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In air combat, "the merge" occurs when opposing aircraft meet and pass each other. Then they usually "mix it up." In a similar spirit, Air and Space Power Journal*'s "Merge" articles present contending ideas. Readers can draw their own conclusions or join the intellectual battle-space. Please send comments to aspj@maxwell.af.mil .*

The American Aircraft Industrial Base

On the Brink

Lt Col David R. King, PhD, USAF*

Today's fighter pilots are the modern equivalent of medieval knights. We consider them products of their societies and dependent upon those societies. That is, the warrior class of knights emerged from a feudal system based on land grants required to support them, as well as their horses and squires (just as fighter pilots have their aircraft and crew chiefs). Not self-sufficient, the knight received support from complex relationships involving serfs, merchants, craftsmen, and religion. The fighter pilot receives support from an even more complex system of taxation and budgeting that enables billion-dollar research and development, together with production programs. Just as a knight depended upon a blacksmith for his weapons and armor, so does the fighter pilot rely upon the capability of the supporting industrial base.

America's armed forces in general and aircraft in particular draw their strength from the underlying industrial base. The United States owes its status as an undisputed world power to sustained investments made during the Cold War. Continued military strength will depend upon the health of the defense industrial base since developing, producing, and fielding major weapon systems can take over a decade. Unfortunately, short-term budget decisions imperil the long-term viability of that base. The decision in 2004 to cut $10.5 billion of the funding for the F-22 Raptor, thus terminating production early, represents a situation whereby current fiscal constraints discount future needs.[1] The latest Quadrennial Defense Review, however, reviewed and partially reversed such reductions to F-22 funding.

When considering the current situation, one must remember the past because airpower's achievements tend to overshadow its imperfections.[2] Due to shortsightedness, the United States, despite having pioneered manned flight in 1903, found that by World War I its industrial base lagged that of other nations—a condition which lasted through World War II. In World War I, American pilots used foreign aircraft—the US Curtiss JN-4 Jenny never saw combat. Further, American tactical aircraft were inferior to both Japanese and German fighters at the beginning of World War II, and US fighter technology trailed its German counterpart through the end of the war.[3] Indeed, Japan's Zero flew farther and faster than *any* plane in the US arsenal as World War II began.[4] To produce successful aircraft designs, the United States looked to other nations for help. For example, the North American P-51 Mustang, one of the premiere US aircraft in the war, used a British engine manufactured by Rolls-Royce.[5] We see this dependence reflected in the decision by Lockheed Martin, recently selected to provide helicopters for the US president, to use a design by AgustaWestland, a British-Italian joint venture.[6] History shows that a country must invest significant time and funds to restore a competitive aircraft industrial base.[7]

Capabilities of the Industrial Base

An industrial base represents a system of capabilities required to create, produce, operate, and support a commodity. One can view industrial capability as a pyramid whose base is the repairing of technology and whose apex is the generation of new technology and designs (fig. 1). The ability to manufacture and adapt technology falls between these two capabilities; as the capabilities progress, they become scarcer and more ephemeral. Although one can consider these capabilities a continuum, substantial gaps occur between their different levels. For example, one discovers significant distinctions between knowing how to repair or manufacture an aircraft and knowing how to create an integrated aircraft design. Both capabilities, however, remain essential to an industrial base.

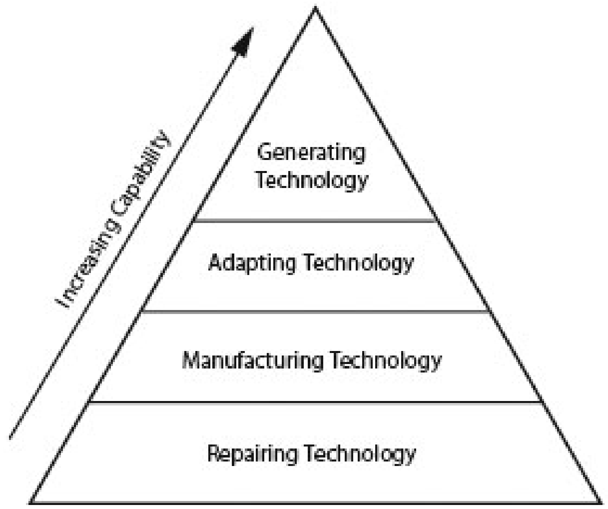

Figure 1. Capabilities of the industrial base. (Adapted from David R. King and Mark L. Nowack, "The Impact of Government Policy on Technology Transfer: An Aircraft Industry Case Study," *Journal of Engineering and Technology Management* 20, no. 4 [2003]: 305.)

Moreover, not all product technology within an industry is equally demanding. In the aircraft business, for instance, fighters require materials, avionics, engines, and systems integration that push the limits of design and manufacturing knowledge. Notably, government funding to develop engines for fighter aircraft often yields advances that subsequently find their way into commercial engines.[8] This significant transfer of experience highlights how industrial capability relies upon learning that transforms knowledge into a sense of order that guides future actions. Maintaining each level of this capability requires continued experience to sustain necessary skills.

A healthy industrial base must have prolonged investment to maintain adequate diversity and thereby enable innovation and workforce renewal. Variety encourages competitiveness in an environment of changing technology, just as multiple firms facilitate efficient operations and adaptation. Additionally, industry needs a workforce large enough so that older, experienced workers train their eventual replacements. A recent decline in the number of firms and experienced workers suggests that the health of the American aircraft industry is deteriorating.

Assessing Capabilities of the Industrial Base

We must be the great arsenal of democracy.

—Franklin Delano Roosevelt

The accomplishments of today's US aircraft industrial base have their origins in investments made during and following World War II. Subsequent declines in the number of aircraft programs pursued by the US government have had a profound impact on both the number of firms and workers in the air and space industry. During the 1940s and 1950s, 40 different jet-fighter designs by nine different defense firms took flight.[9] Consequently, the Air Force, Navy, and Marine Corps procured more fighter and attack aircraft in six years (1951–56) than in the following 34 years (1957–90).[10] To put this in perspective, consider that between 1958 and 1979 the United States and its allies took delivery of a total of 5,195 F-4 Phantom IIs, but between 1990 and 2004, industry produced only 572 fighter aircraft for the Air Force.[11]

The decline in aircraft production has contributed to industry consolidation because smaller procurement quantities and fewer aircraft programs can sustain only a few firms. Since 1990 the aircraft industry has seen significant consolidation (fig. 2), resulting in lower variety, which may adversely affect technological innovation.[12] Innovation does not occur in isolation, and available knowledge that frames the definition and solution of problems constrains the behavior of firms.[13] Thus, insufficient diversity results in a less resilient industry. Meanwhile, policy makers may expect continued innovation without realizing that recent success stems from a more robust industrial base than currently exists.

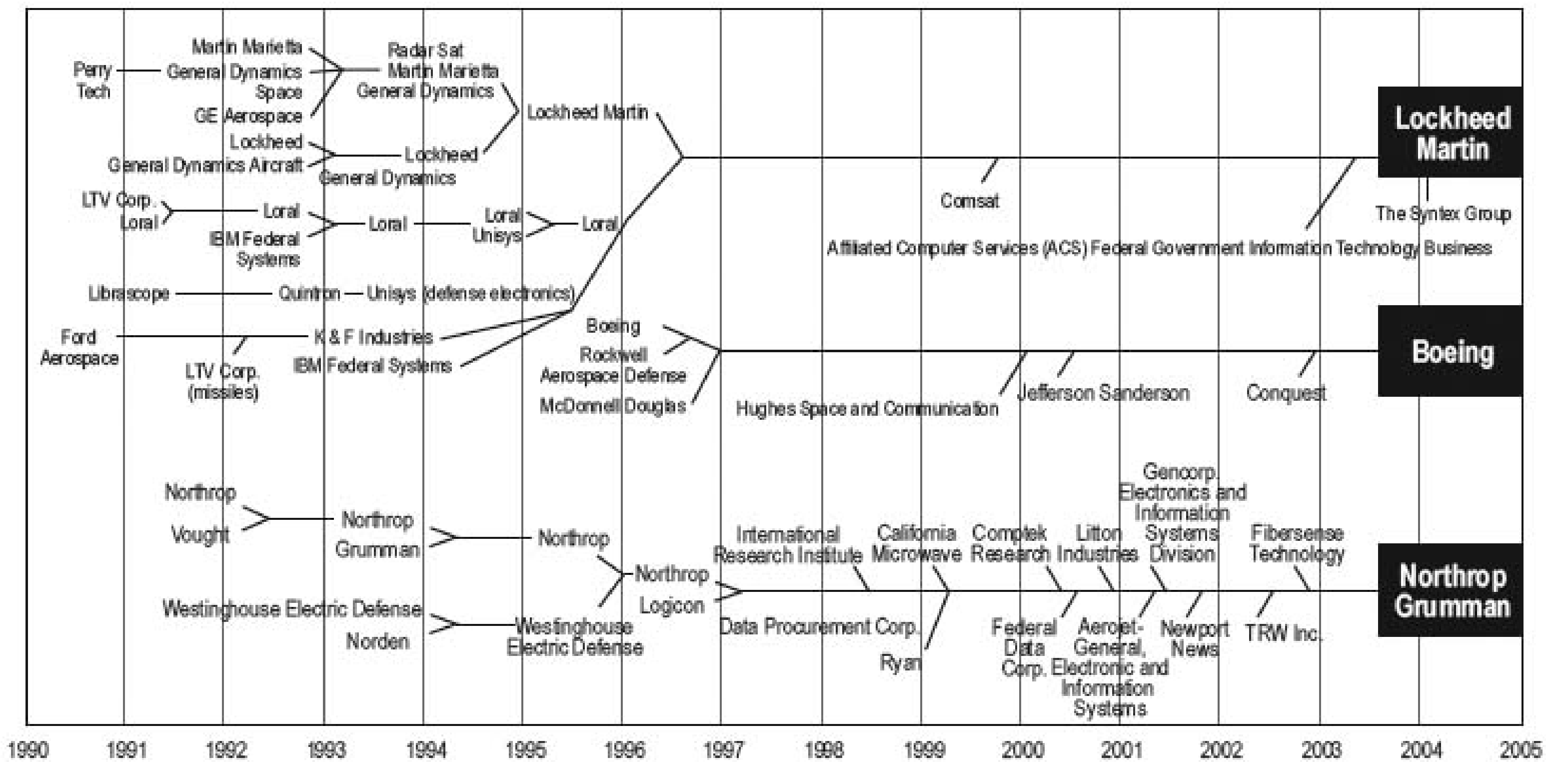

Figure 2. Consolidation of aircraft manufacturers. (From Security Data Corporation Merger Database, 2004.)

One would realistically expect lower levels of innovation from an industrial base with less diversity and correspondingly less competition over ideas and designs. Improved technology that permits fewer, more capable aircraft to replace older aircraft leads to industry consolidation, which coincides with a decline in the number of aircraft designs.[14] For example, the integrated avionics and supercruise engines of the F-22 Raptor allow it to cover two to three times the area of the F-15 Eagle, thus obviating the need for a one-for-one replacement.

Lockheed Martin won the F-22 Raptor and F-35 Joint Strike Fighter contracts—probably the last US manned-aircraft development programs for at least a decade.[15] Those two designs will replace the F-15, F-16, F-117, and A•10 but in significantly lower numbers. Fewer aircraft and improved reliability further decrease demand by reducing requirements for spares and repairs, compounding the difficulty faced by remaining firms. These businesses typically count on cash flows from their support of existing aircraft to help finance research and development that adapts and generates the new technology they need to remain competitive.

Interrelationships among prime aircraft contractors can further heighten concerns about future innovation (fig. 3). The partnering between dominant firms that typifies most recent aircraft programs can have the effect of displacing lower-level suppliers but lowers costs in the short term. For example, BAE, Northrop Grumman, and Lockheed Martin in Palmdale, California, perform work for both the F-22 assembled at Lockheed Martin in Marietta, Georgia, and the F-35 assembled at Lockheed Martin in Fort Worth, Texas, resulting in an estimated 1 to 3 percent decrease in each aircraft's flyaway cost. However, this practice of reducing costs by sharing subcontractors and components on major subsystems may hinder long-term innovation because supporting fewer firms with available procurement dollars limits variety in the industrial base.

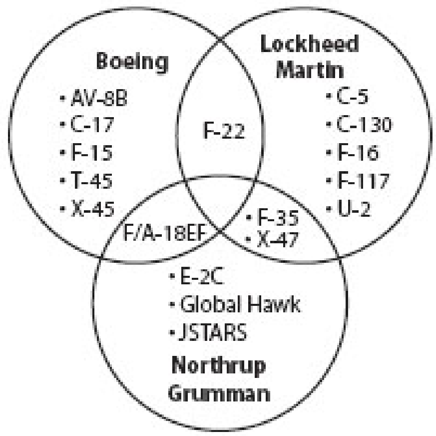

Figure 3. Interrelationships among aircraft manufacturing firms. (Adapted from John Birkler et al., *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry* [Santa Monica, CA: RAND, 2003], 31.)

Development of the Joint Unmanned Combat Air System (J-UCAS) by Boeing and Northrop Grumman seeks to limit risks from concentrating current manned-aircraft development and production with Lockheed Martin, yet Northrop Grumman still teams with Lockheed Martin. Over the next 10 years, the market for unmanned aircraft is expected to experience increased competition from new entrants as that market's value grows to exceed $10 billion.[16] If this projection proves true, the demand for unmanned aerial vehicles may help revitalize the aircraft industry with increased demand, participating firms, and competition. However, since World War II, no new firms have entered manned-aircraft production, and the early termination of the F•22 increases the cost of and risk associated with the F-35 program.

Inadequate Workforce Renewal

Consolidation in the aircraft industry corresponds to a decline in the total number of workers employed (fig. 4). The availability of a skilled workforce represents a genuine concern about maintaining a viable aircraft industrial base since a steady reduction in employment limits workforce renewal. Production of fighter aircraft, a demanding industrial capability, relies largely on an experienced workforce.[17] Sustaining a viable industrial base requires enough work to maintain and renew such a workforce.

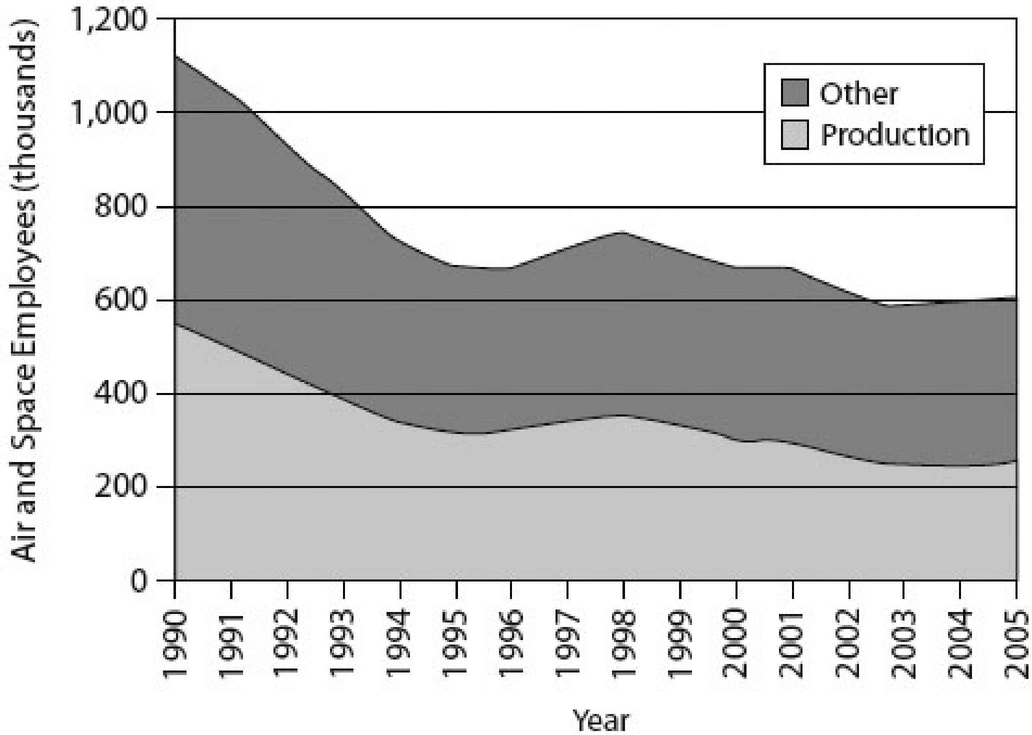

Figure 4. Total employment in the air and space industry. (From "Total and Production Worker Employment in the Aerospace Industry," Aerospace Industries Association, 25 July 2005, http://www.aia-aerospace.org/stats/aero_stats/stat12.pdf.)

The shrinking number of aircraft programs has also had an adverse effect on workforce experience (fig. 5). Sustaining the labor pool of skilled workers may prove difficult if no one replaces them as they retire. For example, machinists producing the F-22 in Marietta have over 20 years of experience but an average age of 54.[18] Although this workforce focuses for the most part on manufacturing, suppliers in over 40 states contribute to the design and manufacture of parts assembled in Marietta. Much of the work performed by these suppliers requires advanced manufacturing techniques to produce assembly components. Structure designs intended to make assembly easier, for instance, have further complicated the already challenging task of machining titanium.[19] However, the age of the manufacturing workforce in Marietta mirrors that of the design engineers working on the F-22 and other aircraft programs. Because the rapidly decreasing experience levels of air and space workers apply equally to manufacturing and engineering personnel, they should be a source of concern.

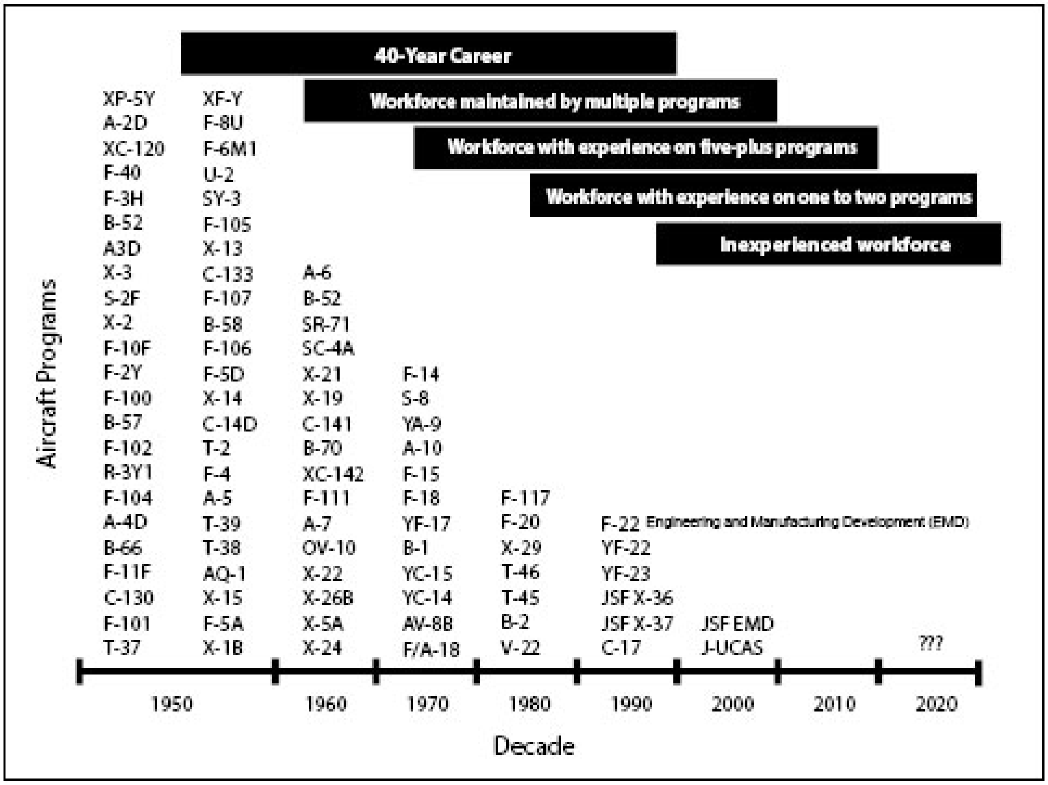

Figure 5. Aircraft programs and workforce experience. (From Mark A. Lorell and Hugh P. Levaux, *The Cutting Edge: A Half Century of U.S. Fighter Aircraft R&D* [Santa Monica, CA: RAND, 1998], 17, 95, 131, 166–99.)

The cessation of F-22 production also stops the training of another generation of workers needed for future programs. The fact that the F-35 will use Lockheed Martin's facilities in Palmdale and Fort Worth, which will no longer produce the F-22, raises concerns about sustaining an experienced aircraft-industry workforce in these locations. For example, the production gap between F-22 and F-35 aircraft in the current budget jeopardizes the crucial "art" of designing and manufacturing stealthy materials and parts in Lockheed Martin's Palmdale plant. Moreover, the F-22 and F-35 programs share several suppliers, thus increasing the risk of losing experienced workers in additional facilities. Termination of F-22 production before F-35 production matures will translate into higher costs for the latter program—at the same time the Air Force begins to rely more heavily on the F•35.

The problem of aging aircraft reinforces our need for the aircraft industry and its workforce. No doubt a "procurement holiday" during the 1990s contributed to the increased age of today's operational fighters. Because of obsolescence and structural limitations, the Air Force seeks an average age of 12.5 years for those aircraft. Currently, fighters have an average age of approximately 16 years—projected to grow to 25 years by 2012. The age of these aircraft is important because they typically have a service life of 8,000 hours, and experience shows that the costs of operating and supporting them increase as they approach that limit (fig. 6). Clearly, we need to replace current fighter aircraft.

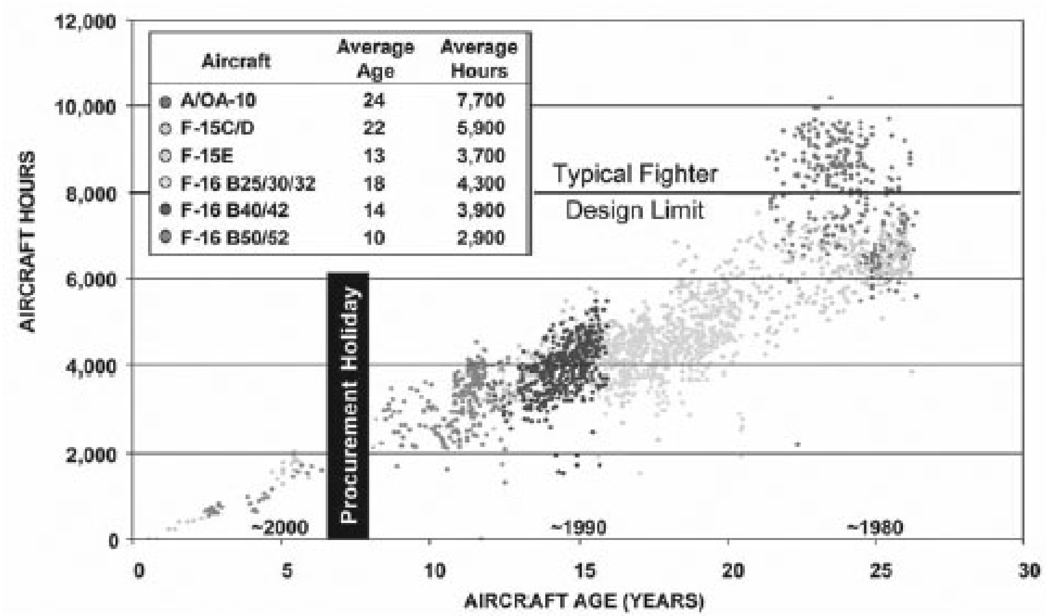

Figure 6. Current age of Air Force fighter aircraft and flight hours. (From PowerPoint chart [Washington, DC: Air Force Studies and Analysis, 2005].)

Maintaining the current force structure for Air Force fighters will probably require production of approximately 120 aircraft per year, starting now; unfortunately, we currently have neither the budget nor production capacity to manufacture that many. Continuing the production of F-22s until F-35s are fielded and their production processes mature would solve this -problem—and help maintain needed industrial capability. Due to their advanced capability, 381 F•22 aircraft could replace over 500 legacy aircraft; procurement of those Raptors would allow the Air Force to meet projected requirements at lower cost with acceptable risk.[20] However, current F-22 program funding will procure approximately 180 aircraft and extend production one year but at a lower production rate. Although the reduced rate will increase costs, one can view the higher price as the cost of insurance to maintain active aircraft production in an uncertain world.

The transition from F-22 to F-35 production needs managing to keep aircraft production open and to control the risk and cost of the F-35 program. Although the F-22 entered full production in March 2005 and established initial operational capability (IOC) in December 2005, the F-35A—the Air Force's conventional takeoff-and-landing variant—will probably not reach IOC until 2013. It is imperative to maintain production of advanced aircraft to meet the requirements of national defense. Recapitalization of America's arsenal of fighter aircraft has come at a time when available funding puts the aircraft industrial base at risk of failing to meet immediate and future needs.

Conclusion

A vital element in keeping the peace is our military establishment. Our arms must be mighty, ready for instant action, so that no potential aggressor may be tempted to risk his own destruction.

—Dwight D. Eisenhower

Industrial capability changes gradually, yet people base performance and capacity expectations on recent experience. Successes in Operations Allied Force, Enduring Freedom, and Iraqi Freedom validate the need for air and space power. However, accomplishments in these operations relied largely on an industrial base that no longer exists due to consolidation of the defense industry and a reduction in its workforce. When a condition, such as industrial capability, deteriorates slowly, perceptions gradually shift so that several years or decades may pass before people perceive significant changes in the baseline. Because the American aircraft industry has declined by many measures, available capability may not meet projected needs.

Some individuals argue that information-age warfare, brought about by advances in information technology, will reduce the importance of industrial capacity.[21] After all, the feudal system ended when changing technology and the rise of nationalism replaced knights with mass armies. Although American society is moving its focus from manufacturing to information, this shift belies the fact that people did not stop eating when the economy switched from agriculture to manufacturing. In fact, the ability to concentrate on manufacturing required modern, more efficient agriculture. Today, increased productivity allows a single farmer to feed over 100 people. Similarly, leveraging information-age capabilities calls for a modern and efficient industrial base. We must ask ourselves whether we are making investments—analogous to those we made in agriculture—to ensure that needed aircraft design and manufacturing capability exist. When it comes to the American aircraft industry, we have reason to doubt whether current investment levels will maintain that capability.

Washington, DC

[Feedback? Email the Editor]

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