms production, American arms firms have not developed a *new* labour process *ab initio*. Rather, they have adopted a series of process changes modelled on their perception of the 'lean production' techniques that had evolved in the Japanese automobile industry during the 1960 and 1970s and that became paradigmatic in the US automotive sector during the mid- to late-1980s. From continuous process improvement to JIT and concurrent engineering, the 'Japanisation' of American labour processes has been a defining element of the transformation of the US arms industry.

Third, while the process of transformation is far from complete, the transition to postfordist production techniques in the arms industry appears to have accelerated significantly over the last five years, at least at the prime contractor and sub-contractor levels.[66] Ten years ago, only a handful of arms producers were involved in any sort of restructuring at the shop floor level beyond the introduction of a few programmable manufacturing technologies. Since the early 1990s, however,

[66]Capturing the adoption of postfordist production techniques at the supplier level is a very difficult task given the low public profiles of such firms and the lack of attention they have received in government studies and surveys.

all of the top ten prime contractors, as well as many of the larger subcontractors, have initiated restructuring programmes. While the introduction of new manufacturing technologies remains an important part of this process, restructuring initiatives aimed at introducing postfordist labour processes such as JIT, continuous process improvement, and concurrent engineering are proliferating rapidly. Whether adopted at a stroke, or introduced gradually through 'pilot' or 'pathfinder' programmes, postfordist labour processes are increasingly common in all sub-sectors of the US armaments industry.

A fourth set of conclusions that can be drawn from this overview is that the US arms industry is somewhere in the late experimental phase of the industrial transition cycle. While progress is being made toward the evolution and implementation of a new arms production paradigm, it is widely recognized that the arms industry is still a long way from realising the agile vision of a 'seamless' web of military and civil firms, linked by computer-integrated design systems, that are organized to fit a particular market opportunity and can function as an integrated whole capable of responding rapidly to customer needs. In this regard, the most that can be said is that we are now in a period of intense experimentation with new postfordist technologies, techniques and organisational forms. While the vision of 'agile manufacturing' is guiding this process, and while islands of postfordist production have emerged, it is still too early to claim that the structural transformation of the US arms industry has been completed. A more accurate claim is that the US arms industry is currently in an early phase of what history suggests will be an extended process of industrial transformation.

A final conclusion is that, although the diffusion of lean production practices is being driven primarily by changes in the mode of warfare, and conditioned by the demonstration effect of changes in the automotive industry, it is clear that state military-industrial policy is at least partly responsible for the widespread experimentation with postfordist production techniques that characterizes the current era. Programmes such as the Lean Aircraft Initiative and the Agile Manufacturing Initiative, coupled with changes in the regulatory environment such as the Federal Acquisition Streamlining Act, have acted both to spur and enable the development and diffusion of postfordist production practices through the US arms industry. It is worth noting in this connection that, as during the evolution of the armoury system in the nineteenth century, the US government's promotion of a new vision of arms production (agile manufacturing) now seems to be driving a restructuring of the broader civil production base.

Efforts to improve flexibility, shorten design-to-field cycles, and minimize waste have begun to remove many of the longstanding barriers to cost-efficient batch/custom production in the US armaments sector, even as the technological density of modern weapons continues to increase. While technical and organisational restructuring is still of relatively recent origin (dating primarily from the early 1990s), their effects are already discernable in the form of reduced unit costs, improved product quality, and accelerated rates of product and process innovation. Continuation of the current trend in restructuring, and the diffusion of agile manufacturing techniques throughout the US arms industry not only constitute the real 'quiet revolution' in the arms industry; they also promise to unleash the full destructive power of the emerging mode of warfare and thus make a major contribution to the ability of the United States to sustain military superiority into the next century.

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