Dual-Use Supplier Management and Strategic International Sourcing in Aircraft Manufacturing

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Introduction

Supplier development and management systems of U.S. aircraft manufacturers have evolved rapidly during the 1990s in an environment of reduced military procurement and a worldwide slump in commercial aircraft sales. The result has been an ongoing restructuring within the aircraft industry supplier base, with significant implications for customer-supplier relationships and, potentially, national security. For example, with excess capacity and increasing cost pressures, many aircraft firms are dramatically reducing their numbers of suppliers.[2] At the same time, many of these suppliers are being asked to take on additional responsibilities in design, assembly, materiel management, risk sharing, and even in fostering the internationalization of their customers' supply base.

Prior research on such "lean" manufacturing principles and associated supplier management practices relied largely on study of the automobile industry (Womack, Jones and Roos, 1990, Womack and Jones, 1994, Helper, 1991, Nishiguchi, 1994). This case study of the anonymous Generic Aircraft Manufacturing Company (GAMC) is part of a larger ongoing effort, through the MIT Lean Aerospace Initiative, to extend the study of lean manufacturing practices to the aircraft industry and to evaluate their applicability.

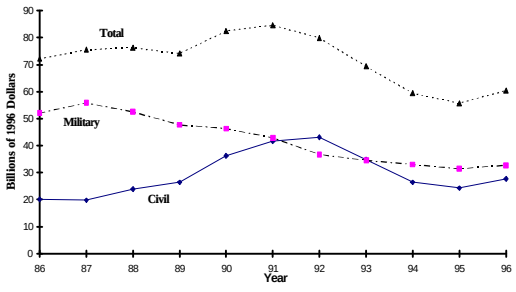
Indeed, GAMC is very actively engaged in implementing total quality management techniques and the entire lean/agile-manufacturing paradigm, as it understands these concepts and practices. For example, to name a few techniques GAMC has adopted, they have: implemented an intensive statistical process control program throughout the firm; developed and begun using a supplier rating and certification system; restructured the entire company into integrated, multi-functional product/process development teams; participated in early supplier involvement programs of their primary customers; involved their suppliers in similar efforts; entered into teaming and long term risk-revenue sharing partnerships with customers and suppliers.

The aircraft industry differs substantially from the automobile industry. Thus, a major research goal is to understand the implications of those differences. The choice of GAMC as a target for a first exploratory case analysis is not intended to identify or suggest "best practice" or "poor practice" in the aircraft industry. No stand-alone case can claim such insight. Rather, the case investigates the implications of three major differences between the auto and aircraft industries.

First, in automobiles the lean manufacturing system was pioneered by Toyota, and emulated by other Japanese manufacturers, during a post-war period of remarkable economic expansion. By comparison, as Figure 1 shows, the US aircraft industry in the 1990s saw a large-scale downturn. The Aerospace Industries Association (AIA) estimates that 1995 US aircraft sales were $54 billion, down 34 percent in real terms from their 1991 peak (AIA, 1995). US aircraft manufacturers have, for the most part, only within the last few years begun implementing techniques drawn from research and writing on lean manufacturing. Clearly techniques for dealing with suppliers could be very different between rapidly expanding and rapidly shrinking industries.

A second major difference is the commercial-military split in the US aircraft industry. As Figure 1 also shows, at the 1987 peak of the US defense build-up, nearly 74 percent of the aircraft industry's output was defense related. Defense production still accounted for more than half in 1996. One key area for research, then, is understanding how firms develop supplier networks across the two sides of the industry. In particular, how can firms maintain cost-competitive supplier networks for meeting the demands of both military and commercial customers, and what are the implications for supplier management strategies?

Figure 1. US Aircraft Sales, 1986-1996



Source: Aerospace Industries Association

A third major difference with the automobile industry is the sheer complexity of today's aircraft. A typical

modern automobile has about 10,000 parts (Womack, Jones and Roos, 1990). The new Boeing 777 has 4 million. As a result, the final aircraft assemblers like Boeing and Airbus rely on suppliers to build and integrate considerably complex assemblies (such as wings complete with hydraulics, fuel monitoring systems, flaps, and thousands of rivets). Major aircraft subassemblies arguably are as complex as entire automobiles. Supplier management in the aircraft industry therefore takes on additional importance in terms of cost competitiveness and the quality and performance of the final product.

Moreover, the first-tier aircraft industry suppliers like GAMC not only have to respond (looking upwards in the supply chain) to the supplier management efforts of their major customers, but also must (looking downwards) manage extensive supplier networks of their own. Womack, Jones and Roos (1990) compare the 340 production suppliers that the "lean" Japanese automobile manufacturers typically have to the 2500 used by General Motors. As indicated below, GAMC manages a supplier network of comparable size.

GAMC as Microcosm of the Industry

GAMC produces major aircraft structural sections for both commercial and defense-related customers. In 1994, GAMC was acquired by a new parent firm, itself created by a recent merger. As of early 1995, and before restructuring under new ownership, GAMC employed approximately 5000 people, and had annual revenues near $600 million. GAMC was made the home of the new parent company's commercial operations.

Both before and after the acquisition, GAMC has seen itself as a major subcontractor with a focus on integration of major structural assemblies, such as wings, tails and engine nacelles. GAMC's strategic vision has been that of moving more towards full responsibility for complex design and integration and gradually away from in-house detailed part fabrication.

The recent acquisition is but the latest episode in the long history of the company. Until the 1980s, GAMC for many decades had been a prime contractor producing complete military aircraft as well as major structural assemblies for commercial aircraft. After the Vietnam War, however, defense prime contract work fell, and the company moved into integrating large structural assemblies for the top-tier final assemblers in both the military and civil segments of the industry.

GAMC in many ways reflects the aircraft industry as a whole. It has been through several major restructuring efforts and changes in ownership over the past decade, in large part due to the continuing consolidation in the US aircraft industry as a whole. As Table 1 shows, changes since 1991 at GAMC mirror the downsizing and restructuring of the aircraft industry more broadly. GAMC's sales fell about 40 percent between 1991 and 1995, from more than $1 billion per year. Employment fell to about 5000 from 9700. Floor space, at one time more than 8 million square feet, also contracted by about 40 percent to 5 million square feet. Throughout this downsizing process GAMC also underwent significant restructuring, including several different owners. Like nearly every upper-tier firm in the industry, GAMC also significantly reduced its number of approved production suppliers, from more than 1400 in 1989 to 725 in 1995. And, like the industry as a whole, while GAMC retains a balance of commercial and military production, the commercial fraction increased. GAMC managers report that the mix shifted to about 60 percent non-defense work in 1995 from about 40 percent in 1991.

Table 1.
Major Reductions & Restructuring at GAMC, 1991-5

	1991	1995*
Sales ($millions)	1000	600 (est.)
Employment	9700	5000
Approved Suppliers	1400	725
Civil Percent of Sales	aprx. 40%	aprx. 60%
Owner	Diversified conglomerate not focused on aerospace	Top tier aerospace & defense company

* 1995 figures do not include restructuring w/ new parent firm

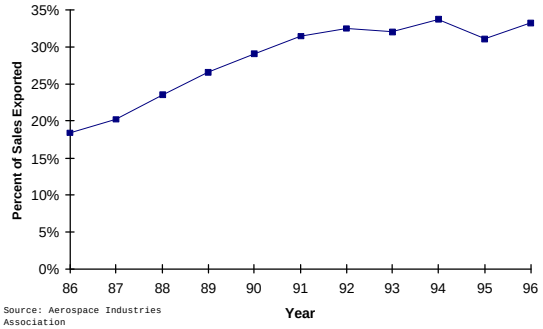
GAMC is also of interest for study as a first-tier supplier to the major aircraft final assemblers (the "airframers"). GAMC's strategy has been to place itself immediately below the major airframers in the supply chain, and to increase its own responsibility for integrating major structural aircraft assemblies and managing subcontractors for these top-tier firms. Thus, GAMC's pre-acquisition promotional materials described GAMC's market niche as a "support partner" and a "major subcontractor with prime capabilities: integrated concurrent engineering, sophisticated testing labs, and advanced manufacturing." GAMC thus provides an opportunity to examine the effects in the supply base of the supplier management practices of the top-tier aircraft companies.

In addition, as a supplier of complex integrated assemblies, GAMC itself must manage a network of more than 700 lower-tier suppliers of sub-assemblies, detail parts and raw materials. Given a supplier network comparable in magnitude to those of major auto suppliers, GAMC's supplier management practices are of interest not only as a significant challenge on their own, but also because of how they are shaped by GAMC's customers. Like its customers, GAMC is delegating increased responsibilities to its own suppliers for design, quality control, risk-sharing and supplier management. This reflects an apparent trend in the aircraft industry more generally, following the

lead of the Japanese automobile industry, towards turning historically loosely tiered and arms-length subcontracting relationships into more tightly tiered, more closely controlled structures.

At the same time, GAMC's supplier management organization has had to adapt over the last decade to the globalization of aircraft markets. As Figure 2 shows for the US aerospace industry, of which aircraft is by far the largest segment, exports have nearly doubled as a fraction of total sales over the past decade. GAMC's major customers, the major players in aircraft export markets, are seeking growth globally, and aggressively turning to GAMC for help.

Figure 2. US Aerospace Exports as a Percent of Total Sales, 1986-1996



In sum, both GAMC and the US aircraft industry are rapidly moving targets. Caution is clearly in order concerning interpretation of conclusions from this (or any other) single case. Nevertheless, GAMC does represent a reasonable microcosm of the aircraft industry as a whole. It therefore provides considerable insight into the implications of major differences with the automobile industry as well as into some of the major issues and tensions confronting supplier management in the US aircraft industry today.

In particular, the discussion below focuses mainly on three related issues: 1) GAMC's management of suppliers to both its military and commercial programs with a single dual-use integrated materiel and procurement system; 2) the impact on GAMC's supplier management practices of the globalization of its customers' markets and strategies; and 3) the tensions created by GAMC's implementation "lean" supplier management practices at the same time that the industry is restructuring and globalizing.

Dual-Use Integrated Supplier Management

How did these major restructuring efforts affect GAMC's supplier management and materiel operations? These operations were somewhat insulated from the organizational upheaval over the decade prior to the acquisition because throughout the period these functions remained integrated across the whole organization. Except for international strategic sourcing, the changes discussed below were related largely to the implementation of practices suggested by "lean" manufacturing principles.

Before the acquisition, a common functional group with a single procurement system supported all GAMC programs and divisions (whether commercial or military). Approximately 400 people at GAMC performed materiel functions, including subcontract management, supplier development and technical support, inventory control, purchasing, administration, procurement quality, receiving, warehousing, shipping and off-site personnel. Purchases from suppliers and subcontractors represented an estimated 35 percent of GAMC's cost of sales.

GAMC's main decision making tool concerning suppliers was its "Preferred Supplier Process." This supplier management system included: supplier assessment, certification and selection systems; technical assistance to suppliers to foster supplier statistical process control (SPC) and TQM capabilities; passing more responsibilities to sub-tiers for design, quality, risk sharing, and management of lower tiers; and longer term teaming where possible. These efforts were relatively new to the company, having been implemented beginning in the early 1990s.

The supplier assessment system included GAMC's "supplier rating system" (SRS) which collected data on supplier performance to quantity, schedule, and documentation. Essentially, SRS scored suppliers on how well they met the terms of purchase orders. The next level of GAMC's supplier assessment system, the "supplier performance improvement program" (SPIP), added a metric to track quality: the cost of defects discovered after receipt by GAMC.

The certification program, called the "Qualification System," applied these supplier assessments to determine which suppliers were approved for doing business with GAMC. When a supplier's performance score fell outside acceptable limits, the supplier was removed from the list of suppliers approved for bidding on new business. These suppliers submitted corrective action plans, and were given an opportunity to demonstrate improvement. If the supplier remained substandard, it lost its qualified status. All suppliers, whether for military or commercial programs, were measured and certified under the same set of criteria.

In monitoring and selecting suppliers, GAMC's system distinguished three types of suppliers. First, "Vendors" supplied catalog items, office and maintenance supplies. The SRS (performance to purchase order) applied to vendors. Companies typically have large numbers of this type of non-production (often called "indirect") supplier. Yet many, even those with supplier rating systems, do not track vendor performance.

Second, GAMC called "Suppliers" those firms with "build-to-print" capabilities, in other words those who do detail parts or assemblies and subcontract labor

based on complete design drawings (prints) provided by GAMC. Both SRS and SPIP applied to "Suppliers." Third, "Subcontractors" had "build-to-spec." capabilities, did major structural assemblies and/or had proprietary products or processes. They could be integrated with GAMC's design teams and share risks for major aircraft sections. When selecting "Subcontractors," GAMC managers used SRS and SPIP for guidance, but also considered broader strategic partnering or marketing goals and the supplier's capability for greater responsibilities in design, risk-sharing and lower-tier supplier management. Examples of suppliers selected with these broader strategic goals in mind are discussed below. Special cross-functional selection teams, called "Buy-To-Build Package Teams," with members from various functional areas, were formed for decisions on subcontractors for fracture critical parts, complex machined parts, assemblies, parts with high reject histories, major sources of costs, and hot/superplastic- or spin-formed parts.

Indeed, such cross-functional teams remain the organizational norm at GAMC, making GAMC a truly dual-use company. Integrated, centralized functional groups such as engineering, machining and fabrication, quality assurance, and so on, serve all programs, both military and commercial, with the same people and procedures. The company operates under an "integrated product/process development" (IPPD) philosophy with what GAMC human resource managers call a "strong matrix" organizational structure. In addition to reporting to a functional group, one axis of the matrix, people also report to (and are co-located with) multi-functional product or process teams, the other axis, that have full responsibility for integrating and managing all aspects and the whole life-cycle of each program, from development through delivery and post-production support.

Functional groups such as materials, business operations, and human resources assign members to "integrated product teams." However, members also retain ties to the functional department, importantly, because responsibility for managing and improving functional processes (e.g. deep-pocket machining, materials tracking) falls to "process management teams" within the functional departments. GAMC managers expect this matrix approach to maintain communication and sharing of expertise among functional professionals at the same time as fostering inter-functional problem solving within the product teams. Accountability is shared among team members, and budgets, schedules and decision making are allocated to teams, not departments. This integrated team organizational structure as of 1995 is shown in Figure 3, and an example team is shown in Figure 4. On the charts, "IPT" stands for "integrated product team" and "PMT" for "process management team."

Consistent with the IPPD philosophy, GAMC's supplier management approach is to deal the same way and with the same procurement system with suppliers to both its commercial and military programs. But the integrated approach to suppliers is also driven by the dual-use nature of GAMC's supplier base. More than 80 percent of GAMC's suppliers serve both civil and military programs. For example, aluminum alloys from one raw material supplier are milled for commercial and military programs alike in GAMC's central fabrication operations by huge robotic machining stations from another single supplier. A small California supplier does heat treat processing in the same facility for GAMC's military and commercial programs alike. Other single facility suppliers provide film adhesives, glass and other "pre-preg" fabrics, graphite composites, and primers for use on several different programs on both sides of the business. There is not 100 percent supplier overlap between military and commercial

Figure 3. GAMC IPPD Organization

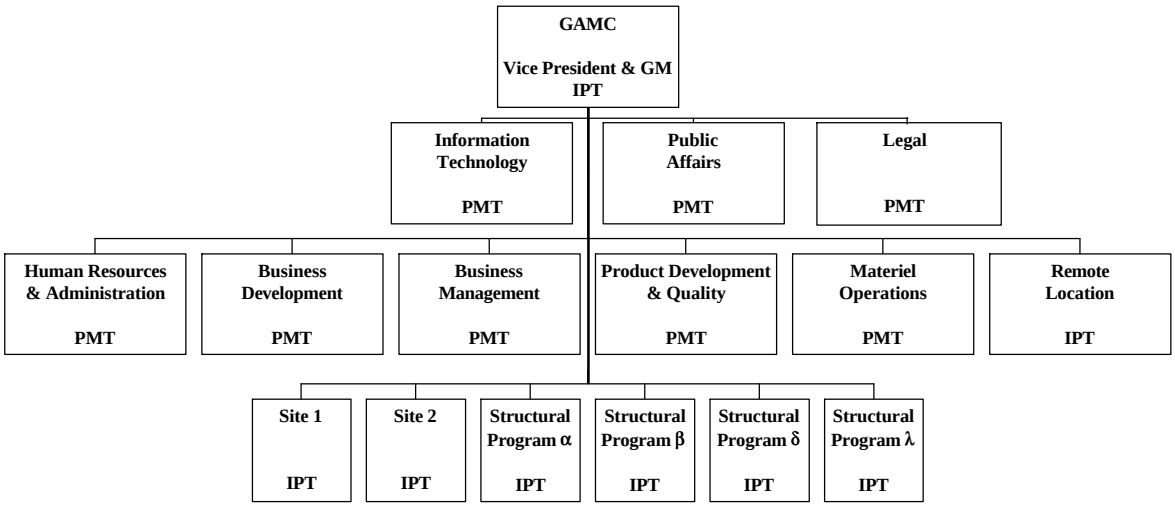
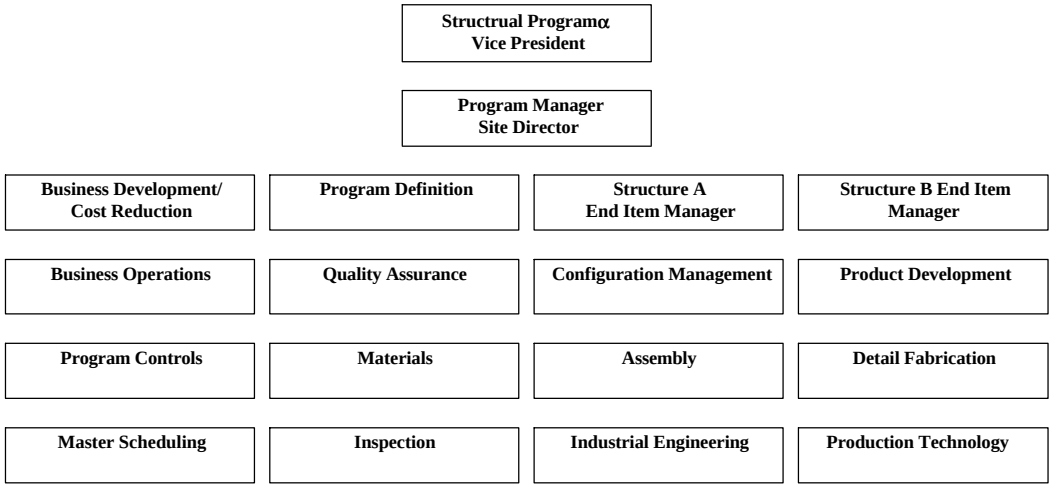


Figure 4. GAMC Structrual Program Integrated Product Team (IPT)



programs in part because occasionally program (or customer) specific requirements arise, either on the commercial or defense side, and in part because many of GAMC's suppliers must be approved by GAMC's customers, who historically have not had identical approved supplier lists.

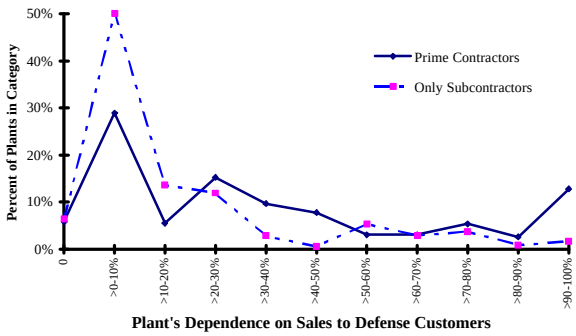
One question that arises is whether the substantially dual-use nature of GAMC's supplier base might somehow be uniquely encouraged by the IPPD philosophy. Two research findings, however, suggest otherwise. First, there is, to a very considerable extent, overlap and integration between the broader US manufacturing base serving military programs and that serving commercial markets. In a survey-based statistical study of manufacturing plants in 21 different durable goods industries (including but not only aircraft) that account for half of all durable goods purchased for defense, Kelley and Watkins (1995) found that in 1990 the vast majority of defense contractors and subcontractors served both defense and commercial customers. Indeed, as Figure 5 shows, most plants doing defense work in the industries studied, both prime contractors and subcontractors, actually do more commercial work than defense work. It is, then, not surprising that GAMC's suppliers reflect the dual-use nature of the broader supplier base.

A second indication that an integrated, dual-use approach to supplier management is not unique to the IPPD philosophy is that GAMC also used the integrated approach previously under two otherwise very different organizational structures. First, during the peak of the defense buildup in the 1980s, GAMC had separate divisions for military aircraft, for commercial aircraft, and (much smaller) for aircraft modernization and support (Figure 6).

Under this divisional structure, according to managers with the company at the time, GAMC operated basically segregated military and commercial businesses, from engineering and accounting through marketing and manufacturing. For example, the military division had a manufacturing engineering group and the commercial division had its own manufacturing engineering group. Even the small aircraft modernization and support division had a manufacturing engineering group. One production manager described it as "a dividing line between the two where we could not interface . . . It was like two totally different companies." Nevertheless, materiel functions were centralized. The same people, using a single system of procedures, served the whole, including both the military and the commercial divisions.

Then, second, at the end of the decade, GAMC reorganized from substantially separate defense and military divisions, to substantially integrated functional groups serving individual assembly programs. A major motive was the downturn in business due to the double slide of end of the Cold War and rapid decline of commercial sales as foreign competition increased and

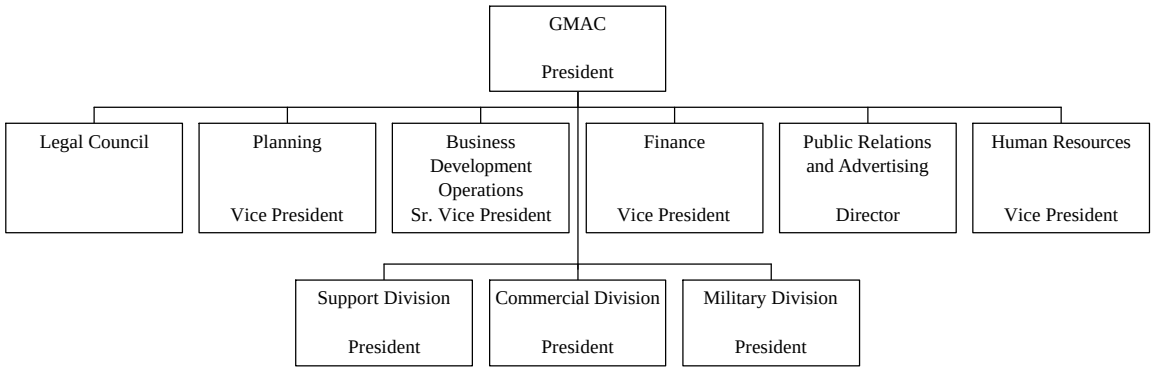
Figure 5. Defense Contractors' Dependency on Defense-Related Sales in 1990



Source: Kelley and Watkins, 1995

airlines, struggling with cash flow problems or bankruptcy, cut back on orders for new aircraft. As business on both sides shrank, redundancies and over-capacity in functional areas duplicated across the two

Figure 6. GMAC Organization Structure, Mid-1980s



sides became more problematic. The organization after this (what GAMC managers refer to as) "de-divisionalization" is shown in Figure 7.

The company moved to what might be called a "weak" matrix organization. One axis of the matrix structure was divided by structural program for program management. The other axis was divided by function: including design, manufacturing engineering, logistics, central detail fabrication, and quality assurance. The centralized functional groups supported both military and commercial products. A single vice president oversaw all assembly operations, both commercial and military. The matrix was "weak" in the sense that the reporting, promotion and reward structure relied primarily on one axis, these functional homes.

Again, supplier management, procurement and materiel functions were common across all programs. But now this was more in line with the rest of the organizational structure. Indeed, there was near unanimous agreement across interviews with people who were performing supplier management, procurement and materiel functions at the time that the "de-divisionalization" had little or no impact on how they operated. This despite the rest of the organization going from substantially separate military and commercial operations, to integrated, dual-use functional organizations. To the materiel people, the transition was transparent because they had already been operating a system common to both sides of the business.

Then, by early 1995, the company had integrated further with the IPPD structure. One manufacturing manager put it this way:

> "Now we're trying to break down the traditional barriers between manufacturing and engineering where you had a VP of manufacturing, a VP of engineering and a VP of materials. We've gone to where we just have one VP of operations, and he has design engineers, manufacturing, everything."

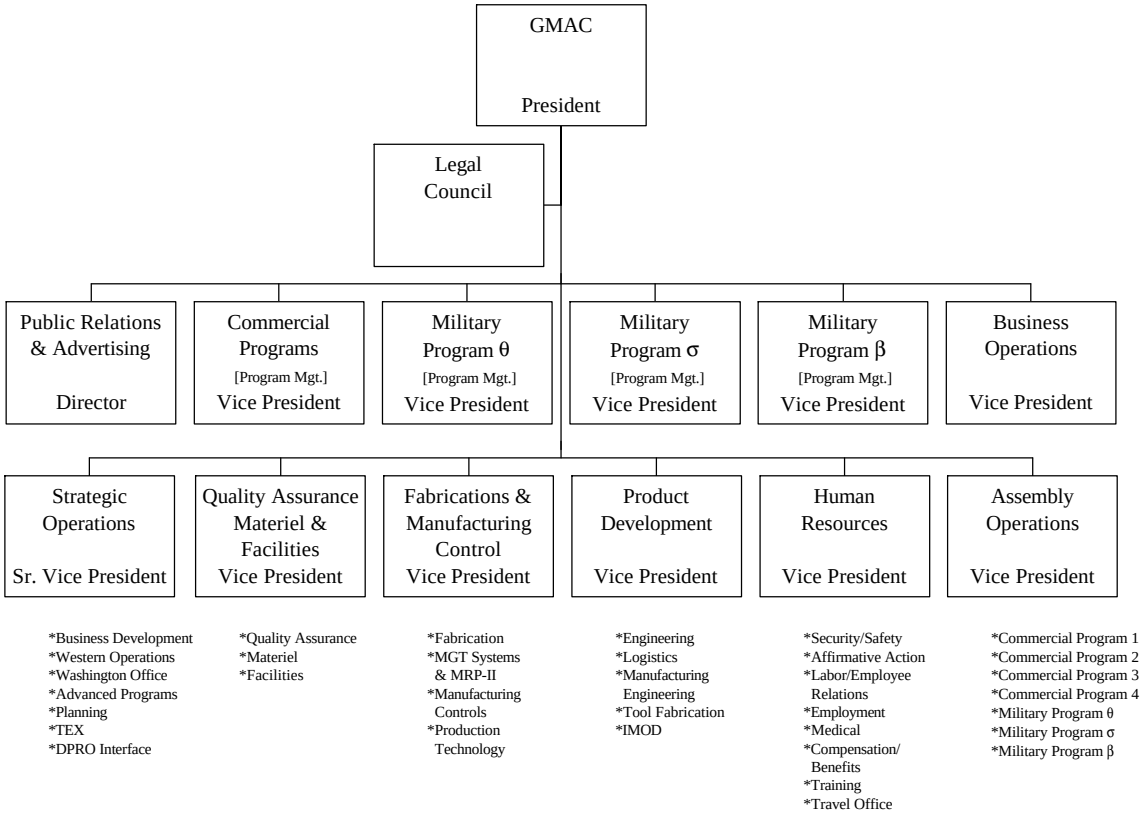
Rather than being a difficult transition for the supplier management, materiel and procurement operations, the move actually made their integrated, dual-use approach fit more neatly with the strategic philosophy of the whole organization. As a management tool, integrated product and process development teaming is inherently dual-use in a company with large shares of its business in both commercial and military markets. The main point is to improve communication and learning along both axes in the matrix organization: across different programs, whether military or commercial, and among different functional areas. The functional homes within the company take on the role of establishing procedures and best practice guidelines common to all programs, as well as helping the functional professionals learn from one another, regardless of the program to which they are assigned. The multi-functional product teams aim to encourage experts across disciplines to learn from and help one another.

GAMC's dual-use approach to suppliers has, indeed, fostered cross-program learning. By using a single set of suppliers for both military and commercial programs, learning and supplier development on one side of the business can more readily be applied to the other.

For example, GAMC worked closely with the dual-use suppliers mentioned above, their aluminum supplier and the small California-based heat treatment process supplier, to reduce distortions in heat-treated aluminum parts. The original efforts were to improve part quality and consistency on one of GAMC's military products. As one engineer put it:

> "We'd get a lot of material warpage. Particularly when you got a forging they've done a lot of pounding on. Our machinists here would machine them and they'd warp and bend in the machining process. We've worked with [the aluminum supplier] a lot, and they deliver [the aluminum] in an annealed condition. We worked with another vendor … out in California that does a real good

Figure 7. GMAC Organization Structure, 1990



> heat-treat job for us. It's called a high glycol quench that really controls the distortion. They'll heat treat it to the T-73, and then we'll bring it back here and do the final machining on it"

The aluminum alloy (7050) for which this process was developed was different from the alloy (7175) GAMC used in some commercial work, where distortion induced by the heat treating process was also problematic. Because of their success with controlling the quality of parts using the new process on the military program, GAMC then worked with its commercial customer to apply the lessons to GAMC's commercial programs:

> "We actually asked [our customer] to change the material on that. We went from a 7175 to a 7050, which is a big deal because you have different properties. So we were able to integrate that, do a lot of working with our customer and supplier. There were meetings where we had the whole chain involved, our materials people, the suppliers and [the customer's] people would be sitting in the same room, or conference calls, or phone calls. Because our suppliers have to be certified [by the customer] too, we had to make sure that [the heat-treat supplier] had that relationship with [the customer]. We just can't send our fracture critical forgings out to anybody."

Pros & Cons of Integrated Supplier Management

Based on GAMC's experience, then, there appear to be several advantages of dual-use integrated approach to supplier management, as summarized in Table 2. The first is flexibility with respect to organizational form. The integrated approach was flexible enough to have been used without much change in three very different organizational structures. Supplier management, materiel and procurement operations were integrated across the company, even when the rest of the organization was not. Second, the dual-use approach is strategically compatible with the integrated product and process development philosophy espoused by theories and research on "lean" enterprises (e.g. Womack and Jones, 1994). It is also compatible with recent movement by the Pentagon to embrace "commercial practice" in defense procurement. Third, it facilitates cross-program learning and the sharing of ideas and information between military and commercial programs. Customers and suppliers on both sides of the business benefit, as the heat treat example demonstrates. This is exactly what the IPPD matrix teaming approach attempts to encourage, by integrating functional areas across programs.

Table 2.
Advantages of Integrated Supplier Systems

1) Flexible to organizational form:
- At GAMC used under 3 very different organizational structures.
- Can integrate supplier systems without integrating whole company.

2) Strategic fit:
- Integrated Product/Process Development (IPPD) philosophy.
- "Commercial Practice" in Defense Procurement.

3) Cross-program learning with suppliers and customers.

4) No duplication of:
- Suppliers ("work with the best").
- Materiel/procurement systems or positions.
- Quality systems.

5) Structure and control imposed by MilQ approved system:
- "Good practice" for commercial programs, both in-house and externally.
- Financial information helpful in value engineering and target pricing.
- Movement in "cooperative supplier relations" to more information exchange.

Fourth, a single materiel system for both military and commercial programs allows a single set of suppliers to serve both sides. This eliminates the need for duplication of suppliers, and is consistent with the general trend in many industries to reduce the overall number of suppliers a company must manage. It also means no duplication of materiel procedures, systems or positions within the company. Finally, it allows GAMC to maintain only one internal quality system and a single supplier quality system. Commercial and defense suppliers are not treated differently, and indeed are the same in the vast majority of cases. Thus, GAMC's supplier development efforts, GAMC's supplier quality monitoring system, GAMC buyers, and so on can serve to improve both sides of the business.

The fifth advantage expressed by GAMC managers is related to the requirements of military contracting. GAMC's procurement system must remain approved under the so-called "MilQ" regulations, which specify the kinds of information GAMC must collect and make available to the government. There was general consensus with the prevailing conventional wisdom that these regulations go too far in, as one materiel manager put it, "crossing and dotting all the i's and t's." Yet it also had some advantages mangers liked for their commercial programs as well. Primarily, some managers thought the structure and control imposed by the regulations forced both GAMC and its suppliers to maintain, if not best practice, at least good managerial practice in terms of accounting and other information systems, tracking materials, negotiating and communicating with suppliers, and so forth.

For example, sharing sensitive financial information is a relatively new but increasing practice among US companies adopting principles of cooperative supplier relations and joint problem solving (Helper, 1991, Lyons, Krachenberg and Henke, 1990).[3] Yet, suppliers providing detailed cost information has been standard practice for many years under military contracting regulations. GAMC managers report they have found this a valuable information source, particularly in practices suggested by "lean" theories, such as long term contracting, target pricing, value engineering and value analysis, as well as in identifying opportunities for working with suppliers to reduce cost.

Yet, GAMC's movement towards these same "lean" practices has also increased some of the tensions of trying to maintain a supplier management and materiel system integrated across defense and commercial sides of the business. A particular disadvantage of the dual-use approach has been its inflexibility with respect to "life-of-product partnering." In GAMC's newest commercial program, the company entered into a revenue sharing agreement with a top-tier commercial aircraft final assembler to design and make a major critical structural assembly for its new aircraft (call it the "COM-Z"). Indeed, as discussed in more detail below, this commercial customer has revenue sharing partners worldwide. The willingness of suppliers to take on more risk was one of the customer's major supplier selection criteria.

By undertaking design and capital investment responsibilities for this major critical structure, GAMC takes considerably more business risk than under traditional subcontracting if the COM-Z is a commercial failure. In return, GAMC has contractual guarantees to get orders from the customer for the commercial life of the product, and stands to garner more return per unit, should it be a success. GAMC has also, in turn, a life-of-product revenue sharing agreement with one of its Japanese COM-Z strategic source subcontractors, discussed below.

Such long term contractual relations are increasingly common in the US both within and outside the aircraft industry, and have been the norm in Japan for several decades (Helper, 1991, McMillian, 1990, Nishiguchi, 1994). By increasing the buying firm's commitment to the supplier, life-of-product contracts encourage suppliers to take on the increased up-front risks of investing in design, development, and equipment. The revenue sharing is in part designed to align the supplier's incentives for quality and cost control with the buying firm's. However, these type of agreements do constrain the buying firm from sending work out for new competitive bids later.

Herein lies a major tension within a single procurement system across both military and commercial business. Defense procurement requirements call for periodic "re-competing" on subcontracts. It is, therefore, problematic on the military side of the business to make guarantees for purchases from a subcontractor for the entire life cycle of programs. GAMC's procurement system is approved and regularly reviewed under these regulations, and re-competing has been the normal practice. However, there is a clear empirical trend from commercial customers towards more "partnering" and long term contracting. The single system is strained as GAMC moves to increase its partnering with its own suppliers on commercial programs.

There is a formal mechanism in place allowing GAMC's top materiel managers to deviate from their standard (and MilQ approved) procurement practices when they believe commercial programs have special needs. Though commercial programs now make up more than half of their business, such deviations have occurred in less than 1 percent of buying actions. However, the new COM-Z program is only just coming into production: the first major critical structures were recently delivered. The need for deviations may increase substantially should "partnering" becoming the commercial norm. Maintaining a single procurement system throughout the business may thereby become problematic.

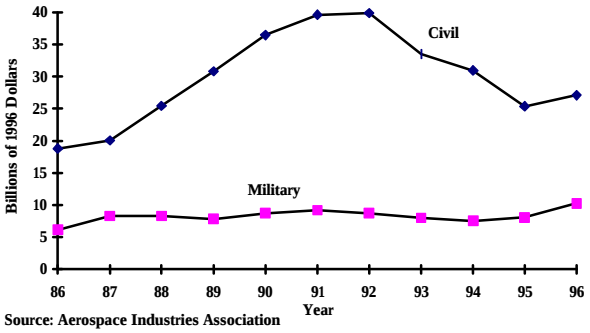
While the outcome of ongoing procurement reform is as yet uncertain, this increasing tension may be reduced. The Pentagon and Congress are signaling significant change in procurement regulations. Countless Congressional hearings have addressed the broad issues, and a number of large scale experiments are underway (e.g. F-22 program) allowing for, among other things, long term partnering and "best value" rather than best price selection of subcontractors. Whether this will become the regulatory standard, however, remains to be seen.

International Strategic Sourcing

A second area of tension between commercial and defense programs in GAMC's supplier management has to do with the globalization of aircraft markets and the aerospace industry supply base. Indeed, the single major difference between GAMC's supplier management approach on the two sides of the business is in what GAMC calls international "Strategic Sourcing," efforts to increase its use of foreign suppliers. The purpose is to help GAMC's customers increase their competitive position in foreign markets. This program is entirely geared to support GAMC's commercial programs. It has no counterpart for military programs.

Several factors contributed to GAMC's seeking to increase its use of foreign suppliers. First, growth markets for aircraft sales have largely been overseas. Figure 1 above showed that even though U.S. defense aircraft sales began falling after 1987, industry sales as a whole continued to rise until their 1991 peak. As Figure 8 indicates, however, this growth came nearly exclusively in overseas markets. More specifically, the growth was in civil exports. Military aerospace exports are small compared to civil exports and have been flat in real terms since 1987. GAMC's international strategic sourcing efforts grew directly from the push into these overseas growth markets by its commercial customers.

Figure 8. US Aerospace Exports, 1986-1996



Source: Aerospace Industries Association

Second, foreign markets are particularly important to GAMC's major commercial customers. Prior to the consolidation with its new owner, GAMC's single most important customer accounted for the vast majority of their commercial business. In the five years through the end of 1996, more than 70 percent of that customer's commercial sales were outside the U.S. Significantly for GAMC, this foreign fraction of orders was above 80 percent for its single largest commercial program. This is much higher than the already high industry average. As Table 3 shows, according to the Aerospace Industries Association, as of the end of 1996 almost 63 percent of the U.S. civil transport aircraft industry's unfilled order backlog was from foreign customers.

Table 3. US Civil Transport Aircraft Backlog

As of 9/30/96	Total Backlog	GMAC's single largest program
Number of Aircraft	1447	X
Of Which Foreign	741	more than .8X
Foreign as Percent of Total Value	62.6%	n/a

Source: Aerospace Industries Association.

Foreign sales will also be critical to commercial success on GAMC's newest program, the COM-Z. The customer designed the COM-Z as a trans-Pacific aircraft. Pacific Rim countries are obviously the key market.

Third, local content is a major factor in purchasing decisions by GAMC's customers' customers, particularly foreign government-run airlines. Thus, GAMC's customers' foreign marketing efforts entail, in part, using suppliers in key foreign markets. The pressure on GAMC for international sourcing, sometimes called "offsets," has come entirely from the commercial side of the business.

All the top-tier airframers are aggressively pushing foreign sourcing as a marketing tool. For example, an advertisement Boeing ran in a major international news magazine, The Economist, in early 1995 highlights the importance to Boeing of foreign sales and also of overseas suppliers: "And aerospace firms in nations around the world help build our jetliners. Trade works both ways. The more they sell us, the more we sell them." Indeed, fully 25 percent of the value of Boeing's new 777 is from Pacific Rim sources, the highest fraction of Asia-Pacific components of any previous wide-body.[4] Boeing's five major Japanese partners alone have a 20 percent risk sharing stake.[5] The European Airbus consortium ran a similar ad in the same magazine several issues earlier consisting of a map of the U.S. showing the location of all its American suppliers. For similar local content reasons, the China National Aero-Technology Import and Export Corporations (CATIC) has co-produced about 40 McDonnell Douglas MD-80 jet transports in China.[6] McDonnell Douglas also recently let a $1 billion contract to Halla Engineering and Heavy Industries in Korea to supply wings for the MD-95.[7]

Similarly, the fourth largest civil airframer, Canada's Bombardier, in 1996 unveiled its new ultra-long range corporate jet, the Global Express, with a marketing bash called "The Power of Global Vision." According to Aviation Week, this was:

> "a reference to the international team [of 9 partners across six countries] assembled by Bombardier to develop the Global Express. It was unveiled to the accompaniment of … a 45-piece orchestra [and] a 1,000-person choir…. The suspense mounted with the appearance of images of the first aircraft and the choreographed appearance of the flags of Canada, France, Germany, Japan, the U.K. and the U.S."[8]

Fourth, offshore suppliers can be a competitive alternative to US suppliers. As they gain experience, offshore suppliers are becoming increasingly competent and cost-effective in meeting the exacting requirements of aerospace subcontracting. Moreover, the mid 1990s global slump in aerospace industry sales left excess capacity worldwide, creating additional opportunities for attractive subcontracting prices.

Example Strategic Sources: Pacific Rim Suppliers

Under pressure from its largest customer to expand its use of foreign suppliers, in 1986 GAMC contacted five leading Japanese aerospace groups, seeking bids for work on a structural subassembly GAMC had been doing in-house for its major commercial customer. These assemblies account for approximately 25 percent of the overall weight and 15-20 percent of the cost of GAMC's delivered structures. GAMC selected a one Japanese supplier and the first delivery was set for 1987. The next year GAMC also began using a second Pacific Rim source for the same assemblies. When an "act of God" disrupted the parts flow from one of these international suppliers, GAMC's dual source arrangements enabled it to continue its final assembly production without disruption.

There were up-front costs to GAMC for off-loading this assembly to new suppliers. Because GAMC remained responsible for the final complete assembly sent to its customer, and because they had never done business with either Pacific Rim supplier before, GAMC worked with them to ensure that the subassembly continued to meet their customer's expectations. No estimates for how much GAMC invested in these efforts apparently were made, but GAMC had to transfer its technical know-how on manufacturing procedures needed to meet the customer's requirements. GAMC engineers worked training the suppliers on, for example, rivet installation requirements, methods of drilling holes, shank allowances, tolerances, preferred methods for applying sealant, and inspection and quality control procedures. Tips on practical details were passed on, such as air pressures for pneumatic drills to ensure close tolerances and techniques for avoiding air bubbles while mixing sealant. GAMC supplier management personnel also worked to enable the strategic source suppliers to take over responsibility for managing and overseeing the lower tier parts and materials suppliers that had previously been shipping directly to GAMC for the subassembly.

The relationship with the Japanese subcontractor has expanded since. In the mid-1990s, GAMC began off-loading a similar assembly it had also been producing in-house for many years for another commercial program for the same customer, this one its largest single program.

Most recently, GAMC entered into life-of-product design and manufacturing agreements for the COM-Z program with a second commercial customer and with the same Japanese strategic source. This time, from the beginning the strategic source has been responsible for selecting and managing its lower tier parts and materials suppliers. Leveraging GAMC's established relationship with this Japanese subcontractor was attractive to the second commercial customer because Japan was a potentially large market for the COM-Z, its new trans-pacific aircraft. Indeed, the international risk and revenue sharing team for the COM-Z includes

suppliers throughout the US, Europe and several Pacific Rim countries.

The first foreign strategic subcontracting in 1986 actually pre-dated GAMC's formal "strategic sourcing" program. The goals and approach of the formal program, however, are similar. One difference now, however, is that instead of seeking bids, GAMC develops a "target price" with potential foreign suppliers. The price is based on input costs in the target country, combined with GAMC's estimates of its own labor and equipment hours for manufacturing the subassembly under consideration.

Generally, GAMC hopes to see a lower unit cost than in-house. However, foreign sources have also been selected for strategic reasons when there was little difference in costs. For example, in 1994 GAMC began moving two of its large commercial structural subassemblies (again along with responsibility for oversight of lower tier suppliers) to a European supplier even though their costs were similar. Why? One of their customer's largest commercial markets outside the U.S. was in the supplier's home country.

Once a subcontractor is selected, GAMC forms what it calls a "buy-to-package team." In the spirit of IPPD, the team, headed by the procurement organization, has representatives from the various functional organizations as well as from the subcontractor. The team provides technical and managerial assistance to the subcontractor to ensure a successful transition of the work. After the "lean" model of collaborative supplier relations, the goal is to help the supplier improve while at the same time passing down all responsibility for the subassembly. This includes quality control and managing lower-tier suppliers of parts and materials (even those that GAMC previously may have used on the same part). One team participant described how GAMC works with the subcontractor:

> "We do have them participate on the team. We ask them to send an engineering crew on the front end to evaluate it completely, the tooling, the engineering data, all that.... We bring them in, we give them everything and anything they want to look at: engineering data, we give them access to our shop floor. We have some controls. It does get a little anxious [on our shop floor] when people know that there is a possibility that they'll lose that assembly and then they'll lose their job. So we're need to be attuned to what is going on on the shop floor and have to be very sensitive to it.
>
> "Our objective is to reduce [the subcontractor's] first unit [costs]. We want the hours to be down, so that when they start learning they recover a lot quicker. Everything we try to do is let them know how we did it, let them know where we think they can improve, and help them along in that matter....
>
> "We do a lot of program reviews, make sure they are following guidelines, meeting their milestones, and so on. We do a lot of on-site support. Not only short visits, but we may have resident people at the subcontractor's facility. We do things like facilities evaluation. If they are taking on a new job and they are somewhat puzzled about the floor space, we help them out and tell them what the floor space it is occupying in our facility.
>
> "It's all a process of functional organization support, and ultimately of subcontract management. Once the subcontract is in place the procurement organization manages that subcontract to ensure that we get quality and delivery on time, on schedule...."

The assistance also sometimes includes training in program management techniques such as total quality management, statistical process control, or integrated product teaming. In addition, because the sources have been selected to support the company's customers, the customers may also be involved in developing the supplier:

> "We work very closely with our customers in the development of that subcontractor, because they in turn may be trying to develop that same subcontractor. So we work together to be sure we don't duplicate things. One example is where [our customer] provided composite training to a small company. They left [the customer's] facility, came here and received program management training from us. So, we work very closely with our customers in that respect."

In short, considerable effort and cost goes into supplier development in support of GAMC's international strategic sourcing. All of this effort is geared toward commercial programs. While there may be future connections to military work, the more general dual-use approach of the company has not yet applied to international strategic sourcing. Indeed, the government's preference is clearly for a "buy American" strategy, driven by the politics of defense spending and by security concerns about the industrial base and guaranteed access. While "offset" agreements for foreign content are common when US military products are sold overseas[9], this has not affected GAMC because its primary military programs are not sold internationally. The closest analogy on the defense side of the business would be suppliers chosen because of their location in particular states or Congressional districts. But GAMC has no "political sourcing" supplier development program, and managers were, understandably, reluctant to discuss how important such issues are in supplier selection or any specific examples.

New Roles and Responsibilities in Supplier Chain Management

The movement at GAMC towards strategic sourcing, and more generally towards the IPPD philosophy in working with suppliers, has changed the nature of supplier management, materiel and procurement operations at the company. The teaming approach is similar to that pioneered by Toyota in the automobile industry. Indeed, GAMC managers are explicit in saying much of their organizational philosophy comes from their understanding of research on the Toyota system. As seen in each of the strategic sourcing examples above, GAMC is applying the approach not only internally but also externally in its interactions with its customers and suppliers, both domestic and international.

The changes stem mainly from GAMC's response to the globalization of markets and industry-wide contraction since 1991. Increased competition for new contracts led to a re-evaluation of GAMC's market niche and core manufacturing competencies. Corporate strategy shifted from seeing GAMC as a subcontractor to envisioning GAMC as teaming with final assemblers, designing, manufacturing and integrating complete sub-structures, and at the same time teaming with lower tier suppliers. As one manager put it:

> "What we hope to do is, gradually, build the large structures, and have support partners who are feeding us good sized subassembly, where we do the integration here, and possibly go one step further and maybe put some systems in the product, and then ship it to our customer. So we want to take the next step up from being a major subcontractor to be more of a support partner [for the final assemblers]."

GAMC's ongoing internal evaluation of its core competencies guides decisions about which products and processes to subcontract out, and which to retain in house. GAMC has developed a systematic process for determining what it's strategically important core processes are. Cross-functional teams develop "activity maps" to benchmark GAMC's capabilities in each area relative to competitors and potential suppliers. The goal is to identify processes and products for which GAMC no longer has the volumes to justify maintaining in-house capabilities, or where GAMC is not cost competitive.

At the same time GAMC has moved to reduce the number of suppliers it has to manage and, following a "tiering" strategy, has begun gradually pushing down to suppliers the responsibility for managing lower tier suppliers of components and raw materials. We saw examples already, in the context of strategic sourcing. When the process is complete, suppliers inherit responsibility for managing all the component and raw materials in the offloaded subassemblies.

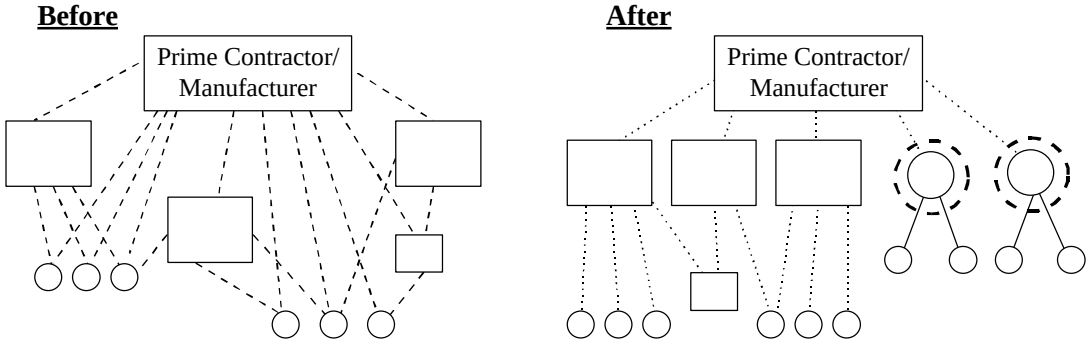
The strategy also means developing longer term collaborative "teaming" relations with suppliers which GAMC believes are capable of taking on larger responsibilities, and helping the company be both cost-competitive and strategically placed for future contracts. A subcontract manager described the concept:

> "When we pick a supplier, we don't want to pick a supplier and just give him one component, and that's all he's going to provide us for the balance of our relationship. We want somebody that we can develop, work with, so that when we pursue new programs we know they have the capability.... So that if we pursue another contract with our customers, and it involves a similar structure, then we can invite them to participate with us. . . . We don't have to start from scratch."

Figure 9 is a representation of this combination of "tiering" and "teaming," towards which GAMC is moving with both its customers and suppliers. As indicated earlier, GAMC's new COM-Z program is modeled on this tiering and teaming approach. The approach is also central to Japanese and (some) European automobile subcontracting networks (Nishiguchi, 1994).

But the transition in the US aircraft industry will take many years, in light of the long product life cycles. For instance, GAMC has been supplying structures on one program since the 1960's. As a result, GAMC supplier relations look more like the "before" diagram than the

Figure 9. Tiering and Teaming in Supplier Management



Source: Nishiguchi, 1994

"after." The process has really just begun.

The activities described above illustrate a trend among airframers to move certain of their assembly and integration functions downstream to their major subcontractors. Undertaken by the airframers to achieve cost saving, streamlining, and marketing goals, this trend gives subcontractors like GAMC positive benefits in the form of revenue sharing, and hands on experience in design and development teaming. At the same time, the trend imposes more responsibilities and risks as well. As we've seen, one effect has been to increase the subcontractors' roles and responsibilities in supplier chain management. GAMC is expected, in the tiering structure, to fully manage and coordinate the next tier suppliers. In response, GAMC has taken on new roles, adding a supplier certification and rating system, with a preferred supplier program. It added a "Supplier Process Management" group for providing technical assistance to suppliers. It added the "Strategic Sourcing" group discussed above for developing international sources as offsets in support of customer marketing efforts. Moreover, because GAMC integrated its supplier system across all programs, these supplier-related efforts are complicated by the fact that each customer has its own set of requirements and preferences, its own supplier rating and certification systems, and its own set of approved and preferred suppliers. As a supplier also responsible for an extensive supplier network of its own, GAMC's materiel and supplier management operations took on increased and changing responsibilities from two directions.

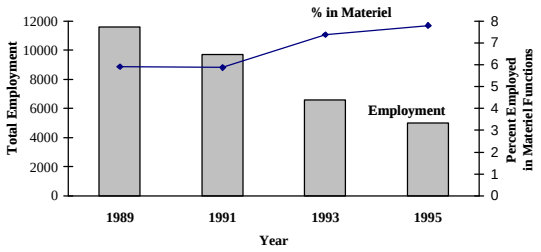
The result was that the whole set of "buying" activities at GAMC moved much further towards oversight and management roles and away from the procurement tradition of price negotiation and contracting. Negotiation and contracting activities continued, of course, but pricing was complicated by "best value" supplier selection and "target pricing." More importantly, in the IPPD approach, materiel and supplier management personnel take on additional responsibilities such as liaison and coordination activities between suppliers and internal functional groups working with suppliers on process and product improvement activities. GAMC materiel and supplier management personnel also oversaw and coordinated teaching, monitoring, and evaluating suppliers, and as the quote above suggests, even managed in-house morale and union tensions as the company moved to outsource internationally.

These added responsibilities also require an expanded set of skills in the materiel functions. For example, the strategic sourcing initiative meant finding people with international experience and an understanding of managing the risks of international markets, as well as of business practices and cultures in the Far East and elsewhere. Several people at GAMC have "China" in their titles. Negotiation and supplier selection by buyers no longer is simply a matter of finding the best price. Rather it often requires sound technical judgment and an understanding of how the supplier will fit within GAMC's internal functional activities. Different organizational and "people" skills are needed, too, because GAMC buyers participate in cross-functional teams. This means communicating with engineers and designers and human resource people, and sharing responsibility for the team's performance.

The changes have also increased the need for expertise and resources in information management. GAMC's supplier rating and certification systems must efficiently gather and process and organize performance metrics such as on-time deliveries, defect rates, statistical process control data, and supplier financial information, and make it available in a timely way to the appropriate decision makers. Outsourcing "make-buy" decisions cannot be made without good internal cost accounting information. In the cooperative supplier relations model, advanced scheduling information is gathered from GAMC's functional organizations and program teams and then processed and made available to suppliers for planning purposes.

As a result, personnel engaged in materiel functions at GAMC as a fraction of overall employment increased between 1989 and 1995. As Figure 10 shows, though the approximately 400 people performing materiel functions at GAMC before consolidation with its new owners (including subcontract management, supplier development and technical support, inventory control, purchasing, administration, procurement quality, receiving, warehousing, shipping and off-site personnel) was much reduced from 685 in 1989, employment in these functions fell less precipitously than overall employment.

Figure 10. Employment at GAMC and Materiel Functions as Percent of Total



Risks from International Competition

The combination of the increased importance of foreign commercial markets compared to US commercial and defense markets, and the implementation of collaborative supplier relationships, poses an additional significant dilemma for the major structural subcontractors like GAMC, and perhaps for all suppliers in the US aircraft industry. If GAMC is representative, the combination of market globalization and "lean" supplier development strategies implies that the major subcontractors outsource to the strongest

foreign firms, particularly in the Pacific Rim, and work with those foreign firms to improve them. Are the major U.S. subcontractors like GAMC, through their technology sharing and supplier development practices, helping to create their own overseas competitors?

For example, one of GAMC's customer's newest commercial programs includes one of GAMC's original Pacific Rim strategic sources but not GAMC, despite the company's long history with that customer. It is obviously impossible to determine the extent to which GAMC's supplier development efforts contributed to that customer's sourcing decisions. GAMC's absence is, in part, explained by differences in technology. Their customer developed proprietary manufacturing processes for use on the new program. While GAMC possessed similar capabilities, their customer elected to use this new technology rather than subcontract that portion of work to other suppliers. Whatever the reason, GAMC's Pacific Rim strategic source has work on the customer's new program and GAMC does not. Ironically, GMAC was instrumental in introducing the Pacific Rim supplier to its commercial customer in the first place.

Similarly, another of GAMC's strategic source Pacific Rim suppliers has a widely reported and very clear strategy across all its businesses, from chemicals to electronics to automobiles to aircraft: "acquire technology abroad, then go independent." It acquired robotics technology by jointly producing with other equipment manufacturers, and now makes its own. It licenses automobile technology, but plans to go alone by 2005. It bought leading electro-optical technology firms in Europe and the Pacific Rim. It is now aggressively pursuing teaming with international partners in order to use its experience as a second and third tier aerospace supplier in order to eventually compete directly with the major airframers, the top design and final assembly tier of the aircraft industry.

GAMC managers report that in their efforts to find foreign sources, few suppliers they approached wanted to do detail fabrication of parts. Rather, the foreign firms wanted to integrate and produce more complex sub-assemblies. GAMC's experience is consistent with the findings of a US General Accounting Office report in 1994 that China, Japan, Indonesia and Taiwan are all intent on developing their own aerospace industries.[10] According to the GAO, all are importing product and process technologies and have strong links between military and commercial projects. And their progress has been steady. For example, in the 1960s Korean firms did light repair and aircraft maintenance. In the 1970s they moved up to depot maintenance and contract assembly. In the 1980s they manufactured aircraft parts locally and did increasingly complex assemblies. In the 1990s they have self-developed a small jet aircraft (50 seat) and have moved to do co-production of the F-16. Future plans call for developing a 100 seat jet aircraft.

Conclusions

Case studies, by nature, do not offer statistically useful hypothesis tests and cannot control for any other possible explanatory events. Nevertheless, with its emphasis on the whole lean paradigm, GAMC does provide the opportunity to begin to explore the hypothesis that the methods derived from studying the automobile industry will also pay off in the aircraft industry. Because the central focus of this case has been limited to supplier management and international sourcing, it has not explored the broader lean paradigm at GAMC. In particular, a closer and independent investigation of manufacturing practices and costs would be needed to confirm the performance metrics listed in Table 4, which shows GAMC's self-reported improvements on its major programs. The company, at least, believes it has seen significant results from the whole package of changes undertaken in pursuit of "lean" manufacturing practices.

More specific to supplier management, the lean paradigm derived from research on the automobile industry suggests several practices. As we have seen, GAMC embraced and implemented many of them, including: increased outsourcing of non-core manufacturing activities; teaming with suppliers and customers in design and development; working with suppliers to improve their technical and managerial capabilities; enhancing information flows and technical exchange with suppliers to improve joint problem solving; and reducing the number of suppliers through working only with the best ones.

Table 4.
Performance Improvements Reported by GAMC

1. Overall cycle time to customer delivery:
   - 17 percent reduction on commercial programs.
   - 14 percent reduction on a military program.

2. Product cost:
   - Cost per pound improvement on all programs.

3. Rework, repair and re-fabrication costs:
   - 40 percent reduction per standard hour.

4. First time quality:
   - Passed 89% of first article inspections on new program.
   - Second upper skin structure on new program was "defect free."
   - First fully integrated structure mated in two hours vs. three days original job allocation

5. Customers' perceptions:
   - Award for Excellence
   - Supplier of the Year
   - Preferred Supplier [top 2%].
   - Outstanding Quality Recognition on a Military Program

These trends increased the roles, responsibilities and costs (as a fraction of overhead) of GAMC's materiel functions. They also began to strain the integrated dual-use approach to supplier management. However, the dual-use approach will likely remain a viable alternative to separate program or divisional supplier management. The advantages, outlined above, of the dual-use approach appeared to outweigh the problems. GAMC continued to use a single MilQ approved procurement system for both military and commercial programs with very few deviations for commercial reasons. Moreover, duplication of materiel functions is not likely to be attractive in the future, either, in an era of intense commercial competition and significantly reduced levels defense spending. So too, the Pentagon has increased its preference for "commercial practice" both in manufacturing and contracting.

However, if GAMC is representative of the broader supplier base, the upper supplier tiers of the US aircraft industry are getting squeezed between, on one hand, the push towards "lean" practices, which increase supplier responsibilities and risk, and, on the other, the global sourcing and offset initiatives of top-tier companies. GAMC has no real choice but to do everything it can to meet its customers' needs. GAMC's customers may have no real choice but to do everything they can to increase their foreign sales. The commercial side of GAMC's customer base may, indeed, do very well by increasing the pressure for foreign sources. Yet even at the top tier there is risk together with the potential returns in combining foreign offsets with the strongly developmental practices suggested by "lean" mantras of collaborative supplier management. It is clear that with experience gained from ever increasing responsibility in the aircraft supply chain, Pacific Rim competition is on the horizon not only for GAMC-like first supplier tier assembly work, but also for entire 100 seat transport aircraft. The Pentagon, too, must be concerned today about the effects of this offset-lean squeeze on the health of the US aircraft industrial base. The squeeze may end up suffocating the vital middle tiers.

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[1] The Lean Aerospace Initiative at MIT provided support for this research. Analysis and conclusions expressed herein are solely the responsibility of the author and not of the GAMC, its parent company, nor the Lean Aerospace Initiative, the other sponsoring organizations, or MIT. The quotes within represent the opinions of personnel interviewed by the author, but not necessarily of these organizations. These disclaimers aside, I must express my sincere gratitude for the friendliness and cooperation, not to mention their countless valuable hours, with which GAMC personnel have been willing to talk with me about these issues. I have found both a warm reception and knowledgeable people throughout the enterprise, vice presidents to shop floor operators. The case study would not have been possible without that help. Thanks also to Maryellen R. Kelley for sage advice during preparation of the case, and to members of the LAI Supplier Systems and Relationships team for comments on an earlier summary of initial findings.

[2] For example, unpublished data show that the average number of suppliers projected for 1995 by the business units in the survey were more than 50 percent below 1989 levels. This from the MIT Lean Aerospace Initiative Supplier Systems and Relationships Survey of nearly 80 business units of the US aircraft industry's top manufacturers

[3] The same appears to be true in the defense aircraft industry. Unpublished data from the MIT Lean Aerospace Initiative Supplier Systems and Relationships Survey of nearly 80 business units from the US aircraft industry's top manufacturers, for example, show that 53 percent of surveyed business units regularly receive proprietary financial information from their major suppliers.

[4] International Herald Tribune, February 23, 1994.

[5] Boeing Company, Press Release, December 12, 1990.

[6] US Department of Commerce, "1994 National Trade Data Bank, Market Reports" March 17, 1994.

[7] Korean Economic Daily, November 30, 1994.

[8] Anthony L. Velocci, Jr., "Global Express vs. G5: The Contest Heats Up, Aviation Week & Space Technology, September 2, 1996.

[9] For example, the F-16 is co-produced in, among other counties, Korea by a group led by Samsung, and 36 British companies are building parts of the C-130J, in large part because it is in competition with the planned European F.L.A. airlifter for purchases by the British military. The Weekly of Business Aviation, February 27, 1995.

[10] US Congress, General Accounting Office, "Asian Aeronautics: Technology Acquisition Drives Industry Development," 1994.