AIRCRAFT INDUSTRY STUDY
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ABSTRACT

The U.S. aircraft industry is clearly a nationally important strategic industry. Despite a global decline in the industry between 1991 and 1995, most U.S. and international aircraft manufacturers predict a positive future. However, to keep their current 60 percent market share, U.S. companies will have to focus on several key areas in the future. The most competitive global aircraft manufacturing companies are focusing investment and management resources on modernizing and capitalizing on the benefits related to the potential of the computer. And aggressive marketing techniques, such as the use of full-scale cockpit and fuselage mock-ups to demonstrate advanced designs and concepts, appear to be very effective mechanisms for selling aircraft. Despite their current dominance of the global market, we believe U.S. aircraft manufacturers will have to not only aggressively modernize their production and engineering base but also become much more customer oriented to retain their lead.

INTRODUCTION

The study group evaluated the aircraft industry by dividing it into four major sectors--commercial transport aircraft, military fixed-wing aircraft, civil and military helicopters, and aircraft engines--and three key subsectors--design and integration, advanced materials, and avionics/flight controls. Based on research and numerous visits to domestic and international manufacturers, the group assessed the global competitiveness of the U.S. aircraft industry and developed several recommendations for government goals and roles with regard to this strategic industry. We also formulated several recommendations for actions we believe would help the industry help itself in an increasingly competitive global market.

CURRENT CONDITIONS

After steady growth in sales from 1980 through 1990, averaging 3.7 percent annually, commercial and military aircraft sales entered a period of depression because of reduced military expenditures and diminishing demand on the commercial side. In 1995 activity in the aircraft industry
continued to decline overall, with sales diminishing by over 6 percent to $54.5 billion. Sales of civilian aircraft declined almost 10 percent to $23.6 billion while sales in the military sector dipped almost 4 percent to $30.9 billion. Despite the defense drawdown, military aircraft still accounted for 57 percent of total sales (Napier, 1995). However, this share is expected to continue declining as a result of budget pressures and the perception of a reduced threat.

For the third straight year, the U.S. trade surplus declined in 1995. This decline included a 31 percent drop in commercial aircraft exports. However, the aircraft industry is still one of the largest export industries in the United States, with exports totaling $32 billion and an overall positive trade balance of $21 billion.

Aircraft industry employment dropped in 1995 for the sixth consecutive year, falling by 33,000 to 436,000 since the industry's peak employment level of 700,000 in 1989. Overall, jobs in the aircraft industry have been reduced by nearly 38 percent since 1989: 18 percent in the civilian sector and 55 percent in the military sector.

Commercial Transport Sector

The sector defined. This sector includes aircraft capable of carrying 100 or more passengers and similar-sized cargo aircraft. Aircraft configurations include passenger only, passenger and cargo, and pure cargo. Three companies form the major portion of this mature, oligopolistic industry: Boeing and McDonnell Douglas in the United States, and Airbus Industrie in Europe. Entry into the industry by other substantial competitors is not expected because of tremendous start-up, design, and production costs.

Current conditions. Manufacturers must offer a variety of transport models to ensure that they offer aircraft with the capacity to service a wide variety of airline markets as demand grows in the next few years. Manufacturers anticipate strong demand for large aircraft to service Pacific Rim countries, particularly Japan, China, and India, where the potential for additional commercial aircraft sales is great. South and
Central America, along with Africa, represent smaller growth markets in the early 21st century.

Until the end of the Cold War, the buying cycles in the commercial aviation and military segments offset each other. But in the last five years, both sectors have reduced spending, which has led to reduced production and the need for fewer employees. In 1995 the number of production workers continued to fall from its peak in 1989. Current employment in the civil aircraft manufacturing industry is just over 260,000, down from 345,000 in 1991 (Napier, 1995, Table 9). During the last four years sales of civil transport aircraft have declined from over $28 billion to just over $15 billion, or more than 45 percent (Napier, 1995, Table 5). Most of this year's decline was caused by falling exports.

Surge capability is available within U.S. commercial aircraft manufacturers at final assembly facilities. However, of the experienced employees who have previously been laid off, few are now willing to return to the industry because of the cyclical nature of the work. The companies surveyed estimated the average time to produce significantly more aircraft at two years. Additionally, second-tier suppliers would require much more time to develop the additional competent work force and suppliers needed to support substantial surge requirements.

Challenges. Because of the maturity of the commercial transport sector, additional consolidation is probably not possible without creating a monopoly. Therefore, manufacturers are turning to other techniques to further reduce costs and increase efficiencies. For example, the practice of manufacturing component parts internationally is expanding, encouraging global purchasing and easing entry into international markets. Additionally, advanced manufacturing methods help ensure competitiveness in the marketplace. Companies are also expanding the use of computer-assisted design (CAD) and computer-assisted manufacturing (CAM) systems to reduce manufacturing costs and increase product quality. Finally, enlightened companies are emphasizing employee development and training, thereby helping ensure higher-quality processes and products.
Outlook. Aircraft manufacturers forecast an increase in large commercial aircraft orders within the next three years. Replacement of older aircraft that do not meet International Civil Aviation Organization noise and pollution standards is the foremost reason for the increase. Uneconomical flight operations and poor parts support are other reasons for replacing aging aircraft.

Plans for a very large commercial aircraft capable of carrying 600-800 passengers, co-developed by Boeing and Airbus Industrie, dissolved during late 1995. However, we believe future demand requires the development of aircraft of this capacity to continue now, with final design and production delayed until market conditions are more favorable. However, international development of a new large aircraft does not seem feasible at this time.

Military Fixed-Wing Sector

The Sector Defined. As a result of mergers and acquisitions over the past 10 years, the total number of prime manufacturers of military fixed-wing aircraft has declined from eight to four. By 2000 this number is generally expected to be down to only two. Three aircraft manufacturers currently dominate the military fixed-wing market: McDonnell Douglas, with 52 percent of market share; Northrop Grumman, with 27 percent; and Lockheed Martin, with 11 percent (Morracco, 1995, 123).

Current conditions. With sales of military aircraft dropping dramatically (from 497 in 1985 to only 46 in 1996), primary manufacturers and subcontractors continue to scramble to cut costs and manage their overcapacity. The resultant impact on the work force has been devastating. Employment within the aerospace industry has declined steadily since 1987. The military aircraft sector, which saw the biggest cutback, employed 396,000 employees in 1987 but only 169,000 in 1995. An additional drop in 1996 will bring the work force in this segment of the industry down about 60 percent from 1987 levels, to a new low of only 158,000 (Napier, 1995).

To forestall irreversible damage to key areas of the defense industrial base, the Pentagon released over $94 million to Boeing, Northrop
Grumman, and about 45 suppliers to keep the B-2 industrial base warm while planners reexamine future heavy-bomber force requirements. Another proposal is to transfer a greater share of the maintenance and upgrade work from government depots to the private sector.

**Challenges.** During 1987-95, sales of military aircraft dropped 30 percent, from $44 billion to $31 billion. Projections through 1997 are for a leveling-off at $30 billion. To keep production lines running, military aircraft manufacturers have placed substantial emphasis on the foreign military sales (FMS) market. Unfortunately, the FMS market, the traditional escape valve for military aircraft producers, is shrinking, and the competition for export orders is growing more intense as the number of opportunities dwindles. FMSs of U.S. aircraft plummeted 65 percent from 1992 to 1995, from $1.3 billion to only $460 million (Napier, 1995).

**Outlook.** As for current fixed-wing military aircraft programs within the United States, Lockheed-Martin's F-16 line will continue in production, but only to support FMS. Lockheed-Martin is also teamed with Boeing to produce the Air Force F-22. The program is slated to receive $2 billion in 1997 and $13.1 billion through 2001 for the initial 40 aircraft, with first flight scheduled for May 1997 and production to begin in 1998. Current plans call for the eventual procurement of 442 aircraft at a projected cost of $72 billion. Both of these contractors are also contenders for the Joint Strike Fighter (JSF). A recent decision by the administration to add one more B-2 to the operational bomber fleet will allow Northrop Grumman to keep that line open as an early test aircraft is refurbished and brought up to operational standards for an estimated $700 million.

Other ongoing programs include a $400 million contract for long-lead items needed to build seven E-2Cs, subcontract work with McDonnell Douglas on the F/A-18E/F, and various modification programs. McDonnell Douglas mainstays include the C-17, F/A-18E/F, T-45, and F-15 FMS. Current plans call for buying 120 C-17s at a rate of 8-15 aircraft per year, as well as 268 T-45 aircraft worth approximately $5 billion. Future F-15 production will continue, but primarily to support FMS programs. The company's largest military program, the F/A-18E/F, will receive $2.6 billion in 1997 for 12 aircraft and $16.9 billion for 150 aircraft through 2001. Production will begin in 1997, and 1,000 aircraft
(including those for FMS) are currently expected to be built, for an estimated program value of approximately $89 billion.

The ultimate prize for the military fixed-wing sector lies in the JSF program. In 1997 the program is budgeted for $600 million, and it is expected to receive $3.8 billion over the next five years. As many as 3,000 aircraft (including FMS) could be produced at an estimated cost of $1 trillion, making the JSF program the largest military aircraft acquisition program ever. Currently the major competitors include Lockheed Martin, Boeing, and a team composed of McDonnell Douglas, Northrop Grumman, and British Aerospace. By the end of 1996, competition will be reduced to only two contractors, who will build prototypes for a fly-off competition. The results will lead to the selection of a final contract in 2000. The first JSF should roll off the production line in 2005. The only other new military fixed-wing aircraft program is the Air Force and Navy’s Joint Primary Aircraft Training System (JPATS). Recently awarded to Raytheon Aircraft Co., the 711-aircraft program is expected to be worth $7 billion.

Finally, operational successes with U.S.-built UAVs is drawing increased interest from the military as well as civilian and foreign military markets. Although UAVs currently are not considered direct competition for the military aircraft industry, their future is promising. Rapidly broadening applications and capabilities, along with average unit prices of $3 million to $10 million, are starting to have an impact around the globe as countries weigh the cost and capabilities of UAVs against those of manned aircraft. U.S. contractors producing UAVs include Lockheed Martin teamed with Boeing on the stealthy DarkStar, Teledyne Ryan with the high-altitude, long-range Tier 2+; and General Atomics with the Tier 2 Predator, currently in use over Bosnia. There are many foreign manufacturers of UAVs and, as in the military aircraft industry, competition within the UAV market is expected to be extremely keen.

**Helicopter Sector**

*The sector defined.* The helicopter industry consists of military and civil components. U.S. manufacturers include Bell Helicopter Textron, Inc., which makes the Bell Huey, Cobra, and Kiowa Warrior (OH-58) aircraft.
and coproduces the V-22 with Boeing Helicopters. Boeing Helicopters produces the CH-47D Chinook cargo helicopter and coproduces the Comanche with Sikorsky. McDonnell Douglas Helicopter Company (MDHC) manufactures the Apache AH-64 (including the Longbow system) and the OH-6 (for special operations units). Sikorsky Aircraft Corporation makes the CH-53 and numerous variants of the UH-60 Blackhawk, while sharing the Comanche production with Boeing.

Foreign countries with helicopter manufacturers include Italy, where Agusta produces models for civil uses and military attack, and medium-utility models for civil and military use. France and Germany cooperatively support Eurocopter, a manufacturer of civil and military helicopters that was formed by the union of the largest helicopter manufacturers in these countries. Under licensing agreements with Sikorsky, McDonnell Douglas, and Boeing, Japanese manufacturers produce UH-60Ls, MD 500s, and CH-47s, respectively. Russian manufacturers mainly produce heavy-lift helicopters. South Korean builders are licensed by Sikorsky to coproduce UH-60P Black Hawks. In the United Kingdom, Westland produces the light-utility Lynx. Westland is also teaming with Agusta on the medium EH-101 and will produce 51 percent of the McDonnell Douglas AH-64s. Westland is licensed by Sikorsky to produce UH-60Ls.

Current conditions. Entry barriers are high because of the costly capital investment, substantial design expertise, and extensive manufacturing capabilities needed for success in this complex business (Industrial Assessment for Helicopters, 1995, I-15). Additionally, due to substantial overcapacity within the current manufacturers, it is unlikely that any new helicopter companies will be formed in the foreseeable future.

Challenges. The U.S. helicopter industry today is in a perilous situation. Of the four major U.S. manufacturers, only one has ventured significantly into the commercial arena. The other three are subject to the whims of the Department of Defense (DoD). During the 1970s and 1980s, the military helicopter business thrived on ever-increasing budgets, but now defense funding is rapidly declining along with requirements for military helicopters. Companies such as Sikorsky, Boeing, and McDonnell Douglas will be forced to diversify into the commercial marketplace while
working aggressively to open up foreign markets. We also believe consolidation is certainly feasible and probably overdue. Bell Helicopters is already strongly positioned in the worldwide commercial helicopter market, so DoD budget reductions should only marginally affect them.

**Outlook.** An examination of DoD helicopter requirements through 2001 reveals that the numbers are dwindling while the value of the lower quantities is actually increasing (*Industrial Assessment for Helicopters, 1995, III-8*). In other words, the cost per aircraft will be significantly higher than for those procured in the early 1990s. The reasons for increasing costs include the low production rate, which drives up unit costs, and the increasing sophistication of the equipment produced today. Although Sikorsky will begin manufacturing the V-22 aircraft in 1997 or 1998, the Comanche program will be the only U.S. helicopter in development after 1997. Until the Comanche enters production in 2003, total U.S. helicopter production will be only 36 UH-60s per year.

The past and projected global market share in percent for U.S. producers of civil and military helicopters is shown in Figure 1 (*Industrial Assessment for Helicopters, 1995, II-10*). The decline in military helicopter requirements affects Sikorsky more than the other three U.S. manufacturers, as its market share is projected to fall from 26 percent to about 7 percent. MDHC's share actually rises as a result of its production for FMS and its recent aggressive entrance into the civil helicopter sector.
To survive, companies must diversify and compete in the civil market, pursue foreign markets, and seek assistance from the Commerce Department, and consolidate further. Boeing Helicopters and Sikorsky appear to be good candidates for merger because they have substantial overcapacity resulting from vastly reduced production lines and will begin coproducing the Comanche helicopter in 2003. Merging to streamline overhead could reduce costs and produce higher profits.

**Aircraft Engine Sector**

*The sector defined.* The global engine sector consists of 18 manufacturers, excluding the nations of the former Soviet Union. Pratt & Whitney (U.S.), General Electric (U.S.), Rolls Royce (UK) and SNECMA (France) account for almost 77 percent of the market share based on installed engines and those currently in production. Numerous second-tier manufacturers provide parts and subassemblies to the industry. High capital costs and complex technology are barriers to market entry (1995 Aircraft Industry Study Analysis, 4-21). In 1995, commercial and military engines held 60 percent and 40 percent of the market, respectively (Aerospace Facts & Figures 1995-1996, 28).

*Current conditions.* A buyers' market exists in the commercial sector because of the current excess of aircraft and projected slow sales in the near future. Buyers demand low engine prices, high reliability, and new technology that is cost effective before it earns its way into an engine. Competition among manufacturers is fierce, and profit margins are slim. Firms often sell engines below cost in order to secure market share. Profits from the sale of replacement engine parts typically subsidize losses or very low profits on initial engine sales. However, today's engines require fewer parts and are extremely reliable as a result of improved designs and materials. The once-lucrative spares market can no longer offset expensive research and development (R&D) costs that may take 20 years to recoup (Ropelewski, 1994, 34-37).

Commercial R&D continues to produce affordable and reliable engines at an average industry investment of 3 percent of net sales. Derivative engines are being used to satisfy emerging requirements, such as those for
the Very Large Commercial Transport Aircraft concept. Existing engine configurations are often modified to satisfy higher thrust requirements for new aircraft models as a way of avoiding the long lead times, high cost, and risk inherent in developing an entirely new engine design (Ingrassia and Carley, 1996, 1, 10).

The DoD is funding engine R&D with the Integrated Performance Turbine Engine Technology Program, which focuses on enhanced reliability and maintainability, increased thrust-to-weight ratios, improved fuel efficiency, and reduced weight. In addition, the Defense Advanced Research Projects Agency and the industry are jointly funding R&D in ceramics, organic, metal matrix composites, and intermetallics under the Technology Reinvestment Project (Kandebo, 1995, 55-57; 1994, 63-67).

Challenges. In 1995 sales of civil aircraft, engines, and parts declined 9 percent to $23.6 billion, and sales of military aircraft, engines, and parts declined 3 percent to $31 billion. In 1995, the U.S. aerospace balance of trade was over $21 billion, with aircraft, engines, and engine parts accounting for over $10 billion. The primary tool for countering declining sales and slim profit margins is increased productivity (Napier, 1995, 2). Mobilization surge capacity has also diminished because of the reduced supplier base.

To enhance their competitiveness, U.S. engine manufacturers are increasing productivity and quality; collaborating, merging, or seeking joint ventures to share development costs, risks, and revenue; fostering long-term customer relations; providing buyer financing; exploiting export markets; investing in new product lines to increase top-line growth; and using industrial participation incentives. Additionally, some companies are focusing on providing total product support (combined aircraft and engine sales and aftermarket services in maintenance, training, and spares tracking) and providing engine-lease programs for customers according to hourly usage (Spinker, 1995, 86).

Outlook. Engine manufacturers have a poor record of accurately forecasting the short-term market (Velocci, 1995, 47-48). Nonetheless, for 1996 they forecast a rise of 24 percent or $5.6 billion in the sale of civil aircraft ($5.3 billion for airliners), engines, and parts. U.S. military
aircraft sales forecasts for 1996 are for a $1.4 billion decline (Napier, 1995, 2).

Over the longer term, DoD engine procurements are expected to continue declining with the defense budget. Engines for the C-17, F-22, F/A-18E/F, V-22, and JSF are the only major development and production programs for the future. A derivative engine design is likely to be used in order to minimize the cost and risk of the JSF program. For the period 1996-2013, the commercial sales forecast is an optimistic $200 billion. These forecasts reflect aircraft retirements and traffic growth. One opportunity is for FMSs in Asia: the gross domestic products of Korea, Taiwan, Japan, and China will increase by 94 percent, and their combined economies will total $4 trillion. However, the Asian forecast is subject to change by domestic and international political factors (Kandebo, 1995).

**Design and Integration Subsector**

*The subsector defined.* The use of computer design tools is revolutionizing U.S. industry, especially the aircraft industry. Part of the third-wave technology, these tools are evolving into full life-cycle support systems that provide virtual engineering and significantly improved design, test, manufacturing, and modification capabilities.

The use of computer-based design tools has been evolving since the early 1970s, but the industry is now beginning to use an advanced generation of design tools that are capable of providing end-to-end integrated design and manufacturing support. Powerful design packages are now becoming an integral part of the complete process of engineering, design, manufacture, sale, and product support.

The Boeing 777 is the first U.S. example of an aircraft developed exclusively using CAD tools. A computer-based design tool called CATIA was used to develop the entire aircraft, down to the smallest parts. These designs were given to subcontractors in electronic format for manufacture. Using this tool, Boeing was able to build the first aircraft to production specifications, thus skipping the prototype phase and cutting years off of the development time.
Current conditions. Within the aircraft industry, the five major design-tool programs shown in Table 1 currently dominate.

<table>
<thead>
<tr>
<th>Product</th>
<th>Company</th>
<th>Operating System</th>
<th>Clients/Seats</th>
<th>Customers</th>
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<tr>
<td>Unigraphics</td>
<td>EDS</td>
<td>UNIX</td>
<td>4,500/45,000</td>
<td>McDonnell</td>
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<tr>
<td>CADDs</td>
<td>Computervision Corp.</td>
<td>UNIX</td>
<td>1800002</td>
<td>Aerospatiale, British Aerospace</td>
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<tr>
<td>CATIA</td>
<td>IBM/Dassault</td>
<td>UNIX</td>
<td>100,000+</td>
<td>Boeing, P&amp; W, GE</td>
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<tr>
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<td>MICROCADAM, Inc.</td>
<td>Windows</td>
<td>600003</td>
<td>Lockheed</td>
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<tr>
<td>Pro/Engineer</td>
<td>Parametric Technology</td>
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Challenges. The capabilities and costs of these systems vary; single licenses can cost thousands of dollars. All of these products can be described as systems of modules integrated via data exchange. Although data standards are evolving, the exchange of data between different systems is not flawless. Subcontractors are sometimes forced to use the same system as their prime contractor in order to control the risk of noncompliance.

Outlook. The use of "virtual design environments" will continue to increase until products are wholly supported by computer tools that assist in concept development, market strategy, design, manufacture, distribution, maintenance, logistics support, and disposal at the end of the
product's life cycle. Companies that embrace these tools will have a competitive edge.

**Advanced Materials Subsector**

*The subsector defined.* Advanced composite materials, including advanced polymer composites, advanced ceramics, and metal matrix composites, are used in both military and civilian aircraft manufacturing. These materials offer improved performance, exceptional strength at reduced weight, durability, and design flexibility (Tortolano, 1994, 70).

*Current conditions.* Following the pattern established by the B-2 program, military aircraft such as the V-22 and RAH-66 Comanche are being developed with advanced-composite primary aircraft structures (*Industrial Assessment for Helicopters*, 1995, IV-13). As we observed during our visit to McDonnell Douglas, the lessons learned in the area of advanced materials during the development of these military programs, along with the civil Boeing 777 development program, will readily transfer to future applications. However, the industry still does not use advanced materials at their full potential because they are relatively expensive and usually involve complex manufacturing processes.

Until recently the main thrust in developing advanced composites was to increase performance, despite increased manufacturing costs. But recent developments in state-of-the-art machinery have significantly reduced both assembly and inspection times for composite parts. As we saw in visits to McDonnell Douglas, Boeing, and Northrop Grumman, acquisition of automated tape lay-up equipment; unidirectional fiber placement machines; sophisticated ultrasonic inspection devices; large, high-pressure five-axis automated trimming machines; and adaptive control tooling all provide tremendous savings over earlier methods.

*Challenges.* While composite materials offer numerous benefits to the industry, repairs to damaged composite components are substantially more complex, time consuming, and expensive than on traditional metals. The proprietary aspect of these materials also exacerbates the situation. In partial response, manufacturers are changing their composite designs to place greater emphasis on durability and repairability. Additionally, in an
effort to reduce the financial strain on airlines and to simplify repairs, the Commercial Aircraft Composite Repair Committee is working to develop industry standards for specifications and repair processes (Smith, 1995, 60-61).

Under the U.S. Commerce Department's Materials Technology Subcommittee (Mat-Tec) program, private sector groups form partnerships with government agencies to work out such challenging materials issues as developing subsonic aircraft materials that are affordable and lightweight and high-temperature-tolerant material for engines and supersonic aircraft. Additionally, the groups are involved in developing standards for materials and processes that lower costs and reduce environmental impacts (The Role of Materials in Global Competitiveness, 1996, 25).

The reduced availability of advanced titanium alloys, such as Titanium 10-2-3 and Titanium 6-4, which are used extensively in aircraft manufacturing, may harm the aircraft industry in the near future. According to information gained from a visit to Shultz Steel, anticipated high prices, supply shortages, expanding demand for titanium in other commercial products, and suppliers operating at peak capacity will present major challenges to titanium-forging companies as they attempt to keep pace with demand by the aircraft industry.

Outlook. A current goal is to double engine thrust-to-weight ratios, which will require lightweight engines that can operate at extremely high temperatures. Toward this end, titanium matrix composites with ceramic reinforcement are prime advanced-material candidates to replace current metal engine components (Zaretsky, 1994, 124). Improvements in materials and processes can be expected to focus on higher-thrust engines, weight reduction initiatives, improved reliability, and reduction of production processing costs (Directorate of Science and Technology, 1996, 6).

In the future, materials programs for manufacturing will most likely include temperature-cured, toughened thermosets, thermoplastics, bismaleimides, high-temperature thermosets, and titanium composites. As a visit to Boeing demonstrated, future process improvement programs will
focus on advanced fiber placement, improvements in automated composite
tape lay-up, unitized and fastenerless assembly techniques, titanium
castings and welding methods, high-speed machining, and rate-adaptive
manufacturing, such as flexible tooling and nonautoclave curing. The U.S.
aircraft industry's supersonic airliner, which has a roll-out target date of
2006, is expected to be produced using new lightweight composites and
metallics that are currently under cooperative research with the National
Aeronautics and Space Administration (Williams, 1994, 12A(1)).

Avionics/Flight Control Subsector

The subsector defined. Avionics and flight controls comprise the
electronic components and systems in civil and military aircraft. They are
produced by diverse firms related to the aircraft industry.

Current conditions. Like the aircraft manufacturing industry, the global
avionics market has been declining over the past few years. But now it is
poised to begin a period of modest growth if anticipated commercial
aircraft orders materialize. Growth is also expected in specialized areas
such as air traffic control systems, data links, software, and global
positioning system (GPS) navigation equipment.

Companies dedicated to the military sector are faced with shrinking
markets, ferocious competition, and the lure of less expensive commercial
alternatives. However, military aircraft are increasing the content of
avionics/electronic systems, which should mitigate some of the effects of
the budget decline. The value of avionics components generally equals
about 40 percent of the total cost of military aircraft, and avionics are
expected to drive as much as 55 percent of the cost of the Air Force's new
F-22. According to an Electronics Industry Association analysis, the
avionics share of the defense electronics market is predicted to increase
slowly from $5.5 billion in 1996 to $6.9 billion by 2000. However, this
increase will be offset by a steady decline over the same period in R&D
funding; the current $3.2 billion dropping to about $1.5 billion, where it
should stabilize (Nordwall, 1995, 81).

Challenges. Some of the challenges in military avionics are GPS
incorporation, sensor data fusion (especially in tactical platforms), and the
increasing economic pressures of tight budgets. GPS navigation systems have been mandated for all platforms by 2000. Data fusion seeks to couple and process information from various sensor inputs to give flight crews a clearer picture of their tactical situation. A system might integrate inputs from passive radar receivers, fire control radar emissions, and infrared sensors to build a target profile for the weapon system. Integration and processing of sensor information highlights the critical role software now plays in military systems. Another impact of data fusion and software growth is the stimulus they provide for using flexible, open-system architecture in the basic system design.

The forces of economics are also formidable in military avionics. A Booz, Allen & Hamilton study on excess capacity reported that in the defense electronics industry today half of the current contractors would have to be eliminated during the next five years to achieve the more efficient capacity utilization rates of the 1987 era (Nordwall, 1995, 83).

Military customers, like their commercial counterparts, are recognizing that affordability must be a key consideration in acquiring new avionics systems and are increasingly trading off some performance for lower cost. One of the impacts of this shift in focus is the use of commercial off-the-shelf (COTS) equipment in military applications. Additionally, defense contractors are now increasingly interested in developing commercial spin-offs of their military systems to capture profits from the much larger commercial market. Many contractors are also adopting teaming arrangements rather than trying to design and produce many products in-house.

**Outlook.** New orders for commercial airliners mean growth for the avionics industry. Many analysts predict a $1 trillion market for new and replacement commercial transports through 2015, and avionics will account for approximately $1 million of the price of each new aircraft. Additional business equipment, including interactive passenger displays and handsets, could easily add another $1 million of additional electronics to a 400-seat aircraft (Nordwall, 1995, 81). Affordability, long a key consideration in the commercial airline market, is even more influential today. Instead of the previous three- to five-year payback period, airlines
now want payback on their investments in only one year. Technology has
to earn its way into commercial aircraft by being cost effective.

One new technology that has gained initial commercial market penetration
is the flat-panel liquid crystal display (LCD). The Boeing 777 cockpit
incorporated this technology in its initial design, and an upgrade program
planned for the Boeing 737 is also installing this technology. Although
LCD technology is inherently more reliable than older cathode-ray tube
(CRT) displays and can display more information, it is also more
expensive. Therefore, while LCD flat-panel displays have achieved some
market penetration, they will not dominate cockpit displays until they
achieve price parity with CRTs.

Rapid changes in avionics technology create a dilemma for both
corporate and military customers: component parts are sometimes out of
production by the time the new product is certified and fielded. Using a
COTS approach results in lower purchase prices, but often at the expense
of long-term supportability. The short life-cycles of some commercial
components often dictate two or three major upgrades or replacement
programs over the operational life of the aircraft.

OUTLOOK

Civilian aircraft and engine sales are projected to grow by 24 percent,
driven by jetliner sales growth of $5.6 billion. While they will not reach
the levels of the 1980s, deliveries of commercial aircraft should increase
as a result of growing airline traffic and early replacement of older, less
fuel-efficient aircraft that will not meet airline fuel efficiency requirements
or new stringent noise and emissions standards. Projections indicate a
potential commercial transport market of $1 trillion over the next 20
years, with a moderate upturn in the near future and accelerated growth
by the turn of the century.

The dynamics of international markets will affect the future of the U.S.
aircraft industry. In the 1980s global businesses earned market share
through head-to-head competition, and major firms used large-scale
layoffs to survive during an extended period of declining sales. As a
result, U.S. builders lost over 553,000 seasoned workers, and financial
troubles proved fatal for Holland's aircraft manufacturer, Fokker Inc. (Fuqua, 1995, 3). Today rivals increasingly form teams to share the high cost and risk of new product R&D. Fortunately, industry analysts predict the worst is over.

Traditionally, aircraft sales hinge on the level of passenger and cargo traffic, with healthy economic conditions increasing traffic for airlines and bringing in orders for new aircraft. Economic growth projections for most major regions of the world are positive, as shown in Table 2.

Table 2. Percent Changes in Real GDP, 1974-2014

<table>
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<tr>
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<tr>
<td>North America</td>
<td>2.5</td>
<td>2.6</td>
<td>2.8</td>
<td>2.7</td>
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<tr>
<td>Latin America</td>
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<td>2.6</td>
<td>4</td>
<td>3.9</td>
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<td>Western Europe</td>
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<td>2.1</td>
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<tr>
<td>Eastern Europe</td>
<td>2.8</td>
<td>-4.4</td>
<td>4.1</td>
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<td>Middle East</td>
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<td>1.5</td>
<td>4.6</td>
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<tr>
<td>Africa</td>
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<td>1.4</td>
<td>3.9</td>
<td>4.1</td>
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<tr>
<td>Asia/Pacific</td>
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<td>4.6</td>
<td>4.9</td>
<td>4.5</td>
</tr>
<tr>
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<td>-7.3</td>
<td>4.2</td>
<td>3.9</td>
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<tr>
<td>World</td>
<td>2.6</td>
<td>1.8</td>
<td>3.5</td>
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Industry analysts predict that global economic growth will generate requirements for a worldwide fleet of 18,000 passenger and cargo aircraft by 2013. This larger global fleet would require the industry to build almost 14,000 new aircraft: 9,300 to satisfy new demand and the remainder to replace aging aircraft.

Future developments in CAD/CAM should link the machines most subcontractors use to manufacture components with their prime contractor's requirements data base. Additionally, competitive aircraft and component manufacturers will invest in flexible, automated manufacturing and assembly equipment that enables them to easily change projects and accommodate low production runs. Finally, future customers can be expected to continue to base purchase decisions primarily on safety and
performance factors, but "final-quality," full-scale cockpit and fuselage mock-ups could enhance marketability by allowing buyers to see and touch new concepts and product quality firsthand.

GOVERNMENT GOALS AND ROLE

Continued support from the government and changes in some government policies could help ensure the success of the aircraft industry. In response to the dwindling industrial and technological base, we submit eight recommendations for government action:

1. Continue the dual-use approach that merges civil and military practices in technologies critical to both defense and commercial enterprises.

2. Give the industry incentives to invest in high-technology facilities and advanced manufacturing equipment.

3. Promote partnerships between industry and local governments to develop and enhance education and training programs that produce workers with adequate knowledge, skills, and abilities.

4. Continue to review and, where appropriate, reform government regulations and acquisition policies that impose unnecessary and costly environmental, safety, antitrust, trade, and export restrictions.

5. Streamline the government acquisition process by adopting the best commercial procurement and accounting practices.

6. Provide incentives for companies that conduct independent research; then reward pioneering companies by adopting their products, processes, and commercial standards whenever possible.

7. Provide tax incentives for greater capital investment.

8. Reform tax laws to shorten depreciation cycles so that they more accurately reflect today's rapidly decreasing capital equipment life cycle.
CONCLUSIONS

Despite recent declines in the global aircraft industry, most U.S. and international manufacturers look forward to a positive future. During the recent decline, many U.S. manufacturers restructured and downsized their operations to ensure future competitiveness, although we believe further consolidation in the helicopter sector is still needed. However, to retain their current market share, U.S. companies will have to concentrate attention in several key areas.

The most competitive global aircraft manufacturing companies are focusing their investment and management resources on attaining the maximum benefit from the potential of the computer. Computer-based aircraft design, integration, configuration control, and manufacturing are clearly trends that will not abate. Additionally, aggressive marketing techniques, such as the use of full-scale cockpit and fuselage mock-ups to demonstrate advanced concepts and designs, appear very effective in selling aircraft. Despite their current dominance of the global market, U.S. aircraft manufacturers must become much more customer oriented and aggressive in modernizing their engineering and production base to retain their lead.

The following steps by the aircraft industry could substantially improve its success as it faces increasingly stiff global competition in the future:

1. Develop an industrywide strategy for sustainment, growth, and cooperative competition in the global marketplace, with the president of the Aerospace Industry Association leading the effort. Although members of the industry are progressing, they should advance in the same direction by means of a strategy that focuses on sustaining the core capabilities and competencies needed to advance the industry, making every effort to improve its infrastructure, technology, and work force.

2. Support efforts to eliminate artificial barriers to worldwide cooperation and consolidation. We believe the era of protecting U.S. industries from
foreign competition has passed and that emerging markets will create a new paradigm requiring global cooperation and consolidation. We expect the global industry to eventually obscure international boundaries. U.S. companies will continue to thrive if they work together with foreign companies to design, develop, and manufacture aircraft for the future.

3. Expand flexible manufacturing capabilities and exploit programs that allow high efficiency at low volume with multiple products.

4. Integrate independent R&D efforts and, when practical, merge commercial and government-subsidized R&D programs.

5. Continue efforts to automate the design, development, and manufacture of aircraft using computer-based systems. Link prime contractors and subcontractors using CAD tools that reduce the time from design to full production.
BIBLIOGRAPHY


