Chapter Five

DUAL-USE TECHNOLOGIES: IMPLICATIONS FOR COST, SCHEDULE, AND CONTRACTOR CONFIGURATION CONTROL

INTRODUCTION

Possibly the single most important claim of CMI advocates is that closer integration of the military and commercial industrial bases will lead to significantly lower-cost weapon systems that will be developed more quickly. As has been pointed out in the previous chapter, limited evidence suggests that equal or better performance is obtainable through the use of commercially derived parts and technologies in military RF/microwave systems. At the same time, our examination of case studies also indicates that risks are incurred in moving toward a full-blown CMI strategy, particularly with respect to durability and reliability. These risks are at least partially offset by the promise of much reduced weapon system costs. In this chapter, we examine some of our case study evidence to determine if significant cost-savings and schedule benefits are really likely as a result of dual-use products and technologies. Once again, we divide our analysis into two parts: Parts insertion and technology insertion. Finally, we discuss more fully the question of the importance of contractor configuration control throughout the life-cycle of a system for the successful implementation of CMI.

INSERTION OF COMMERCIAL PARTS AND COMPONENTS

AIL has generated considerable data during the development of its Modular Radar prototypes on the potential cost and schedule benefits of using commercial-grade parts and components.[1] One reason AIL engineers dropped their original plan to use all Mil-Spec parts was because the far-shorter delivery times for commercial-grade parts shortened the schedule and thus the cost for development of the prototype radars. AIL discovered that deliveries of Mil-Spec parts often took six to nine months. Mil-Spec parts that were available in catalogs (GOTS parts) were often not kept in stock. Producers did not keep many Mil-Spec microwave parts in stock and did not produce for inventory. Rather, factories routinely waited for sufficient orders to come in to justify startup of a new production run. Mil-Spec suppliers also tended to arbitrarily discontinue a part at any time with little advance notice.

AIL found that delivery schedules for industrial- and consumer-grade parts were much shorter. Delivery of industrial-grade parts took four months or less. If consumer-grade parts were kept in stock, delivery schedules were even shorter. However, delivery schedules could be as high as six months if the parts were not in stock. On the negative side, commercial vendors usually required minimum buys and would either not sell at all or would charge much higher prices for smaller quantities.

Figure 5.1 gives two examples of the differences in schedule and cost for Mil-Spec and commercial-grade parts. The left side of the figure compares prices for a Mil-Spec and an industrial-grade Pulse Compression Network, a custom-designed RF part. Two part versions are shown, the Dash-1 and Dash-2. The industrial-grade and Mil-Spec versions of the part are identical in performance but not in recommended temperature range, resistance to humidity and vibration, and so forth. The industrial-grade parts are about 40 percent cheaper than the Mil-Spec parts. Furthermore, the industrial-grade parts take one-third less time for delivery. Figure 5.1 also compares the price of a custom-designed Mil-Spec power-supply component with a consumer-grade component with the exact same design and

[1]See Chapter Four for a more detailed discussion of this program.

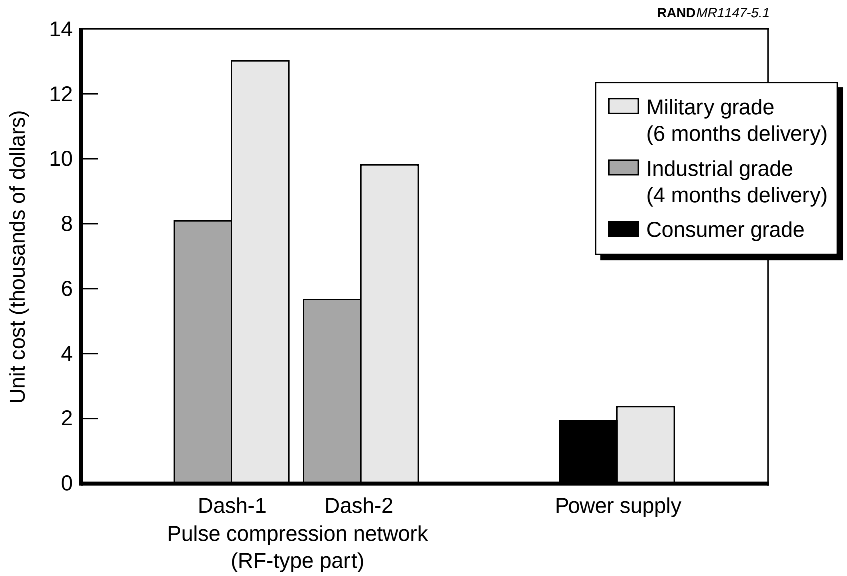

Figure 5.1—Schedule and Cost for Mil-Spec and Commercial-Grade Parts (Pulse Compression Network)

performance characteristics. The consumer-grade component costs about 20 percent less.

For many years, numerous Mil-Spec electronics parts have been manufactured on dual-use commercial lines and are in fact identical to commercial parts. However, these parts may have enormous price differences because of the extra screening and testing required of each Mil-Spec part. In the commercial world, manufacturing processes or specific vendors—but not each and every part they produce—are often qualified by the system integrator.[2] In contrast,

[2]Sometimes a commercial parts vendor is required by a buyer to qualify each part through a specific process. In the commercial world, the integrator usually works with the parts vendor prior to mass production and takes part in the testing of prototype parts. Further, many parts purchasing agreements in the commercial arena include provision for financial rewards and punishments with respect to timeliness of delivery, parts quality, and so forth.

each Mil-Spec part is subjected to rigorous testing, which greatly increases its cost.

Figure 5.2 shows the basic 10-part lot cost for two parts investigated by AIL for their Modular Radar program, plus the cost of screening. Engineers looked at two RF mixers: one Mil-Spec and one consumer grade. The basic 10-part lot cost for both is $410. However, for the Mil-Spec version, the vendor adds a lot charge plus $15,000 for screening the parts. Whereas the commercial RF mixer was in stock and immediately available, the Mil-Spec version required a minimum of four months for delivery.

AIL also investigated using two Mil-Spec digital integrated circuits (ICs) (750-1, 751-1) in their modular radars (see Figure 5.2). The vendor had discontinued manufacture of the Mil-Spec parts, but the nearly identical consumer-grade ICs were available for $10–$20 each. To deliver the Mil-Spec part, the vendor asked for $121 for the die per

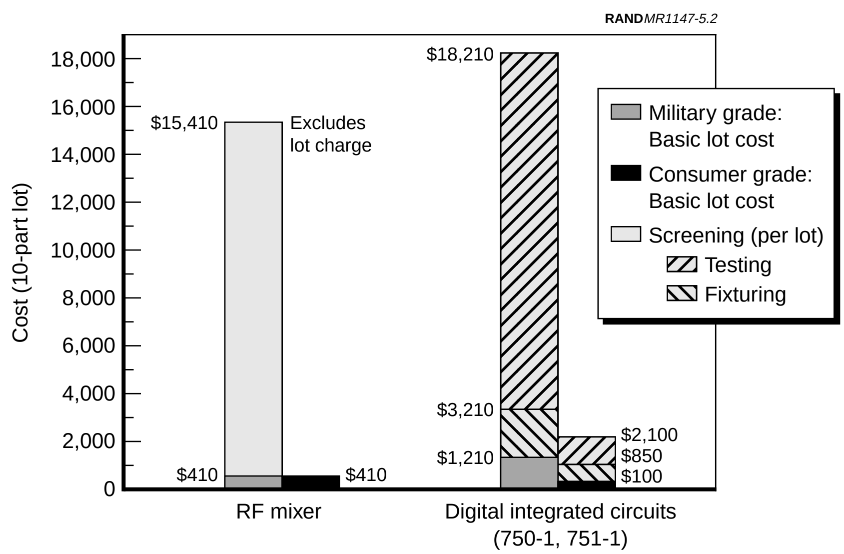

Figure 5.2—Large Cost Premiums Are Paid for Mil-Spec Parts Screening

IC, plus $2000 for fixturing[3] and $17,000 for hermetically repackaging and testing the IC. AIL decided to buy the consumer-grade parts, which are encapsulated in plastic, and conduct its own limited temperature tests. This testing cost $750 for fixturing and $1250 for lot testing. By adopting this approach, AIL was able to purchase a small lot of 10 parts for less than one eighth the cost of a 10-part Mil-Spec lot. The consumer-grade ICs were then inserted into the prototype radar modules, which are themselves being further tested for durability in harsh environments.

The U.S. Air Force/Wright Laboratory IBP program discussed in Chapter Four for developing and manufacturing lower-cost modules for fighter and helicopter CNI systems also demonstrates the cost savings that can occur through the insertion of commercial-grade parts and the manufacture of military avionics components on higher-volume automated dual-use production lines. After the maximum insertion of commercial parts, the two CNI modules are estimated to cost only about 60 percent of the original F-22/RAH-66 baseline cost projection. It is likely that the projected cost would be even lower if the modules had been designed from inception for the insertion of non–Mil-Spec parts. It will be recalled that the program did not permit basic electrical redesign of the modules. In part because of this restriction, 10 percent of the parts remained Mil-Spec. These 10 percent, however, accounted for 50 percent of the module cost.[4]

In sum, limited evidence from case studies indicates that use of commercial parts, when feasible, results in dramatic cost savings. Most commercial parts would have to be screened and possibly

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[3]Fixturing includes the costs of setting up rigs and making other special hardware required for custom testing.

[4]A breakout of costs by the General Accounting Office (GAO) suggests that the bulk of the estimated savings result from the insertion of commercial parts and the manufacture of the modules on a standard (low-volume) commercial production line. According to the GAO, about 40 percent of the cost savings arise from reduced labor costs resulting from automated commercial manufacturing facilities. Twenty percent of the savings is attributed to less-expensive materials, and about one quarter to the elimination of military specifications and standards that called for special testing, screening, and other material compliance measures. The remaining 20 percent of savings is attributed to reduced administrative burden attributable to the relaxation of standard defense acquisition oversight measures. See GAO (June 1996, pp. 4–5).

ruggedized or repackaged prior to use in military systems, but it appears that even with these caveats commercial parts may often be less expensive than Mil-Spec parts.

INSERTION OF COMMERCIALLY DERIVED DESIGN APPROACHES, TECHNOLOGIES, AND PROCESSES

Part of the cost savings projected for CNI modules from the U.S. Air Force/Wright Laboratory IBP pilot program arise from the application of commercial manufacturing processes to the production of the modules. Several of our case studies indicate that insertion of commercial technologies and processes in other areas could lead to significant cost savings in military-specific RF/microwave avionics.

For several years Wright Laboratory has sponsored various radar technology demonstration and pilot programs that encourage the incorporation of commercial technologies and techniques directly into military aircraft radars. Two such programs are the Advanced Low Cost Aperture Radar Program (ALCAR) and the Radar System Aperture Technology Program (RSAT).

One purpose of these two programs is to promote the development of much lower-cost technologies for phased-array fire-control radars. The participating contractors have examined a wide variety of strategies to reduce costs while maintaining system performance. These strategies include assessment of different technical approaches based on commercially developed technologies. A complementary program, the Multifunction Integrated Radio Frequency System (MIRFS) program, sponsored by the Joint Strike Fighter Program Office (PO), is looking at similar questions for development of the next-generation U.S. Air Force fire-control radar.[5]

As mentioned in Chapter One, a key cost driver in new-generation fire-control radars is the high cost of T/R modules for electronically scanned antenna arrays. Pilot programs are examining different techniques and design approaches to solving this problem. On the RSAT program, Raytheon has developed a completely new low-cost antenna architecture and technology that was originally developed

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[5]Both Raytheon and Northrop Grumman participate in all three of these programs.

for commercial applications. Raytheon calls its new approach the Continuous Transverse Stub (CTS) Electronically Scanned Array concept. Commercial uses under consideration for CTS technology include antennas for DBS TV. For airborne military radar applications, the CTS concept replaces a planar-array aluminum antenna with a much less expensive array manufactured from common extruded plastic. No expensive machining or milling is required. Using other innovative mounting and phase-shifting techniques, the CTS antenna can be combined with a relatively small number of T/R modules to produce a low-cost active array.

Another approach examined by Northrop Grumman for a low-cost ESA was to exploit rapidly evolving commercial technology developments in MPMs to develop a lower-cost MPM-based transmitter as an alternative to expensive solid-state transmitters or low-reliability traditional travelling wave tubes. These MPMs are used as building blocks for a modular design architecture for the antenna that is projected to result in a much lower-cost array. The basic technological approach adopted to achieve this effect has been widely applied throughout commercial industry. As shown in Figure 5.3, the resulting redesign of the antenna results in significantly fewer parts and components at much less cost.

Both of the new technology approaches discussed, however, lead to somewhat lower-performance radar antennas when compared to more-traditional arrays populated with large numbers of T/R modules. Several radar developers have been examining approaches to reducing the manufacturing costs of traditional T/R modules and related high-cost microwave components and assemblies. Many of these approaches include incorporation of technology or design approaches first developed in the commercial sector. As a result of such efforts, the costs of military T/R modules have declined dramatically since the beginning of the 1990s. Figure 5.4 shows a generic curve that describes the typical cost reductions that have been achieved by the leading producers of military T/R modules. These cost reductions are in the range of an order of magnitude.

Many factors are responsible for these enormous decreases in average unit cost, including increased automation in assembly, reduced MMIC costs, new technology insertion, and greater use of commer-

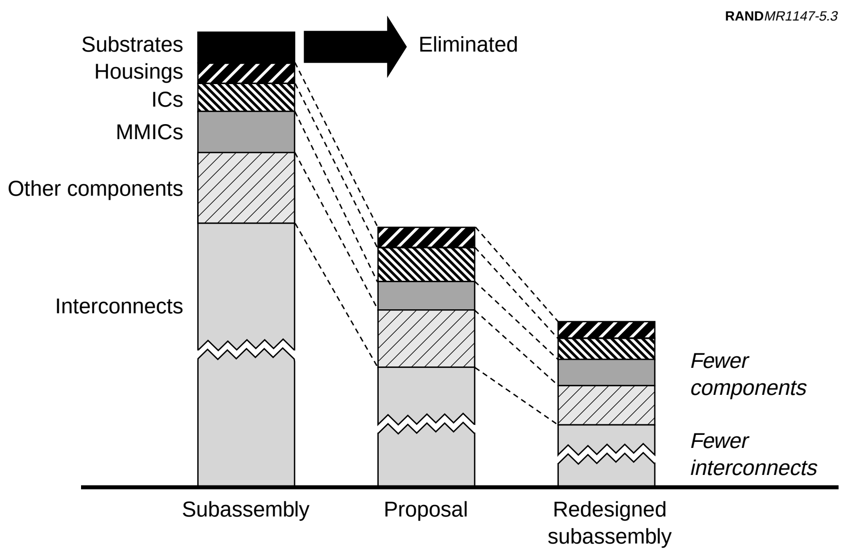

Figure 5.3—Nontraditional Technology Approaches and Commercial Spin-On Can Reduce Antenna Complexity and Costs

cial parts and technologies. For example, costs have been reduced through insertion of commercially developed parts into T/R modules such as low-noise amplifiers drawn from direct broadcast television systems. Closer adherence to commercial design rule practices have contributed to cost reductions. Insertion of new technologies developed for dual-use applications, such as aluminum nitrate substrates and silicon germanium wafer processing, have helped to bring costs down.

Two other examples are of particular interest in regard to T/R modules. In one case, a contractor's military division worked closely with an automotive commercial electronics division to improve manufacturability and yield. As a direct result of the interaction with the high-volume commercial electronics division, the military division redesigned its T/R module to reduce the number of wire bonds, decrease the number of chips on a single substrate, and separated the GaAs and Si chips onto separate substrates.

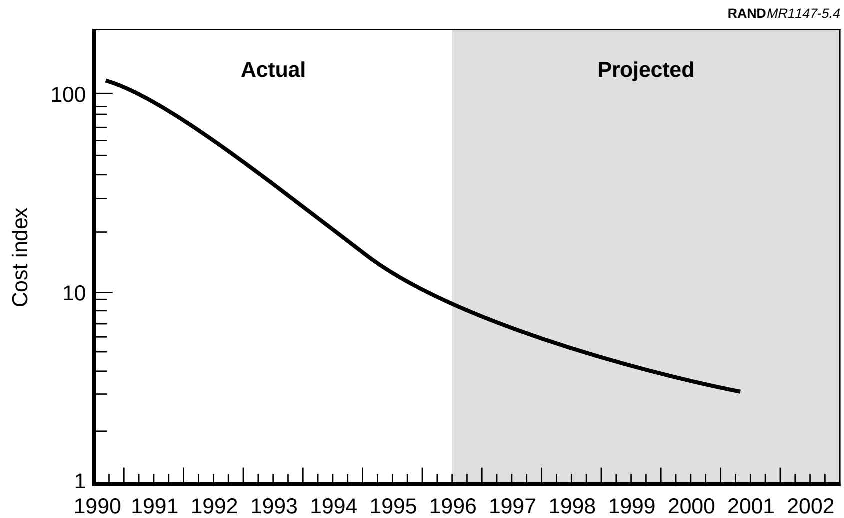

Figure 5.4—Typical T/R Module Cost History and Projection

In another instance, a defense division, after interacting with a commercial electronics division, decided to adopt "flip chip" technology for military high-power microwave applications. This technology is common in the consumer electronics world in various straight digital logic applications, but had never been used before in military microwave applications. The advantage of attempting to apply commercial flip chip technology to microwave applications was an increase in the thickness of the chip and elimination of wire bonding to permit manufacture on high-speed automated equipment and to increase yield and reliability.

The cases related here are just a few examples among many that we encountered. As a result of our analysis of the case study evidence, we conclude that:

- The systematic insertion of commercial parts, technologies, and manufacturing processes, combined with dual-use automated manufacturing, is likely to reduce the costs of typical military avionics modules by roughly 20 to 50 percent, and to shorten R&D schedules. Cost-saving potentials appear to be greater in digital avionics than in high-end RF/microwave applications, but this may change as commercial microwave applications become more widespread.

THE ROLE OF CRADLE-TO-GRAVE CONTRACTOR CONFIGURATION CONTROL

Our examination of the case studies has led us to conclude that contractor configuration control "from cradle to grave" may be necessary to realize the full potential benefits of CMI, for three reasons:

- During R&D, the contractor may need maximum flexibility to select the optimal mix of grades and types of commercial (and Mil-Spec) parts and technologies, as well as design approaches, to achieve the desired performance at minimum cost.
- Limited evidence suggests that a substantial percentage of the projected cost savings from insertion of commercial parts and technologies flows from a strategy of continuous technology insertion over the lifetime of the system. Contractors granted long-term support contracts at a prenegotiated fixed price and configuration control may have strong financial incentives to reduce costs through continuous insertion of more-capable, lower-cost technologies available from the commercial sector.
- The problem of diminishing manufacturing sources for Mil-Spec parts, combined with greater use of commercial-grade parts, means that military electronics will be increasingly affected by the short life-cycles and rapid turnover of commercial electronics technology. Long-term support of military equipment may require a policy of continuous insertion, which may be most efficiently handled through granting configuration control and change authority to the contractor during and after system R&D.

The first point has been made in Chapter Four and elsewhere. The lack of complete and easily accessible characterization data for commercial-grade parts, the need to make thousands of cost-benefit-schedule tradeoff decisions down to the lowest parts level during the design process for each module, and the need to experiment and test mixes of different parts grades in new combinations throughout the design and development process, all suggest that the design engineers actually developing the module need to be granted maximum configuration control and change authority during R&D for the potential benefits of CMI to be realized. Performance and reliability requirements, and form, fit, and function (FFF) parameters need to be provided to the contractor. The efficient incorporation of commercial parts and technologies at minimum cost seems unlikely unless the contractor is granted significant configuration control and change authority at the module level, along with increased responsibility for outcomes.

The second point is illustrated by a major bid submitted in 1995 by a leading avionics contractor for modernizing key RF/microwave areas of existing U.S. Air Force fighter avionics suites with a new series of avionics modules. The contractors' total life-cycle cost estimate was about one-third the baseline estimate generated by the U.S. Air Force, as shown in Figure 5.5.[6] The contractors' lower estimates were based on the following assumptions:

- Maximum insertion of commercial designs, parts, and technology into the new avionics modules.
- Manufacture of the modules on a commercial electronics production line.
- Contractor configuration control and change authority for design and development of the modules.
- Contractor logistics support and depot maintenance for the life of the system.

The costs of installing the new avionics modules remained about the same for both the baseline Air Force estimate and the lower CMI estimate. However, as shown in Figure 5.6, the contractors' estimated cost of the modules themselves was less than 50 percent of the baseline estimate. The CMI estimate included O&S and EMD costs of about 15 percent less and 35 percent less, respectively, than the baseline estimates. The Air Force assessment of the contractors' bid concluded that it was largely reliable and credible.

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[6]The cost estimates included R&D, production and installation, and operations and support (O&S).

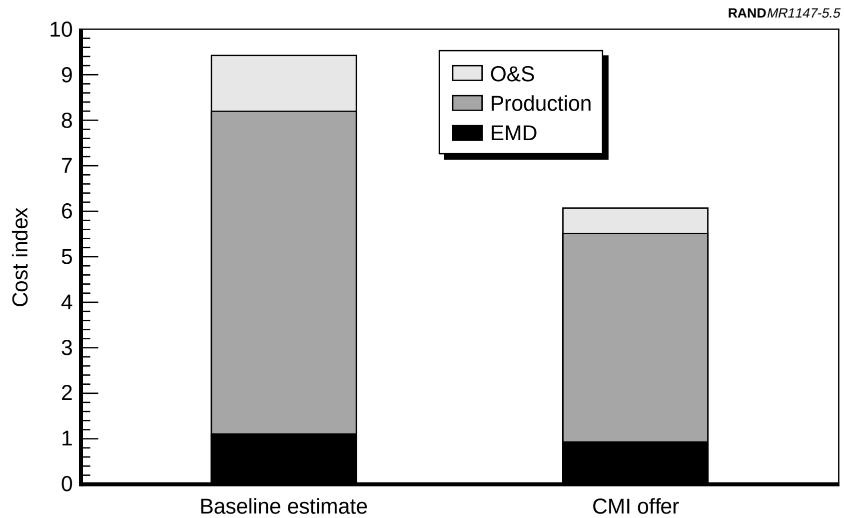

Figure 5.5—Baseline vs. CMI Life-Cycle Cost Estimates for Fighter Avionics Upgrade

The avionics contractor maintained that its lower-cost CMI bid was highly dependent on: (1) contractor support of the system throughout its life-cycle, and (2) full contractor configuration control and change authority. The much lower CMI bid was based in part on projections of trends in costs and capabilities in commercial integrated circuits and other electronics technology over the next decade. The contractor believed that winning full configuration control and change authority would permit continuous insertion of lower-cost, higher-capability parts into the modules. In this way, the cost per module could be reduced by 50 to 70 percent over 10 years. In addition, the number of modules necessary to perform the same function could be reduced drastically, thus further reducing costs or permitting greater capability at the same cost.

The motivation for the contractor would be a prenegotiated fixed-price support contract for a 10-year period. The contractor believed that it might only break even at best on many of the initial modules, but with new technologies constantly arising in the commercial sector, the contractor would have the motivation and the authority to

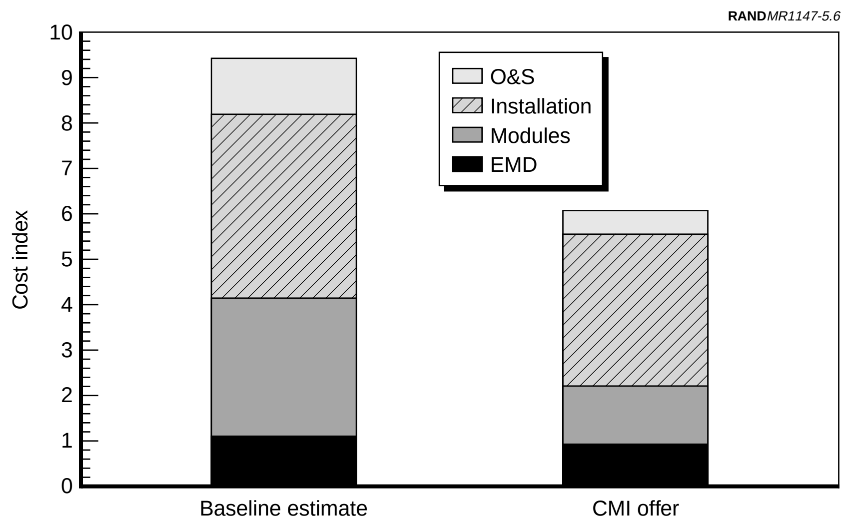

Figure 5.6—Baseline vs. CMI Life-Cycle Cost Estimates for Fighter Avionics Upgrade: Module and Installation Costs

insert higher-performance, lower-cost parts that would constantly reduce costs while the price remained fixed. The contractor estimated that all the important electronic parts within a module could be replaced three times during a 10-year support contract, because the average market life-span of a commercial electronics technology is about three years. This would provide the opportunity to greatly reduce costs and increase profit during the later phases of the support contract.

For these reasons, the contractor insisted that long-term logistics support plus configuration control and change authority were crucial for the credibility of its CMI bid. While elements within the Air Force found this CMI offer attractive, the high cost of module installation and the competing demands of other programs led to a temporary shelving of the project.

Although many remain skeptical about the CMI proposal discussed above, growing numbers of observers recognize that the problem of rapid obsolescence and increasing unavailability of Mil-Spec avionics parts is becoming severe, and might lead to the necessity of greater contractor configuration control and long-term contractor support contracts. The problem is caused by the phenomenon of DMS, Out of Production Parts (OPP), and rapid turnover and obsolescence of commercial technology. Many observers suggest that some form of continuous insertion, combined with contractor configuration control, will be necessary to maintain weapon systems over long periods of time, regardless of any DoD decision or strategy regarding CMI.

The phenomenon of DMS can be described as the rapid shrinking of the lower-tier vendor industrial base that historically provided low-volume, high-performance Mil-Spec and custom-designed parts for military applications. This shrinkage has been caused by the continuing decline in military demand, which itself has been brought about by a combination of reductions in military R&D and procurement budgets, the new emphasis on insertion of commercial-grade parts, and, most important, the vast increase in the relative size of the commercial electronics market compared with the military market.

A commonly repeated example of the latter phenomenon is the dramatic decline in military share of the IC market. As shown in Figure 5.7, the military share of the IC market declined from over 15 percent in 1975 to under 2 percent in 1995. By 1997, military demand accounted for less than 1 percent of global demand for ICs.[7] The military customer now has relatively little leverage in this market, particularly in very-low-volume, high-complexity, custom-designed ICs.

The end result of these phenomena is that, whether or not the services and contractors view CMI as a desirable strategy, the insertion of commercial-grade parts will increasingly be the only option available to military avionics developers. This would be viewed as a entirely positive development by advocates of CMI except for (at least) two problems that it causes: Increasing difficulties in supporting existing all–Mil-Spec "legacy" systems because of the OPP problem and

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[7]Still, at around $1 billion, the military market is not insignificant.

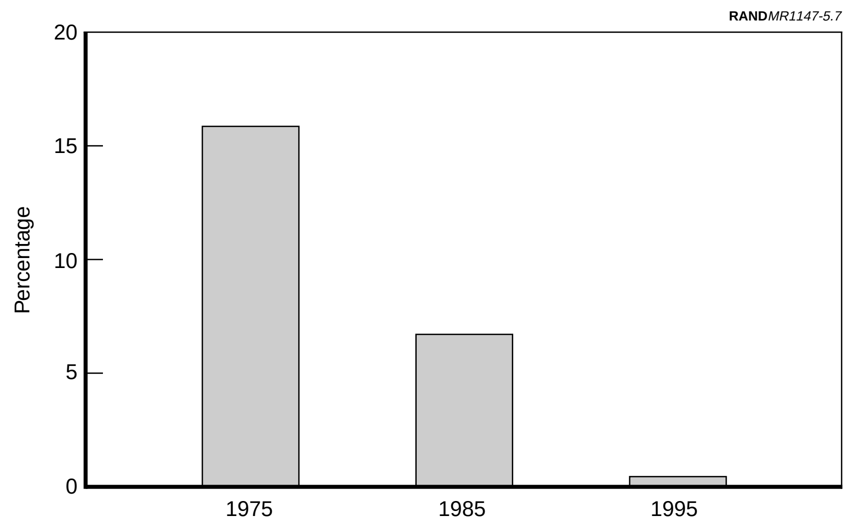

Figure 5.7—Declining Military IC Market Share

premature obsolescence and OPP for developers of new systems because of rapid commercial technology turnover.

The DMS phenomenon and the OPP problem for legacy systems are well illustrated by the ALQ-99 Obsolescence Study conducted for the U.S. Navy by AIL. Upgraded versions of the ALQ-99, an EW system originally developed in the 1960s, are deployed on U.S. Air Force EF-111As and U.S. Navy EA-6Bs. The study found that at least 175 parts out of about 1000 examined were no longer manufactured by any vendor. This finding in fact understated the severity of the problem because it did not include out-of-production parts that the Navy had stockpiled in large numbers prior to the termination of production. The study also found that at least 15 major manufacturers of key parts, mostly RF/microwave specialty components, no longer existed. Finally, the study encountered severe difficulties in finding appropriate commercial or alternative Mil-Spec parts that could be substituted for the out-of-production parts, mostly because of problems with fit (footprint). In short, inserting substitute commercial parts would often require major redesign and new R&D.

Perhaps more important for our research, studies conducted by the F-22 System Program Office (SPO) and other organizations show that the OPP problem is equally serious for new systems now under development, even if they are designed from the beginning to incorporate commercial-grade parts. Studies by the Semiconductor Industry Association (SIA) and others have determined that the average life-cycle of a commercial-grade IC or other complex electrical part is from two to five years (SIA, 1996). As late as the 1980s, life-cycles for parts averaged five to 12 years. Using the example of several generations of standard Intel microprocessor chips, Figure 5.8 illustrates the problems posed by insertion of commercial-grade parts with three-year life-cycles into the typical large system acquisition program that has an R&D schedule of 10 years and an inventory life of 30 years or more. As the figure shows, the chip that is commercially available at the completion of system R&D may be three or four generations beyond the original chip designed into the system years earlier, and may not be backward compatible.

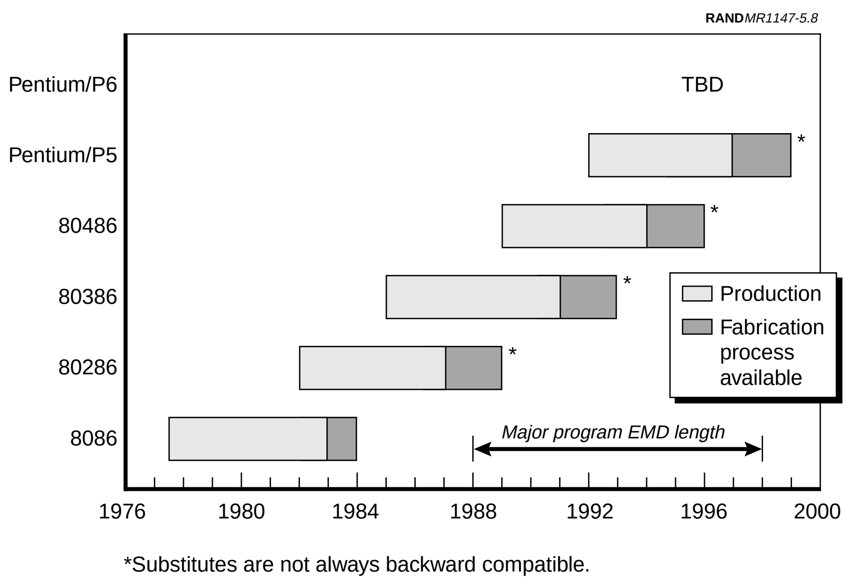

Figure 5.8—Out-of-Production Parts Problem: COTS Intel Example

This problem has been evident for some time on the F-22 fighter program, which is still in its EMD phase. Hundreds of parts have been identified that are already unavailable or will terminate production in the next five years. Scores of parts had become unavailable before the first flight of the first EMD prototype in September 1997. Many of these parts are not exotic Mil-Spec devices but rather commercial-grade off-the-shelf parts. In some cases, the parts become completely unavailable. In others, small after-market vendors buy the technical data packages and produce the parts in small custom batches, but at very high prices. The OPP problem means that avionics modules and components on the F-22 may have to be redesigned several times during and after production to incorporate new types of parts to keep the avionics systems operable.

In the view of some observers, even if commercial-grade off-the-shelf parts are inserted into avionics system to the maximum extent feasible, the problems posed by OPP confront the government with basically three stark choices:

- Buy and maintain large stockpiles of parts in quantities necessary to support the system throughout its entire life-cycle.
- Pay high enough prices to encourage an adequate number of specialty after-market vendors to continue manufacturing small quantities of a wide variety of obsolete parts.
- Grant configuration control and change authority to the integrator contractor, along with long-term fixed-price support contracts.

Many observers believe that the third option would be the most cost-effective. In principle, it would provide financial incentives to encourage continuous insertion of newer, less-costly, and more-capable technology into avionics systems, while at the same time resolving the OPP problem. Why then should the government not implement a similar policy of continuous insertion through its own depot infrastructure? There are no technical barriers to such an approach, but there are at least two reasons why it may not be cost-effective:

- First, the contractor's ability to provide the lowest-cost bid possible for the R&D phase may depend on the assumption of contractor logistics support with configuration control, because it is based on a calculation of potential dramatic cost reductions in parts and technology in future years. Some contractors claim that as much as 50 percent of the cost difference between CMI bids and normal bids is based on this projection.

- Second, although the government depot may have good intentions, it may not have adequate incentives to implement a policy of continuous technology insertion during the support phase of the life-cycle. A policy of continuous insertion implies the necessity for new R&D, which means new development costs and new technological risks. A private contractor has the financial incentives to take on such costs and risks because they can result in more-reliable, lower-cost modules. With a fixed-price support contract, this means higher profits. The government depot has no such incentives to motivate taking the risk of technological failure and increased R&D expenditures.

Whether such a program could be effectively structured in the real world with the appropriate incentives for the contractor is another question. Although careful assessment of this question is a central focus of our ongoing research, little light is shed on the issue in the case studies we have examined to date. But our case studies do suggest that the insertion of commercial-grade parts and technologies has a cost-savings potential of approximately 20 to 50 percent on the level of digital technology avionics modules. They also suggest that, because of the DMS problem, the use of commercial-grade parts will increase dramatically whether or not a comprehensive CMI strategy is already in place that, among other issues, deals with parts obsolescence, OPP, contractor configuration control, and contractor logistics support.