Piloted Concepts for Commercial-Military Integration Ready for Implementation

Military Products from Commercial Lines (MPCL)

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In recent years, *Program Manager* has served as the forum for two timely articles[1] on an Air Force pilot demonstration called Military Products from Commercial Lines (MPCL).[2] Briefly, the goal of MPCL was to enable manufacture of military products on a commercial production line. The results are now in. This article outlines the program's approach and summarizes the results.

Capturing the Processes

In 1994, the Manufacturing Technology Division of the Air Force Research Laboratory (AFRL) began work on the MPCL pilot demonstration. The intent of the lab program was simply to show that MPCL could be done and to capture the enabling processes. By working through barriers to commercial manufacturing and capturing the processes necessary to accomplish it, the MPCL program conceivably could blaze a trail for weapon systems such as the F-22, Comanche, and other DoD system programs to implement commercial manufacturing approaches for affordability.

The Air Force Manufacturing Technology (ManTech) investment in MPCL, $21.5 million, would take much of the risk out of implementing acquisition reform in the program offices and reduce the amount of nonrecurring costs re-

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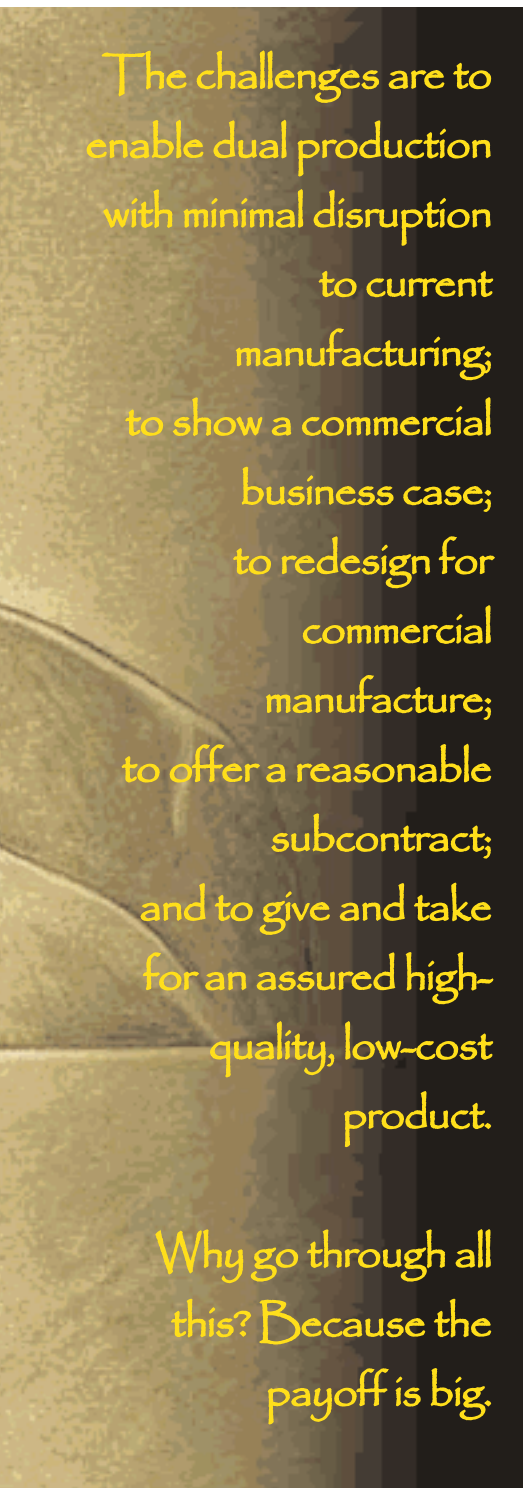
quired for commercial manufacturing approaches in the future.

The MPCL contract was initiated in May 1994. One month later, Secretary of Defense William Perry issued a memo, bringing attention to acquisition reform and mandating the reduction of military specifications and standards. Acquisition reform efforts were in their infancy and ran in parallel with the MPCL program. Complementary to acquisition reform, MPCL actually demonstrated acquisition reform concepts and provided real data in support of its benefits.



After careful review, ManTech awarded the MPCL contract to TRW Avionics Systems Division (ASD) and subcontracted to TRW Automotive Electronics Group North America (AEN). A three-phased effort, the contract's duration would eventually exceed four years.

The MPCL program was defined in terms of three areas—business practices, manufacturing infrastructure, and process technology—and managed through integrated product teams. Emphasis throughout the program was to involve as many customers and stakeholders as possible, increasing the likelihood of buy-in and end results that met or surpassed expectations. Although specific demonstration vehicles from specific programs were chosen, the scope of work included a focus on how MPCL results could be generally applied in addition to how the specific demonstration could be successful. In that way, processes could be documented for future use outside of the demonstration product.

The avionics modules selected for the demonstration were two F-22 CNI modules, which were also common to the Army Comanche helicopter: the Pulse Narrowband Processor (PNP) and the RF Front End Controller (RFFEC). These modules were chosen for their commonality among weapon systems, multiple use within systems, high design-to-cost, standard module construction, compatibility with commercial automation equipment and systems, and commonality with commercial component suppliers.

Within these criteria and the objectives of the program, the MPCL team concluded that the PNP and RFFEC modules would be very good candidates for a high-impact demonstration and, at the same time, would be highly representative of many module types that could potentially be built commercially.

Commercial manufacturing emphasizes cost and quality over performance. The commercial manufacturer maintains highly efficient processes to stay competitive and won't bother with the deal unless it is profitable. Non-value-added contractual requirements are simply unacceptable. The MPCL approach is *not* to change commercial processes and practices to meet military demands. Rather, the challenges are to enable dual production with minimal disruption to current manufacturing; to show a commercial business case; to redesign for commercial manufacture; to offer a reasonable subcontract; and to give and take for an assured high-quality, low-cost product.

Why go through all this? Because the payoff is big. The primary metric used to determine MPCL success is module acquisition cost. The baseline measurement is the F-22 design-to-cost model for each of the PNP and FEC modules. Against this baseline, MPCL redesign indicates 50- to 75-percent cost avoidance, exceeding the original program goal of 30 to 50 percent. Considering the number of avionics modules in a system, potential payoff is significant.

Business Practices

The Old Way of Doing Business—The Baseline Approach

The "old" way of doing business has no room for commercial enterprises. In general, the "old" process of military acquisition has evolved to business practices that are driven by military specifications, standards, and contract clauses to such an extent that the intent has been lost. Unwieldy contracts have so many references and cross-references to specifications and standards that few people can understand them. In many cases, requirements are added only because they are boilerplate, i.e., they have always been added in the past. The emphasis on quality and affordability is not there. Only companies with well-established defense infrastructures can do business this way—and at great expense.

Purely commercial companies dismiss this sort of business without a second thought. They have neither the time nor the infrastructure to take on defense cus-

tomers. To do so would lessen the efficiencies that have kept them competitive in the world marketplace. But since many commercial companies have high quality processes and products to offer the DoD at reasonable prices, MPCL was motivated to break out of the old way and remove the barriers to commercial manufacturing. The estimate for TRW AEN to build the two MPCL demonstration modules was 50 percent less than the military baseline for these modules. It was the goal of MPCL to figure out how to take advantage of that.

Assessments early in the program (Phase I) pointed out some of the discrepancies between military and commercial processes and practices. For example, at TRW ASD, a typical military approval process for nonstandard parts, based on MIL-STD-965, has six steps and lasts 192 days, whereas a typical new parts approval process at TRW AEN has three steps and lasts 135 days.

To illustrate, the cost to produce an automotive air bag crash sensor is 79 percent less than the cost to produce a military helicopter restraint system crash sensor (Figure 1). The F-22 subcontract to TRW ASD for their portion of the CNI system had 183 contract clauses and 204 technical requirements (specifications and standards), whereas a typical commercial contract at TRW AEN has 27 contract terms and conditions and 35 technical requirements.

Convincing TRW AEN to sign up to the MPCL subcontract was no easy task. Several months of negotiation were required. Indeed, the original subcontract had 30 or more contract clauses — not a comfortable contracting situation for AEN. However, once the program was underway, the Business Practices (BP) Team set out to find a way to simplify subcontracts to commercial suppliers, using the TRW AEN subcontract as the baseline.

The New Way of Doing Business — The MPCL Approach

The MPCL approach in the BP area was threefold. First, TRW AEN had to be convinced of the business case for building military products. Second, there had to be a contracting vehicle agreeable to all parties. Third, a practice needed to be established whereby TRW AEN could use their existing processes and would not be mandated only by military specifications and standards.

The business case was accomplished by using a TRW AEN financial spreadsheet, predicting future manufacturing orders, and showing profitability for TRW AEN with reasonable price for TRW ASD. Once this exercise was completed, TRW AEN truly "bought in" to the MPCL program and viewed TRW ASD as a "real" customer. From then on, TRW AEN participated fully in MPCL to establish the commercial manufacturability of the demonstration modules. TRW AEN now has plans to bid on future defense work.

The contracting effort initially involved significant analysis work but soon converged on the definition of commercial items. Declaring the MPCL modules commercial items was the quickest and most effective way to simplify a subcontract to be a commercial-like document. The BP Team had to wait for the implementation of the Federal Acquisition Streamlining Act (FASA) and the Federal Acquisition Reform Act (FARA), which eased some requirements for commercial items. They also worked very closely with contract personnel, discussing and working through every issue.

Finally, after two years MPCL set a precedent and successfully obtained commercial item status for its modules. The determination was based on the fact that the MPCL modules are built using commercial processes and practices. In addition to commercial item status, a price analysis was required to eliminate the cost accounting clauses. MPCL demonstrated and documented a successful (and reusable) price analysis process.

FIGURE 1. **Commercial Manufacturing Costs vs. Military Manufacturing Costs**

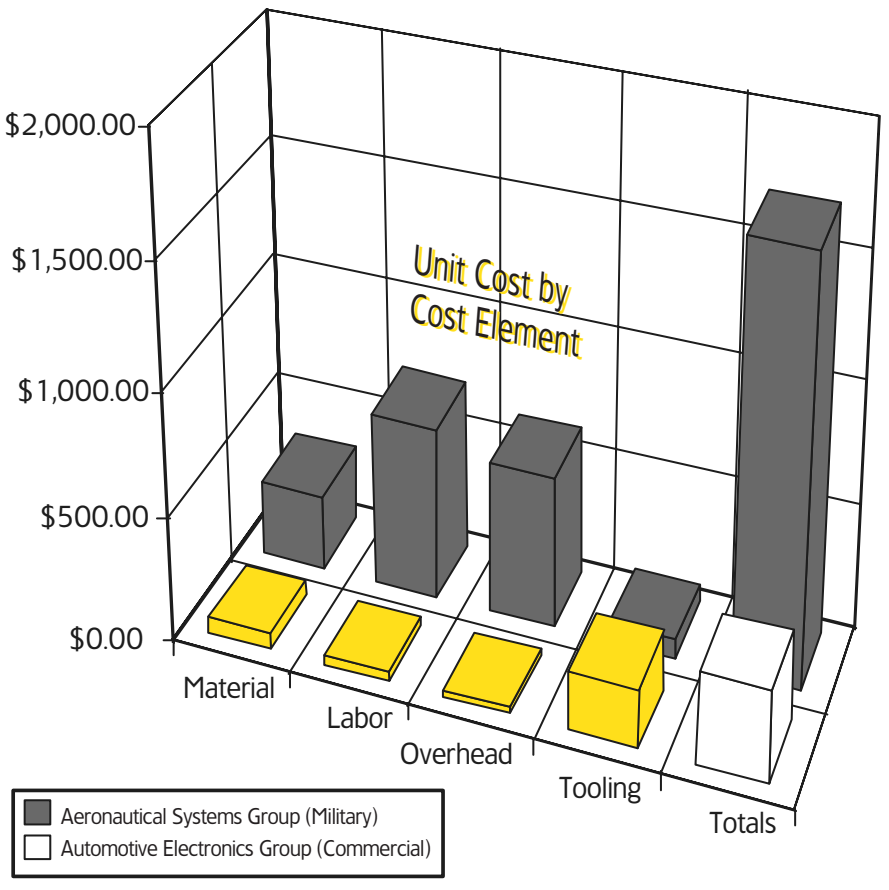
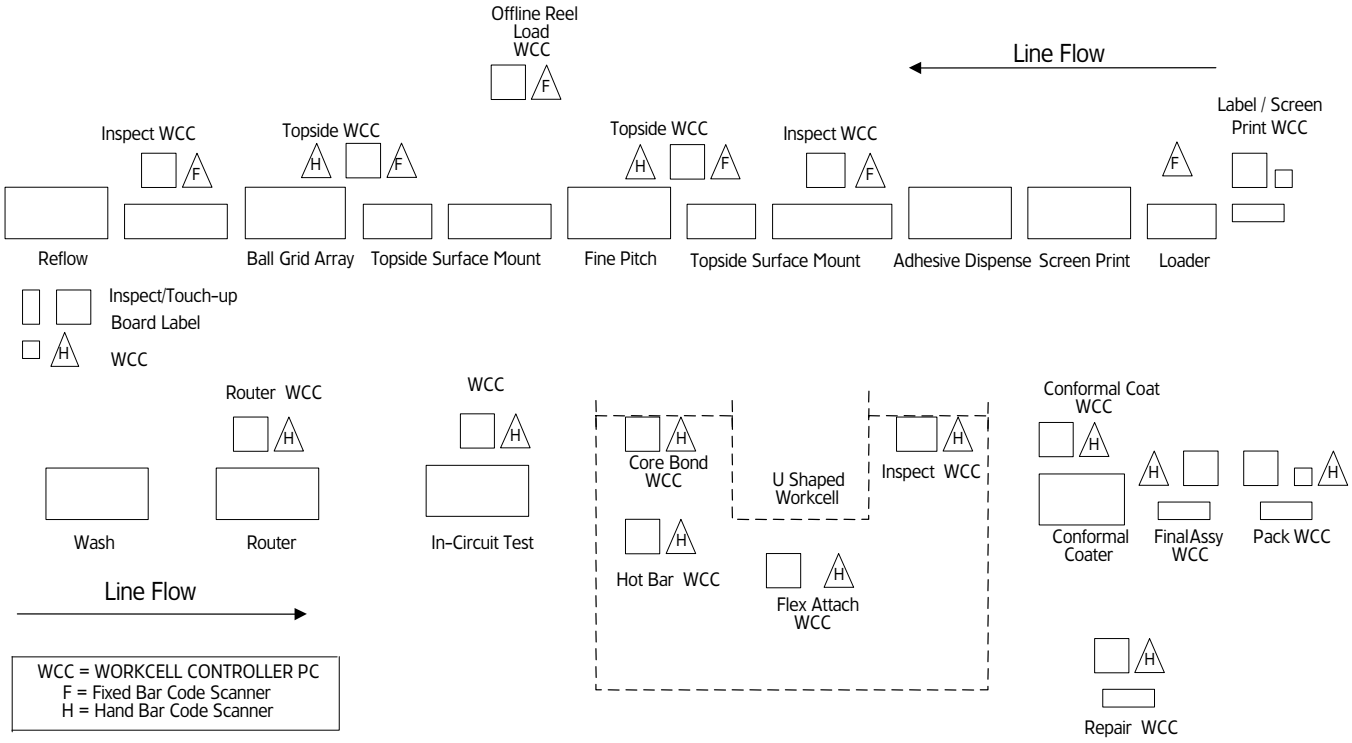


FIGURE 2. **Schematic of the TRW AEN Processing Line Used for MPCL Modules**



The specifications and standards effort involved integrated teams to review technical requirements and determine how they should be stated. This was no trivial task since team participants did not always agree. It was found, however, that many industrial standards worked for many military applications. A *BP Manual* was generated describing technical requirements, incorporating American National Standards Institute (ANSI), International Organization for Standardization (ISO), American Society for Quality Control (ASQC), Society of Automotive Engineers (SAE), and Electronic Industry Association (EIA) standards; the supplier's own competitive commercial practices; and only a couple of military standards. The manual is suitable for the MPCL effort and transferable to other similar commercial manufacturing ventures.

With commercial item status, price analysis, and the *BP Manual,* the TRW AEN subcontract was modified from more than 30 clauses to three, and from 204 specifications and standards to 32. This subcontract was used to generate a Model Subcontract for others to use in similar commercial manufacturing ventures. The efforts of the BP Team have begun the process of drawing interest from commercial manufacturers in producing products for defense systems. (The *BP Manual* and Model Subcontract have been included as part of the final MPCL report.)

Manufacturing Infrastructure

There were several reasons why TRW AEN was selected as the commercial supplier for MPCL, not the least of which was that TRW desired a corporate strategy whereby the efficiency of its commercial manufacturing could be leveraged for some military products.

At their Marshall, Ill., plant, TRW AEN produces safety critical products for a stringent automotive customer. Their processes are well suited to the production of digital CNI modules. And while TRW AEN designs most of the products they build, they do have at least one customer who does their own designs for production at Marshall. TRW ASD emulated this by designing MPCL products for further manufacture at the Marshall plant.

The baseline-manufacturing floor at TRW ASD is a lab-like environment with several people using tweezers and magnifying glasses to place parts. Production is a few hundred modules per year. Flexibility is high; emphasis is on product performance and military specification. In contrast, the manufacturing floor at Marshall is highly automated, with conveyors and several high-speed, pick-and-place robots. Production is tens of thousands of units per day, and millions of components are placed per day. Everything revolves around the price of the product, and every fraction of a penny counts. Emphasis is on quality and efficiency.

Leveraging What Works

At this point, the government members of the MPCL team had to overcome a certain amount of culture shock and stay focused on the objective. How could the efficiency and affordability of TRW AEN manufacturing be leveraged for the MPCL products, and for military products in general?

The answer to this was not simple, but several approaches became clear. First, now that military products are a very small part of the electronics market, the DoD must learn how to be a "good customer." Second, the redesign of the MPCL products must emphasize design-

for-manufacture (and design-for-commercial-manufacture). And third, computer integrated manufacturing (CIM) will enable low-volume, complex military products to be built on relatively high-volume commercial production lines.

CIM — A Key Enabler

In the MPCL case, CIM is a key enabler to seamless commercial-military integrated manufacturing. It is the CIM system that allows military products to be efficiently produced on a commercial manufacturing line along with commercial products. The MPCL Manufacturing Infrastructure (MI) Team developed and implemented the CIM system at TRW AEN. Their primary objective was to develop and deploy a flexible CIM system that not only supports the existing high-volume needs, but also provides for low-volume, high-mix production on the same line.

The MI Team provided software tools and information systems to support product design, enable the flow of data from design to manufacturing, and ensure proper control and monitoring of production. The CIM system now provides design-driven production, product quality modeling, automatic product changeover, process mistake-proofing, factory control, work cell control, a centralized production and quality data model, modularity, and transferability.

The benefits of CIM for MPCL include a reduction in cycle time module procurement through test of more than 30 percent and product changeover in less than 15 minutes per station. Without these efficiencies, TRW AEN would have decided that manufacturing the military modules was too disruptive to their factory, and that future work in this area would probably not be feasible.

Process Technology

Every effort was made in MPCL to approach tasks from the angle of quality and affordability. This is different from the usual approach to acquisition and military design, and required out-of-the-box thinking at every turn, including the Process Technology (PT) Team's redesign process.

FIGURE 3. **MPCL Process Technology Metrics**

METRIC	METHODOLOGY	TARGET (BASIS)	RESULT	INDEX
Pulse Narrowband Processor (PNP) Cost	Material – Actuals Labor – Estimates	$18.0 K (50% Reduction)	$18.6 K	97 %
Front End Controller (FEC) Cost	Material – Actuals Labor – Estimates	$17.4 K (50% Reduction)	$11.0 K	100%
Cumulative Damage Index (CDI) (Durability, Reliability)	Test	1.0 (F-22 Life)	1.0	100%
Form, Fit, Function	Demonstration	100% (F-22 Comparison)	100%	100%
Weight	Test	1.3 lbs (F-22 Baseline)	1.0 lbs	100%
Number of Processes with Process Capability (Cpk) >1.33	Build	14 (Design for Manufacturability [DFM] Analysis)	11	79%
Number of Processes with Set-up Time < 15	Demonstration	11 (Return on Assets Employed [ROAE] Analysis)	11	100%
			TOTAL TECHNICAL PERFORMANCE INDEX (TPI)	97%

Phase I

Once demonstration modules were selected, the PT Team set about the task of conceptual design. No limitations were placed at this point, and the team listed possible design concepts based on design packaging approaches such as plastic, ceramic, chip-on-board, leaded packages, and area array packages. Using a design-for-manufacture approach and a decision matrix methodology, the concepts were scored and the highest scoring concept selected.

A plastic ball grid array (PBGA) approach was chosen, i.e., an approach based on plastic packages for components, attaching them to the modules using an array of solder balls. Elements factored- in to the design selection included durability life; design-for-manufacture; recurring and life cycle costs; weight; platform commonality; technical risk; nonrecurring cost; fit; and functionality. TRW AEN's "Flex Line 3" was selected for module production because of process similarity and because it allows for more frequent product changeover. Figure 2 is a schematic of Flex Line 3.

Such a design approach would never have materialized through the baseline military redesign process. Approaches to affordability are severely limited by longstanding practices such as an attitude of performance-at-any-cost and an exaggerated mistrust of suppliers. In the MPCL program, team members had the freedom to leave this sort of baggage by the wayside and pare the project down to its essential elements: the technology was there, the price was good, and performance requirements were met.

Phase II

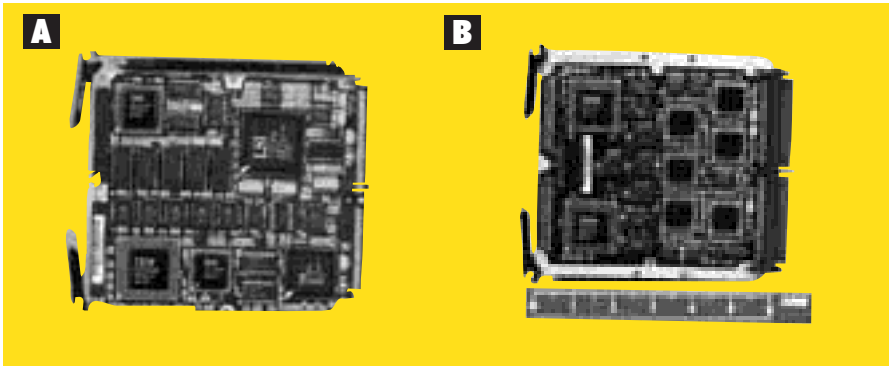
In Phase II, the PT team performed detailed design, demonstrated durability and reliability of the selected design, and built design validation modules. Process development was underway as well, preparing TRW AEN's Flex Line 3 for its first military products.

Phase III

Production validation was conducted in Phase III. The PT Team efforts were not without issue, but no issues were raised that could not be resolved in a manner conducive to sound commercial product and process development.

The primary difficulties for the PT Team had to do with the custom Application-Specific Integrated Circuits (ASIC) in the demonstration modules. These could not be designed out in the MPCL program but had no commercial equivalents. Because these parts are custom, complex, and low-volume, their lead

FIGURE 4. **MPCL Demonstration Module (PNP Sides A and B)**



times are the longest, and manufacturing and test problems abound.

These issues surface in many military designs with custom ASIC components. In MPCL, custom ASICs represent less than 10 percent of the parts, but more than 50 percent of the cost. The remaining 90 percent of the parts are commercially available, and some are already provided by TRW AEN suppliers.

Process development included some capital investment to accommodate features of the MPCL modules (such as cores, connectors, and fine pitch parts) that are not characteristic of TRW AEN's other products. In several cases the capital has dual use application, while a few process steps apply only to MPCL modules at this point. In general, however, the changes to module designs to accommodate the production line *far outweigh* changes to the production line to accommodate modules!

TRW AEN has been able to benefit from a few new processes introduced through MPCL. For example, PBGA process technology is something that TRW AEN has wanted to develop for their other customers. MPCL has allowed them to accelerate that development. MPCL process development in general has prepared TRW AEN to handle more complex products, which will be required for future automotive customers as well as military ones.

Although details of design, development, manufacture, test, and verification are too numerous to include here, they can be found in the PTF Final Report. The results of these activities have demonstrated a 54-percent cost reduction for the PNP module and a 73-percent cost reduction for the RFFEC module. The weight of the modules has been reduced by 35 percent. Durability testing indicates that the modules will survive at least one full 20-year military fighter lifetime using commercial parts and processes. Component reliability far in excess of 12,000 hours has been demonstrated by accelerated tests. Full functional compatibility with the predecessor military modules has been verified by design validation testing. Figure 3 shows program metrics, and a demonstration module is shown in Figure 4.

The MPCL Conclusion

MPCL concludes that neither business practices nor manufacturing infrastructure nor product and process technologies pose any insurmountable barriers to building military products on commercial lines. Military products can be built on commercial lines at significantly lower cost, and of equal or higher quality. This is only one pilot demonstration, but it is not an atypical one. The practices and processes demonstrated in MPCL can be used elsewhere for similar benefits. Every MPCL accomplishment is transferable and, where appropriate, has available data and documentation.

Next Step — Implementation

While the pilot program itself was an overwhelming success, implementation of MPCL is not a trivial matter. It cannot be done piecemeal but, rather, requires an entire change of mindset. It is a business strategy that must pervade the thought processes of everyone involved. TRW is well on its way to leveraging commercial manufacturing for defense needs. However, interest among defense contractors in the MPCL concept has not gone very far beyond TRW. To date, a couple of companies may be interested in a similar corporate strategy; a few more are willing to redesign with commercial components if sufficient Nonrecurring Engineering (NRE) cost is paid but are otherwise noncommittal. Others have ignored the concept entirely, seeing no incentive to change a well-established process.

Why MPCL and related concepts are so slow to catch on is not quite clear. Lack of incentives, fear of competition, and resistance to cultural change have been cited as probable reasons. Indeed, defense manufacturers are still getting paid to keep doing what they've always done; and, while acquisition cost savings is incentive for the program offices, it is not necessarily incentive for prime contractors. Nevertheless, the evidence is clear: *those who can implement the concepts of MPCL will have a competitive advantage.* In fact, the implementation of MPCL is the current topic of discussion among acquisition professionals and the next challenge in this continually evolving effort called acquisition reform.

Editor's Note: Detailed program results have been compiled into several volumes of final reports[3] and are available from AFRL/MLME or on the Web at **http://www.ml.afrl.af.mil/ib/pilots/MPCL-Main.html.** The author welcomes questions or comments on this article. Contact her at **mary.kinsella@wpafb.af.mil.**

ENDNOTES

1. *Program Manager*, November-December 1996, pp. 32-38, and July-August 1998, pp. 48-56.
2. Contract No. F33615-93-C-4335
3. The MPCL Final Report includes an Executive Summary; Volume I, *Business Practices* (includes the Model Subcontract); Volume IA, *Business Practices Manual*; Volume II, *Manufacturing Infrastructure*; Volume IIIA, *Process Technology*; and Volume IV, *Lessons Learned*.