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Design Trends for Army/Air Force Airplanes in the United States

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Summary

Some design trends in Army/Air Force airplane systems in the United States are traced from the pre-World War II era to the present. Various types of aircraft systems are presented with a view toward noting design features that have been used. Some observations concerning the design trends indicate that some may be driven by advanced technology and some by a need for new mission requirements. In addition, it is noted that some design trends are evolutionary and result in an extension of the service life or utility of existing systems. In other cases, the design trends may be more revolutionary with the intent of creating a system with a new capability. Some examples are included of designs that did not proceed to production for reasons that sometimes were technical and sometimes were not.

Introduction

Although the flight of the Wright brothers first airplane occurred in the United States in 1903, there was little activity in the design of new aircraft systems in this country until the 1920's. This delayed activity was, in part, due to World War I, during which time the United States was involved in supporting European countries in the manufacturing process. Experience thus gained was to be used, however, in the development of native U.S. designs. In the early 1920's, the newly created National Advisory Committee for Aeronautics (NACA) began to function at Langley Field, Virginia, and the U.S. aircraft design effort began to accelerate with the impetus provided by the availability of wind-tunnel and flight experimental data. By the time World War II started, a military and civil air fleet was fairly well established in the United States.

World War II resulted in new ideas for military aircraft, and new designs flourished during the 1950's. The growth in technology also resulted in changes to the civil air fleet, and there are some obvious instances where military and civil aircraft developments are related. During the 1970's and 1980's, the pace of new airplane designs slowed but the systems tended to become more sophisticated. Changes in technology as well as changes in mission requirements continue to be reflected in the design trends of today.

The systems included herein are confined to land-based, fixed-wing airplanes. The trends discussed are primarily those related to aerodynamic shaping, structures, propulsion, and design and development techniques. The time period involved is one in which the land-based military air force changed names several times until becoming the U.S. Air Force in 1947,

the airplane designation system was subject to some changes, and several changes occurred in the organizational makeup of the airplane industry.

Discussion

Early History

Modern aviation dates from December 17, 1903 when the Wright brothers successfully flew their heavier-than-air, mechanically propelled airplane at Kitty Hawk, North Carolina. For two decades following Kitty Hawk, however, the United States lagged behind Europe in the advancement of airplanes. It is interesting to note that the British government approached the Wrights in 1904 with an offer to buy their airplane but were refused because the Wrights wanted the United States to benefit. Interest in the United States remained elusive until 1907 when, on December 23, the War Department issued a competitive-bid specification for a flying machine. The specification was based, in part, on the Wrights estimates and, in part, on some operational requirements envisioned by the War Department. Some of these requirements were (1) ability to carry two persons with a total weight of up to 350 lb; (2) fuel for 125 mile range; (3) speed of 40 mph with a 10-percent bonus for each mph greater up to 44 mph and a 10-percent penalty for each mph lower, with rejection below 36 mph; (4) easy assembly and transport; (5) ability to operate from unprepared fields; (6) simple maintenance. The specification was less than one page in length, which is quite in contrast to the situation today where specifications may be contained in several volumes. A total of 41 responses were made with bids ranging from \$500 to \$10,000,000. The choice was eventually made in favor of the Wright's proposal of \$25,000 and 200 days. The Wright Flyer arrived at Ft. Myer, Virginia on August 20, 1908 and was readied for flight test.

The first appropriation for military aeronautics was for \$125,000 in the fiscal year 1912 War Department budget. From these funds, orders were placed for three Wright airplanes and two Curtiss airplanes. As Army flying proceeded, there were some accidents and fatalities. Records seemed to indicate that more accidents occurred with the Wright airplane, which was a pusher type, than with the Curtiss JN Jenny airplane, which was a tractor type. A Signal Corps memorandum of February 28, 1914 recommended that future flying be done only with the tractor-type airplane. Subsequently the Wright Flyer, which had been the progenitor of Army aviation, disappeared and the Curtiss airplane became quite prominent.

During the Mexican Revolution in 1913-17, an attempt was made to use the Curtiss Jenny in a

reconnaissance role. The results were dismal insofar as the mission requirements were concerned, but the lessons learned relative to operational realities were significant. The airplane was not able to perform well in the extreme turbulence near the mountains. In addition, the extreme weather that included rain, snow, and hail as well as very hot and dry conditions caused such things as delamination of wooden propellers. The lesson learned was an appreciation that airplanes must be designed to meet a range of less than optimum conditions in the field.

Thus when the United States entered World War I on April 6, 1917, the Air Service consisted of about 125 airplanes—mostly Curtiss Jennys. The only air experience was that acquired during the Mexican campaign. Some American volunteers had already been flying combat with French and British airplanes, and portions of the U.S. industry were engaged in producing airplanes for Europe.

Post-World War I

The United States acquired several European airplanes at the close of World War I. These included the Nieuport 17 and 28, the Spad XIII, the Breguet 14, the de Havilland DH-4, and the Sopwith 1½-Strutter. In addition, some new airplanes were produced in the United States. These included the Thomas-Morse S-4 series and MB-3 series, the Standard E-1 fighter and SJ trainer, the Packard-Le Père LUSAC-11, the Orenco/Curtiss D, and the Martin MB-1 and MB-2. Each of these airplanes bore a strong resemblance to British and French airplanes of World War I and did, in fact, generally use European-designed engines. Thus it is evident that, while native talent did exist, the post-World War I U.S. airplane designs did reflect a fairly significant European influence.

The Biplane Era of the 1920's

Trainers. The growing air fleet introduced a need for trainers. Among the first to be developed was the long line of Consolidated Aircraft primary trainers that began in 1923 with the PT-1. Successive modifications of this simple biplane led to the PT-3, PT-11, and PT-12, which were in use through the mid-1930's. A parallel development of the PT-3 was the O-17, a reconnaissance type with minimal design changes to fit it for its operational role.

Bombers. In the quest for a new bomber to follow the Martin MB-2, a number of projects were studied. One interesting bomber design was the Barling NBL-1, which was a huge triplane with six engines. The NBL-1 first flew in 1923 and, after limited flight testing at Langley Field, was scrapped in 1928. Other bomber designs of the mid-1920's

were patterned along the lines of the biplanes of the day. One was the Huff-Daland LB-1, which was about the size of the Martin MB-2 but was powered by a single engine. Although about 10 production airplanes were delivered during 1926, the Army decided to drop the development of single-engine bombers in favor of twin-engine types that were considered to be safer and also provided nose space for a bombardier or gunner. Subsequently Huff-Daland began the development of a twin-engine version of the LB-1 and, in a revitalized company under the name of Keystone, began to produce a series of bombers including the B-1, B-3, B-4, B-5, and B-6. Keystone bombers remained in service into the 1930's. One other twin-engine biplane bomber, the Curtiss B-2 Condor, was, in limited numbers, in service during the same period.

Fighters. Biplane designs were also used in the further development of fighter or pursuit airplanes in the 1920's. Among the earliest of these was the Curtiss PW-8 and the Boeing PW-9. These airplanes were similar in design to World War I fighters such as the German Fokker D.VII. The PW-8 became the P-1 and was the start of a long line of Curtiss Hawks. Other Curtiss Hawk biplanes that evolved, generally with engine changes, included the P-2, P-3, P-5 (all in limited numbers), and the P-6, in particular the P-6E, that was produced in greater numbers than all Hawk biplanes. In efforts to perpetuate the Hawk biplane series, Curtiss developed the XP-10, P-11 (never completed), XP-17, YP-20, XP-22, and the XP-23 which, in 1932, was the last of the Army's biplane fighters. Boeing developments in the same period included the XP-4, XP-7, and XP-8, all generally derived from the PW-9 series. With the PW-9 production series drawing to a close, the Boeing company, in a private venture, began the development of a new biplane fighter using an air-cooled radial engine rather than the water-cooled engines previously used. The new Boeing airplane was bought by the Navy and became the first of a long series of F4B shipboard fighters. As a result of an Army evaluation, the airplane was purchased and became the first of many P-12 airplanes. Many modifications were made to the P-12 during its lifetime. These included the adoption of the newly developed NACA ring cowl for improved engine cooling and reduced drag. Balanced ailerons were added, and an all-metal fuselage was introduced. Boeing had gained experience for the metal fuselage with the development of the XP-9, which was an early attempt to produce a monoplane fighter. Experience with both the XP-9 and the P-12 led Boeing to develop the XP-15, which was an all-metal monoplane parasol wing version of

the P-12. It might be noted that the P-12/F4B series represents an early use of a common design for both Army and Navy service.

Other fighter designs of the time included the Thomas-Morse XP-13. Although the XP-13 was a unique design with a metal fuselage covered with corrugated metal skin, it was not accepted, and Thomas-Morse was later acquired by Consolidated. During this time the Berliner-Joyce P-16 appeared in response to a request for a two-seat fighter. The design was a gull-winged biplane constructed of metal tubing with fabric cover and a liquid-cooled engine. The airplane was ordered into production and was redesignated the PB-1 for "pursuit, biplace". No reorders were placed for the airplane and subsequently the Berliner-Joyce company was absorbed into General Aviation Corporation, which was to become North American.

Observation airplanes. The Army maintained an interest in observation airplanes and in the early 1920's sought a replacement type for the DH-4. Curtiss developed the O-1 from the basic Hawk fighter design but lost the bid for the observation role to the Douglas O-2 biplane. The O-2 bore a striking similarity to the Douglas World Cruiser which, in turn, had been developed from the Navy DT-2 torpedo airplane. Many O-2 variants were built and further perturbations resulted in the Douglas O-5, O-7, O-8, O-9, XO-14, O-22, and O-25, all with liquid-cooled engines. These were followed by a series of airplanes having radial air-cooled engines, the Douglas O-32 and finally the O-38 which, through many variants, remained in service until well into the later 1930's. Other entries in the observation role included the Curtiss O-11 and O-39, which were variants of the Curtiss O-1. These airplanes represented the last of the Army observation biplanes. One variant of the O-1, with forward-firing guns, was designated the A-3 and given the role of ground attack.

The Monoplane Era of the 1930's

Although the biplane design had resulted in many successful airplanes, it became apparent near the end of the 1920's that the upper limit of performance for biplanes was about to be reached. Some monoplane racers had, in fact, demonstrated speed capability superior to that for biplanes.

Fighters. Boeing, at the request of the Army, began the design of a monoplane fighter in 1928. Some design and development problems were encountered, but the airplane, designated XP-9, was delivered in September 1930. Structural considerations led to a high, body-mounted, strut-braced wing. The airplane had an all-metal structure and a semi-

monocoque fuselage that was to set the pace for future designs. The cockpit was just aft of the wing, and pilot visibility was poor. The flying characteristics were also considered to be poor, and the XP-9 was not produced.

The second monoplane fighter to be built was also a Boeing design, the XP-15. The XP-15 was a derivative of the highly successful P-12 biplane design and was, in effect, a P-12 with the lower wing removed. The result was a parasol-mounted, strut-braced wing, with the advantages of the monoplane without the visibility limitations of the XP-9. The XP-15 did make use of the metal structure design of the XP-9, however. Although the XP-15 was a good performer, it did not go into production, but some of the metal structure was adopted for later versions of the P-12 series.

The first operational single-seater monoplane fighter to enter Army service was, however, a Boeing design, the P-26 Peashooter. The P-26 had a wire-braced low wing, a radial engine, an open cockpit, and a fixed gear with streamlined wheel and strut fairings. About 136 airplanes were delivered, and the P-26 was the Army frontline fighter from 1934 until the early 1940's. Boeing produced a follow-on design, the evolutionary YP-29, which had a fully cantilevered wing, an enclosed cockpit, and a semi-retractable gear, but kept the same engine as the P-26. The expected drag reduction was offset by increased weight, and the YP-29 showed no great improvement over the P-26 and the project was abandoned. A more powerful reengined version designated the XP-32 was proposed but never built.

Curtiss offered the Army a competitor for the P-26 in the XP-31 Swift, which was the first monoplane fighter built by Curtiss. It was generally similar to the P-26, with a fixed gear having streamlined fairings and with a radial engine. The low wing was strut braced, and the cockpit was enclosed. The radial engine was soon replaced by a liquid-cooled engine. The XP-31 was quite heavy, however, and the performance was inferior to the P-26 and the project was dropped.

Follow-on Army fighters that resulted from a competition to replace the P-26 were the Seversky P-35 and the Curtiss P-36. The P-35 was a private venture of the Seversky Aircraft Company, which subsequently became Republic Aviation Corporation. The P-36 was a continuation of the famous Curtiss Hawk series. Both the P-35 and the P-36 were all-metal cantilevered low-wing designs with enclosed cockpits, retractable gear, and radial engines. While Seversky was declared the nominal winner of the initial competition, both companies were awarded contracts and ultimately more P-36's were produced than P-35's.

The only two-seater fighter to be produced during the 1930's was the Consolidated P-30 (PB-2). The P-30 was a low cantilever-wing design with a fully retractable landing gear and an enclosed cockpit for two. The concept began with the Detroit-Lockheed Company as the YP-24, delivered to the Army in September 1931 as a possible replacement for the Berliner-Joyce P-16 (PB-1) biplane. The general design was based on the successful Lockheed Vega and Orion monoplane airliners. The airplane performed well and production was ordered, but Detroit-Lockheed was in financial difficulty and defaulted. When the company failed, some of the designers joined Bell Aircraft and some joined Consolidated Aircraft. The P-24 design was further refined by Consolidated, and was built as the Y1P-25. The Army was impressed with the performance of the airplane, and a further refined and reengined version was produced as the P-30.

Observation airplanes. Monoplanes were introduced by Douglas after the successful O-38 biplane series. The first was the XO-31, an all-metal airplane with a wire-braced gull-wing and a liquid-cooled engine; it appeared in 1930. Several modifications were made to the airplane, one being a change to a parasol wing, and it was designated the O-43. A further change to an air-cooled radial engine resulted in the O-46 airplane.

The last of the designated observation airplanes was the North American O-47. The O-47 was begun in 1934 by General Aviation, which later became North American. The O-47 was an all-metal airplane with a low cantilever wing and a retractable landing gear. The deep-bellied fuselage had glass panels in the bottom to improve downward observation. The O-47 was in service until the early 1940's but did not perform operational missions in World War II. After the O-47, the role of the dedicated observation airplane was performed by light airplanes for such things as artillery spotting and by special airplanes for reconnaissance and photography.

Attack airplanes. The monoplane design was used in seeking an improvement in the attack role that had been filled by the Curtiss A-3. Designs that were proposed were the Atlantic-Fokker XA-7 and the Curtiss XA-8 Shrike. Both were powered with a liquid-cooled engine and, in addition to forward-firing guns, also carried bombs. The A-8 was selected and produced. Further modifications that included a change to radial engines resulted in the Curtiss A-10 and A-12. Northrop, in a private venture, proposed an attack airplane in 1933 based on their successful Gamma and Delta commercial monoplanes. The first prototype, designated XA-13, had a low cantilever

wing, a fixed gear, a radial engine, and an enclosed two-place cockpit. An engine change resulted in the XA-16. Further changes, including a retractable landing gear, resulted in the production A-17 Nomad.

Bombers. With the aging of the Keystone bombers, some attention was turned to the development of a new bomber. In early 1931, Boeing, in a private venture, produced a design for a bomber that was based, in part, on the successful Monomail commercial airplane. The design, which became the B-9 bomber, was an all-metal airplane with a low cantilever wing, twin radial engines, retractable gear, and four separate open cockpits. One YB-9 was powered with in-line air-cooled engines, but it proved to be inferior to the air-cooled radial engine design. Although the performance of the B-9 was markedly superior to that of the Keystone bombers, the airplane did not go beyond the prototype stage.

The bomber that was to replace the Keystone bombers was the Martin B-10, in development as a company private venture at the same time as the Boeing B-9. The B-10 had a cantilever midwing, radial engines, retractable gear, and three separate enclosed cockpits, including the first rotating nose turret on an American bomber. The performance was superior even to that of the B-9, and the B-10 was ordered in quantity in 1933 and remained in service until the late 1930's. Two other reengined versions of the Martin bomber were designated the B-12 and B-14.

The Pre-World War II Era

Near the end of the 1930's there was considerable activity in the development of military airplanes in the United States because of the impending involvement in fighting that had already begun in Europe.

Trainers. The need for trainer airplanes to follow the Consolidated PT's led to the introduction in 1934 of a private venture of the Stearman Division of United Aircraft that was to become the PT-13. The PT-13 was a rugged, conventional biplane with a fixed gear, a radial engine, and two open cockpits. A reengined version was produced as the PT-17 Kaydet.

Another quite different primary trainer was produced by Ryan as a version of the Ryan ST (Sport Trainer) and was designated the PT-16. The PT-16 was an all-metal airplane with a low, wire-braced monoplane wing, fixed gear with streamline fairings, an in-line engine, and two open cockpits. Other revisions included a reengined PT-20, and the PT-21 and PT-22 with radial engines. These were produced in quantity through 1942.

Another primary trainer began as a private venture by Fairchild and was designated the PT-19. The PT-19 had an in-line engine, a low cantilevered wing, a fixed landing gear, and two open cockpits. A modified version incorporating a radial engine was designated the PT-23.

A private venture by North American, the NA-16, appeared in 1935 and was adopted by the Army as a basic trainer with the designation BT-9. The BT-9 had a low cantilever wing, a radial engine, a fixed gear, and a two-place enclosed cockpit. Further modifications with an all-metal fuselage, a new tail assembly, and a more powerful engine resulted in the BT-14. Further changes incorporating a more powerful engine and a retractable gear resulted in the AT-6 Texan advanced trainer, of which about 20,000 were produced up through about 1945.

A private venture by Vultee, the Model 54, was selected by the Army and became the most used basic trainer, the BT-13 and BT-15 Valiant. These airplanes had a low cantilever wing, a fixed gear, a radial engine, and a two-place enclosed cockpit.

Some advanced trainers of the era included the Beech AT-7 navigation trainer and AT-11 Kansan bombing and gunnery trainer. These were developments of the C-45 Expeditor transport, which was a version of the basic Beech Model 18 twin-engine light commercial transport.

The Beech AT-10 was an advanced pilot trainer developed from the twin-engine Beech Model 26. The AT-10 was constructed primarily of wood to avoid the use of strategic metals.

The AT-8 and AT-17 were developed from the first Cessna twin-engine transport, the T-50. A transport version was designated the C-78.

The Lockheed AT-18 was developed from the commercial Model 14 of the late 1930's. These were used as gunnery and navigation trainers.

Fighters. In the early days of World War II, the latest foreign fighters with slim in-line engines were generally capable of higher speeds than the United States P-36. The Army invested in the development of in-line engines by Allison for potential use in fighter airplanes. Curtiss, with a view toward staying in the fighter market, adapted the Allison engine to a P-36 airframe and produced the XP-37. The length of the engine and radiator was such that the cockpit had to be moved rearward, with a loss in pilot visibility. In addition, the airplane was heavier than its predecessors and did not achieve the anticipated speed. Although a few YP-37's were built for test, the airplane was not produced. A further revised P-36 airframe was used to correct the shortcomings of the YP-37, and the result was the Curtiss P-40

Warhawk with a relocated radiator near the nose and a more forward cockpit. By using the proven P-36 airframe and the proven Allison engine, it was possible to put the P-40 into immediate production, and it was the primary Army fighter at the outbreak of U.S. participation in World War II. Many changes were made to the P-40, and it remained in service until the mid-1940's.

Further revisions of the basic P-36 were pursued by Curtiss in an effort to perpetuate their presence in the fighter market. These designs included the XP-42. The XP-42 kept the radial engine of the P-36, but an attempt was made to reduce the drag by using an extended forebody cowl and a propeller with a large spinner attached by means of an extension shaft. Cooling problems were encountered, however, and the drag reduction was negligible. Although several cowl arrangements were tried, none were adequate and the project was stopped. The XP-42 was used, however, by the NACA at Langley Field in 1942 in flight tests of an all-moving tail that provided much information for later use on the longitudinal control systems of high-speed airplanes.

The Curtiss XP-46, using a new Allison in-line engine, was intended to include modifications thought to be desirable based on pilot combat experience. One of these features was automatic leading-edge slats similar to those used on the German Messerschmitt 109. However, the airplane was a disappointment. The weight was increased by the addition of self-sealing fuel tanks and armor plating, and much of the equipment was inaccessible, making maintenance difficult. The project was dropped.

The XP-53 was another attempt by Curtiss to replace the P-40. Power was provided by a Continental experimental inverted-V in-line engine and the newly developed NACA laminar-flow wing was used. The airplane had self-sealing tanks and a bulletproof windshield. The XP-53 was delivered but never test flown.

The Curtiss XP-60 was built in 1941 in response to an Army request for a laminar-flow-wing fighter powered with a Rolls-Royce Merlin engine. The airplane was derived from one of two XP-53 prototypes primarily by changing from the Continental engine. Many modifications were made in the course of the P-60 program, including various in-line engines as well as radial engines and a contrarotating propeller version. After extensive and generally successful testing, the entire program was finally canceled in favor of other airplanes.

Curtiss built the XP-62 airplane in response to a 1941 Army request for a fighter with a new Wright 18-cylinder radial engine and with a requirement for a pressurized cockpit. At the time, the design was

the largest single-seat, single-engine airplane to be built in the United States. Many delays, particularly with the engine, contrarotating propellers, and cabin pressurization system hampered the program; and eventually, after very little flying, the project was scrapped. It was the last Curtiss fighter to be built.

A follow-on to the Seversky P-35 was test flown by the Air Corps at Langley Field in 1939. The airplane was, in fact, a modified P-35 with a more powerful turbosupercharged engine and an inward retractable gear and was designated the XP-41. Republic Aviation, which was formed from Seversky, further pursued the design with a proposed development that was put in production as the Republic P-43 Lancer. A more powerful modification, designated the P-44, was not produced, but the basic design of the P-43 and P-44 would subsequently lead to the P-47 Thunderbolt of World War II fame.

Lockheed introduced a break in the evolutionary design of fighters with the design of the P-38 Lightning. Lockheed, after having been relatively inactive in the fighter field, responded to a 1936 Army request for a high-altitude interceptor with a completely new design—the XP-38. The P-38 was the first twin-engine Army fighter with two in-line engines mounted on twin booms that extended rearward to support a twin-tail assembly. The single-seat cockpit was mounted in a center pod that also housed a tremendous amount of firepower in the form of four machine guns and a cannon. The P-38 also had a tricycle gear—another first for an Army fighter. When the United States entered World War II, the P-38 was the Army's fastest and most heavily armed fighter. Several modifications were made to the airplane during its service life, including one version with a bombardier nose. The basic design of the P-38 was also used by Lockheed in the XP-49, which had increased power, a pressurized cockpit, and two cannons. The airplane showed no notable improvement over the P-38 and production plans were dropped. Another even larger airplane with the same basic design was the Lockheed XP-58 Chain Lightning, proposed for a requested long-range bomber escort in 1940. The airplane had more powerful engines and, at the rear of the center pod, had a second crew station with a powered gun turret. Two airplanes were built, but plans for production were dropped.

North American introduced another new dimension in the development of fighters with the design of the P-51 Mustang. The P-51 design originated from a request of the British in early 1940 for a fighter to bolster their dwindling strength and to outperform enemy aircraft. The P-51 proved to be eminently successful and was subsequently procured by the United States also. The P-51 used the NACA

laminar-flow airfoil section and a unique low-drag radiator located about halfway back on the underside of the body. Another unique feature of the P-51 was that it was designed and built within a 120-day limit imposed by the British.

Bell Aircraft, formed in the early 1930's by some of the designers from the defunct Detroit-Lockheed Company, was responsible for several unique fighter designs. One, the YFM-1 Airacuda, was a five-place twin-engine pusher design with a tricycle gear. Several were built for testing, but none entered service. Another, the P-39 Airacobra had an unusually located in-line engine in the fuselage aft of the cockpit, with a long shaft under the pilot's seat extending forward to the propeller. In addition to machine guns, the P-39 was equipped with a 37-mm cannon that fired through the propeller shaft. The airplane had a tricycle gear made simpler for nose wheel stowage since there was no engine in the nose. The P-39 was exported to England and the Soviet Union, with the Soviet Union getting about 5000 of the 9558 that were built.

Grumman introduced a twin-engine fighter as the runner-up in the Army competition won by the Lockheed XP-49. The Grumman design was the XP-50, which was based on the existing Navy shipboard design by Grumman, the XF5F-1. The airplane had twin wing-mounted radial engines and twin vertical tails tip-mounted to the horizontal tail. Although one airplane was built for testing, the airplane crashed and the program was terminated.

Bombers. In 1934, the Army issued a specification for a bomber to replace the Martin B-10. Proposals were received from three companies. One, submitted by Martin, was an enlarged version of the B-10 in the hope of perpetuating the life of the design. Douglas submitted a twin-engine design that bore a strong resemblance to their highly successful DC-2 commercial transport. Designated the B-18 Bolo, the bomber was placed in production and was in service with most Army Air Corps squadrons when the United States entered World War II in 1941. Several modifications were made to the B-18 during its production, and a substantially revised design, designated the B-23 Dragon, also saw limited service.

Boeing submitted a four-engine design designated the B-17 Flying Fortress. Previous Boeing experience included the twin-engine B-9 and the Model 247 commercial transport. In addition, Boeing gained further experience since they had already responded to a 1933 Army Air Corps request for a long-range heavy bomber by producing the four-engine XB-15, which, at 70 700 lb, was the largest airplane built in the United States up to that time. Although only a

few B-17's were on hand at the outbreak of World War II, the airplane was destined to replace the B-18 and become the mainstay of the bomber force.

Attack airplanes. The concept of attack airplanes beyond the Northrop A-17 evolved into the later 1930's through a chain of circumstances. Northrop became a subsidiary of Douglas Aircraft and provided the expertise that resulted in the Douglas SBD Navy dive bombers. The Army, having noticed the devastating effects of the German Stuka dive bombers in France, acquired a version of the SBD's and designated them the A-24 Dauntless. Another Douglas design, the DB-7, was a twin-engine three-place airplane originally produced for the French as a light attack bomber. After the fall of France, the airplane was quite effectively used by the British. The United States was interested in the airplane and acquired a number of them as the A-20 Havoc. Another version having a nose-mounted radar was designated the P-70 and was put into service as the first Army Air Force night fighter.

The World War II Era

The United States entered World War II in December 1941 with an Air Corps that was fashioned, in part, on lessons learned by observation of the fighting taking place in Europe. New lessons were yet to be learned, partly due to continued German ingenuity and partly due to the spread of war to the Pacific.

Fighters. Early in the 1940's, the Army was seeking advanced designs for fighters in anticipation of involvement in the war in Europe. Proposals were received from several companies. Bell Aircraft, well known for unusual designs, proposed the XP-52. The design was for a twin-boom pusher configuration. Tail surfaces were mounted on the booms and a center body housed a cockpit in front and an inline engine aft that was to drive contrarotating propellers. Although suggestive of potential advantages in visibility, maneuverability, and armament, the XP-52 and a follow-on larger XP-59 design were never produced. Vultee also proposed an unconventional fighter designated the XP-54 Swoose Goose. This design was a twin-boom pusher type with a single in-line engine mounted in the rear of the center body and tail surfaces mounted on the twin booms. The forebody was fairly long and included an articulating section that could be elevated for lobbing low-velocity cannon shells or depressed for firing machine guns. The bottom of the body was nearly 6 ft above the ground. Access to the cockpit was achieved by dropping a hinged portion of the underside of the body and lowering and raising the seat on a rail.

The same system was used for the downward ejection seat. Only two airplanes were built and, after an extensive flight test program, the project was dropped. Curtiss also proposed an unorthodox design designated the XP-55 Ascender. The XP-55 was a single-engine pusher having a swept wing with tip-mounted vertical tails and a canard surface mounted on the forebody. The airplane experienced stability problems and the project was dropped. Northrop proposed an unorthodox design designated the XP-56 Black Bullet. A flying-wing configuration, the XP-56 had a short, stubby body with a cockpit forward and, at the rear, an air-cooled radial engine driving contrarotating propellers. Vertical surfaces were mounted both above and below the afterbody. The slightly swept wing had tip-mounted venturi tubes with a valve arrangement that was used to provide yaw control. Flight tests of the XP-56 were disappointing, and the project was terminated. Tests of these unconventional designs, while being educational, did not produce the desired results for an advanced fighter. In view of the success of conventional designs in combat, the unorthodox design project was abandoned. Only a few new fighter designs resulted in operational airplanes during World War II. One was the Northrop P-61 Black Widow, intended to fill the need for an all-weather night fighter. The P-61 was a twin-engine, twin-boom, three-place design quite similar to the Lockheed XP-58. The P-61 had almost full-span flaps to reduce the landing speed and had very small ailerons at the wingtips that were supplemented by spoilers for roll control.

The firepower was formidable with four 20-mm cannons and four 0.50-caliber machine guns that were turret mounted on top of the body. Bell Aircraft produced the P-63 Kingcobra as a follow-on to the P-39. While the designs were similar, the P-63 had a laminar-flow wing and a more powerful engine. None of the P-63's were used operationally by the United States, but almost 2500 were sent to the Soviet Union on the lend-lease program. Several other fighter designs appeared during World War II but did not enter the active inventory. The North American NA-50 was developed from the BT-9 as a fighter for Peru and Siam. Six were being delivered to the Siamese at the time of the Japanese attack on Pearl Harbor. These were confiscated by the Army and designated the P-64. Grumman developed the XP-65, following the demise of the XP-50, as a refined twin-engine fighter. The XP-65 had a Navy counterpart, the XF7F-1. As the designs proceeded in flight test, it became apparent that the Army and Navy missions were so different that one design would not be satisfactory—a situation that was to recur in later years. The XP-65 version of the airplane was dropped in favor of the

XF7F-1 since Grumman had been a major supplier of Navy fighters for many years. Vultee, in a company project, designed an airplane intended to provide a place for Vultee in the U.S. fighter inventory. The airplane was a clean single-seater with a single radial engine somewhat similar to the Curtiss XP-42. The Army was not interested, but Sweden placed an order. The United States put an embargo on export to Sweden, and eventually some of the airplanes were delivered to China instead. The United States acquired a few of the airplanes as the P-66 Vanguard. The XP-67 was the first fighter design from the McDonnell Aircraft Company. The airplane had a single seat and twin in-line engines. The XP-67 was a graceful design with blended wing-body and wing-nacelle fairings. The handling characteristics were considered to be good, but the airplane was underpowered and, following an engine fire accident, the project was dropped. Republic proposed the XP-69 as an intended follow-on to the successful P-47. The XP-67 would have had a midbody-mounted radial engine and contrarotating propellers attached with a long shaft passing beneath the cockpit. Only a mock-up was built, and the project was discontinued in favor of another Republic proposal already underway---the XP-72. The XP-72 resembled the P-47 except for a much slimmer nose which, nonetheless, housed a 28-cylinder 3450-hp radial engine. Flight testing indicated outstanding performance, particularly in acceleration. A production contract was approved and then rescinded when Air Force requirements were revised to procure more long-range bomber escort fighters instead. Curtiss proposed the XP-71 as a long-range escort fighter. This design incorporated two wing-mounted 3450-hp radial engines driving contrarotating pusher propellers. Formidable armament would have included two 37-mm cannons and one 75-mm cannon. Two prototypes were ordered, but the XP-71, which would have been about the size and weight of some of the bombers to be escorted, was canceled before construction could begin. The Fisher Division of General Motors proposed a fighter, the Fisher P-75 Eagle, that had a midbody-mounted in-line engine driving nose-mounted contrarotating propellers on an extension shaft. The design included an assortment of components from several existing airplanes as a way to save time and cost. While the idea was worthwhile, the results were not. Production of 2500 was authorized, but because of poor performance only six were produced before the program was canceled. Bell proposed the XP-77 as a lightweight fighter. The XP-77, at a gross weight of less than 4000 lb, was a small all-wood fighter intended both to save strategic metals and to provide performance to counter the Japanese Zero fighter. Of

25 planned airplanes, only 2 were built since no significant advantages were apparent and interest waned.

Bombers. With the reality of World War II at hand, the Army saw a need for additional bombers. Various types intended to augment the wartime needs were produced by several companies. The Consolidated B-24 Liberator was designed by Consolidated Vultee as a 4-engine long-range strategic bomber to augment the role of the B-17. The B-24 was different from the B-17 in having a high wing with the new Davis high-lift airfoil section, twin vertical tails and a retractable tricycle gear. The North American B-25 Mitchell originated as a private venture in response to a 1938 Army request for a medium bomber. The highly successful B-25 had twin radial engines, twin vertical tails, and a retractable tricycle gear. The B-25 was well known for the Doolittle Tokyo raid, for which the fully loaded airplane was required to take off from an aircraft carrier. One B-25 variant introduced a new dimension of firepower in the Pacific war with a 75-mm cannon in the nose and 14 0.50-in. machine guns. The Martin B-26 Marauder was designed in response to the 1939 Army request for a high-performance medium bomber. The B-26 had a high wing with two radial engines, a single vertical tail, a retractable tricycle gear, and was highly streamlined. With a relatively high wing-loading, the B-26 had the reputation of being difficult to fly. The Boeing B-29 Superfortress was designed in response to an Army requirement for a hemisphere defense weapon. The B-29, while bearing some resemblance to the B-17, was more an outgrowth of the XB-15 program and provided a substantial increase in payload, range, and speed over that of the B-17. The B-29 is the airplane that dropped the two atomic bombs on Japan in 1945. The Convair B-32 Dominator was designed in response to the Army requirement for a hemisphere defense weapon. Although the requirement was met by the B-29, prototypes of the B-32 were ordered as insurance against possible failure of the B-29. Several iterations of the B-32 design resulted in a high wing design with four radial engines and a single tall vertical tail, and these were produced in an unpressurized version for low-altitude missions over the Pacific.

Attack airplanes. In response to a 1940 British requirement for a dive bomber, Vultee produced a two-seat, low wing, single radial engine design that was delivered under the lend-lease program as the A-31. When the United States entered the war, a number of the airplanes were repossessed and, equipped to U.S. Army standards, were designated the A-35 Vengeance. The Army made very little operational use of the airplane, however. The

Douglas A-26 Invader was designed in response to a 1940 Army requirement for a light attack-bomber to perform the missions of the A-20, B-25, and B-26. Similar in design to the A-20 but with more powerful engines and a wide assortment of armament, the A-26 was the primary attack airplane for the Tactical Air Command upon its formation in 1946. The designation for the airplane was later changed to B-26 after the Martin B-26 was withdrawn from service.

Cargo airplanes. Logistic support airplanes for transporting personnel and cargo became an important part of the wartime effort. A variety of types were provided by several companies in the World War II era.

In the mid-1930's, Douglas produced a military variant of the highly successful DC-2 commercial airliner which was designated the C-32. Other minor variants were designated C-33, C-34, and the C-38, which became the prototype for the C-39. The C-39 was a hybrid design based on the DC-2, DC-3, and B-18 and was the primary transport in the early days of U.S. involvement in World War II. The follow-on transport, which became very well known, was the C-47 Skytrain conversion from the DC-3. Under a license agreement with Douglas, the DC-3 was also produced in great numbers by the Soviet Union as the Li-2 in both a civil and a military version. The next wartime transport by Douglas was the C-54 Skymaster, a conversion of the four-engine DC-4. Curtiss began the development of a commercial transport in the late 1930's that was converted in the early 1940's to a military transport, the C-46 Commando. The C-46 had an impressive large-volume double-bulge fuselage and was the largest and heaviest twin-engine airplane to see operational service with the Army Air Force during World War II. The load-carrying capacity was put to use in flying the mountainous supply route, known as the hump, between India and China.

Lockheed, in the interest of maintaining a portion of the commercial airliner market, began the design of the four-engine, triple-tail Constellation in the late 1930's. When the United States entered the war in 1941, those airplanes already on the production line were diverted to the Army Air Force and designated the C-69. The C-69 was the fastest transport to be acquired at the time. At the end of the war, the C-69 was declared surplus and was resold to the airlines.

Fairchild designed the C-82 Packet in 1941 in response to an Army Air Force requirement for an airplane expressly intended to be used as a tactical cargo and troop transport. The design featured a high wing, twin engines that faired into twin booms that supported the high twin-tail assembly, and a large square centerbody that was low to the ground

and equipped with an unencumbered loading ramp and large, rear clamshell doors.

The Post-World War II Era

Following World War II, many of the more successful airplanes thought to be necessary from a mission-oriented point of view were retained in the Army Air Force. Others, not considered to be essential, were dropped from the inventory or transferred to a civil role. A new era in design thinking was just beginning, based on mission requirements learned from the war and on new technology that came to light near the end of the war. The primary new technology was the introduction of jet propulsion, and to some extent, rocket propulsion. The British were making good advances in jet engine propulsion and the Germans, before the end of the war, were already flying jet- and rocket-propelled airplanes and missiles. Many new designs and modifications of existing designs were underway in the United States as the war ended.

Fighters. In the post-World War II period, the "P" designation for pursuit was changed to "F" for fighter—hence there are cases where the same fighter airplane might be given either designation. Many fighter designs were forthcoming during this period.

Bell Aircraft, already the creator of several unusual designs, had begun a proposal in the early 1940's in response to the Army's search for advanced fighter designs. The proposal, designated XP-52, was a propeller-driven, single-engine, twin-boom pusher configuration. Continued development of the XP-52 led to a larger version designated the XP-59. Before the mock-up was completed, the design was canceled in favor of an even more advanced design that was to use jet propulsion. To maintain secrecy for the project, the XP-59 designation was retained although the configuration was completely changed. Jet engines, based on the British Whittle engine, were made by General Electric and two were located under the wing roots with twin inlets just ahead of the wing leading edge and twin nozzles just aft of the trailing edge. The XP-59 Airacomet, on October 2, 1942, became the first American jet airplane to fly. The airplane had a tendency to sway from side to side, probably as a result of jet flow interaction, and was not considered suitable as an operational fighter but was used as a trainer. A proposal for a single-engine version with twin wing root inlets and an underbody nozzle was considered but never materialized. Bell did proceed with a larger design similar to the P-59 that was intended to provide greater fuel capacity for increased range. Designated the XF-83, only two prototypes were built. Flight tests indicated

no significant improvement in performance since the added fuel capacity took its toll in weight and drag.

The Bell single-engine proposal was relinquished to Lockheed and within 143 days resulted in the Lockheed P-80 Shooting Star—the first operational U.S. jet fighter. First flown in January 1944, the P-80 was the first American fighter to exceed 500 mph. While not in time for service in World War II, the P-80 was used in Korea. After Korea, the P-80 was gradually replaced by more advanced fighters. The two-place trainer version, T-33, remained in service much longer, and some are still flying today.

High fuel consumption of early jet engines led Convair to the design of the XF-81, in which the first U.S. turboprop engine was combined with a jet engine. The turboprop engine was mounted at the nose and the jet engine was in the afterbody with twin shoulder inlets at about midbody aft of the cockpit and a single nozzle at the fuselage rear. The performance of the turboprop engine was not good, however, and only two prototype airplanes were built.

In the midst of the new jet age, North American introduced an approach to attaining a long-range fighter by designing the piston-powered F-82 Twin Mustang. This was essentially the coupling together of a pair of P-51 bodies with a common wing and stabilizer structure. The F-82 was effective and was used in the Korean war.

In 1944, Republic conceived a highly secret design for a jet fighter to succeed their P-47. The design, known as the F-84 Thunderjet, was similar to the Lockheed P-80, with a conventional tail arrangement, a straight wing, and a single jet engine but differed in that a single nose inlet was used. The F-84 became the first new U.S. fighter to fly following the end of World War II.

A revolutionary concept by North American, the F-86 Sabre, became the first U.S. swept-wing jet fighter. The design was begun in 1944 as the FJ-1, the first Navy jet fighter, and originally had a straight wing. The Air Force was interested in the design and ordered a version designated XP-86. The knowledge of German swept-wing designs had arrived in the United States and additional experimental data were generated in NACA wind tunnels. Because of the speed advantages to be expected from the use of swept wings, the XP-86 design was changed to incorporate a 35° swept wing with automatic leading-edge slats, and thus the first U.S. swept-wing fighter was born.

The Curtiss XF-87 was conceived in 1945 in response to the Air Force specification for an all-weather jet fighter. Curtiss encountered some difficulties, partly because of inexperience with jet airplanes. The airplane was quite large because of the

volume allowed for fuel. The XF-87 had a conventional straight wing and aft tails, side-by-side seating for the two-man crew, and four jet engines wing-mounted in two huge nacelles. Planned armament included four swiveling 20-mm cannons that fired in a 60° arc and could be angled from 0° to 90° from the centerline. One prototype was built and flew in 1948, and a production contract was awarded. However the program remained plagued with problems of weight, buffet, and insufficient power and was soon canceled. The XF-87 was the last Curtiss airplane.

In mid-1946, the Air Force issued a contract to McDonnell for a long-range penetration fighter designated the XF-88. The design was a single-seater that had a 35° swept wing, an aft tail, and twin jet engines housed midship in the fuselage. Twin inlets were located in the wing root leading edge, and twin nozzles were located on the underside of the body about midway between the wing and tail. Such a propulsion arrangement was to appear on other McDonnell fighter designs yet to come. The airplane was underpowered and was placed in storage, and the program, for the moment, was suspended.

The F-89 Scorpion was designed by Northrop as a twin-jet, two-seat, all-weather fighter to replace the P-61. The Air Force accepted the design and ordered the F-89 into production. The configuration had a straight wing and a conventional aft tail. The two jet engines together with inlets and nozzles were semiembedded in a position about midship on the underside of the body with a minimum of ducting.

The Lockheed XF-90 was developed in parallel with the McDonnell XF-88 for the long-range penetration fighter role. The XF-90 had a moderately swept wing and twin jet engines mounted internally in the fuselage. The design was similar to the XF-88 but differed in ducting, having twin inlets mounted on the body forward of the wing and nozzles at the rear of the fuselage. The design also bore a family resemblance to the Lockheed F-80 but differed in the slight wing sweep and in the use of two engines with twin nozzles at the rear. The eruption of the Korean War, however, resulted in the program being dropped.

Bombers. As World War II was ending, Boeing made several revisions to the B-29 including more powerful engines, a new fin, a new undercarriage, and a new lighter wing structure and produced a conversion designated the XB-44. After production began, the airplane was redesignated the B-50 and it became the first new bomber to be delivered to the newly formed Strategic Air Command (SAC).

With an interest in staying in the bomber market, Douglas, in a private venture in 1943, submitted a design to the Air Force for an unorthodox three-place bomber with twin engines driving a pusher propeller at the rear of the body. The design was expected to provide the range of a B-17 at twice the speed. Two prototypes were ordered with the designation XB-42 Mixmaster. With the advent of jet propulsion, a design change was made wherein two jet engines were placed in the body with twin flush inlets just ahead of the wing and twin nozzles on the side of the body just aft of the wing. Designated the XB-43, the prototype was the first U.S. jet bomber to be built. Plans to produce 50 airplanes were canceled, however, and the prototype became a flying engine testbed.

Northrop began the development of a long-range flying-wing strategic bomber in 1941 when the Army Air Force ordered two prototypes of the XB-35. The XB-35 was designed with four engines to drive contrarotating pusher propellers and was expected to be less expensive and more efficient than bombers such as the B-29 and the Convair B-36, which was then under development. The XB-35 suffered a series of propulsion problems and was finally canceled and replaced by a version powered with eight jet engines that was designated the YB-49. Although initially ordered into production, the entire program was canceled and the funds diverted to the B-36 project.

Convair designed the B-36 in response to a 1941 Army Air Force specification for a strategic bomber capable of carrying a 10 000-lb bomb load from the United States to European targets and returning without refueling. One of the largest airplanes ever built, the B-36 was a conventional wing-body-tail arrangement with power, in the final production version, being supplied by six radial engines driving pusher propellers and four jet engines paired in twin pods mounted near the wingtips. The first prototype did not fly until 1946, but the B-36 remained in the inventory as a primary strategic deterrent until it was withdrawn in 1957.

North American designed the B-45 Tornado in response to a 1944 Army Air Force request for a 500-mph jet bomber. The design was selected over three other responders—the Consolidated XB-46, the Boeing XB-47, and the Martin XB-48. The B-45 was a clean, straight-wing, conventional configuration with four jet engines paired in two large wing-mounted nacelles. The B-45 was the first four-engine jet bomber to enter the Air Force. However, it was not a particularly modern design and became a transitional airplane in the bomber inventory. The final production version was modified to be a strategic reconnaissance airplane, the RB-45C.

The Martin XB-51 was the first ground-assault light bomber developed for the Air Force following World War II. The airplane had a 35° swept wing, a T-tail, and three jet engines. Two of the engines were mounted on short pylons on the side of the body below and forward of the wing. A third engine was mounted in the rear of the body with the inlet blended into the base of the vertical tail. Other innovative features included a variable-incidence wing to facilitate takeoff, a tandem gear retracting into the body that permitted the use of a thin wing, leading-edge slats, and full-span wing flaps with lateral control provided by spoilers. The airplane successfully flew in October 1949, but subsequently the program was canceled.

Cargo airplanes. In mid-1942 Boeing proposed a transport variant of the B-29, and the Air Force accepted the first prototype in 1944. Designated the C-97 Stratofreighter, the design used the wing, tail, and engines of the B-29 on a new double-lobe body that provided the volume required to transport troops and cargo.

In 1948, the Air Force ordered the Lockheed C-121, an updated version of the C-69. In addition to transport operation, a radar picket version, the RC-121, was placed in operation in 1953. These were distinguished by large radomes above and below the body and by the addition of tip tanks.

Fairchild produced the C-119, an improved version of the C-82, in 1949. This version, known as the Flying Boxcar, had more powerful engines and a greater load-carrying capability.

Into the 1950's

In the aftermath of World War II and into the 1950's, there was fervent airplane design activity in the effort to maintain the security of the United States.

Fighters. North American, based on the success of the F-86, proposed a modified version having a body with increased volume, a pointed nose, and twin side-mounted NACA flush inlets. The modified version was designated the YF-93. A second YF-93 was built with conventional side inlets. The airplane was intended to compete for the penetration fighter role, but the need for this mission began to fade and the project was dropped with the two prototypes being turned over to the NACA for flight research.

Modifications to the basic F-86 design also continued into the mid-1950's. These modifications included engine changes, an all-moving horizontal tail, wing slat changes, extended wing leading edge, an underslung inlet with a radar nose, extended body, and various armament arrangements.

With supersonic flight becoming a reality, North American turned to a completely new company-funded design for a supersonic fighter. It was a single-engine single-seat design with a 45° swept wing; aft tail; and a flattened oval, normal shock inlet at the nose. The project was approved by the Air Force and designed the F-100 Super Sabre. The F-100 was the first of what were to be known as the Century series fighters and was the first Air Force operational supersonic airplane, having first flown in May 1953. Several crashes occurred following the initial deployment of the F-100, and an intensive wind-tunnel study indicated that supersonic aerodynamic phenomena along with the geometric and mass properties of the airplane led to stability and control problems not encountered with subsonic airplanes. Design changes that were made included a 27-percent increase in vertical tail area and an increase in wing span.

North American undertook further redesign of the F-100 to satisfy an Air Force need for a tactical fighter-bomber with ground-attack capability. The nose inlet was replaced by a pointed closed nose that housed a radar, and a new bifurcated inlet located on top of the body just aft of the cockpit was used to feed air to a 24 500-lb-thrust afterburning jet engine. The design, designated the F-107, incorporated several unique features such as an all-moving vertical tail for directional control and wing spoilers for lateral control. Although three prototypes were built and flight tests indicated good performance, the program was canceled in favor of the F-105. The F-107 was the last fighter built under the name of North American Aviation.

In the late 1950's, while developing the B-70 bomber, North American also designed a supersonic interceptor as a possible escort for the B-70. The interceptor, which was designated the F-108, was a canard-delta configuration with twin jet engines in the body and twin horizontal ramp inlets just forward of the wing root. A single vertical tail was used and the two-man crew were to be housed in individual ejection-type capsules. A range of 1150 miles at Mach 3 was specified. The project, however, did not proceed beyond the full-scale mock-up stage.

As follow-ons to the successful F-84, Republic developed several new designs for the purpose of expanding the operational envelope and mission capability. Initially modifications were made to the basic F-84 in which the original straight wing was replaced with a 40° swept wing and horizontal tail, and a more streamlined canopy was installed. This version, which first flew in 1950, was originally designated YF-96A but shortly thereafter was redesignated the F-84F Thunderstreak. Further modifications included a larger and more powerful engine

housed in a larger fuselage, and this became the production airplane. A second modification had a pointed nose and twin flush side inlets. The side inlets were later replaced by twin inlets built in to the leading-edge wing root. With cameras mounted in the nose, this version was produced as the photo-reconnaissance RF-84F Thunderflash.

In 1951, a unique conversion of the RF-84F came from the installation of a supersonic propeller driven by a gas turbine. The design, designated the XF-84H, was also distinguished by a high "T" tail and a shark-like antitorque fin just aft of the cockpit. While adding to the knowledge of high-speed propeller operation, the airplane did not go beyond the flight test stage.

Another modification intended to extend the life of the F-84 was the RF-84K. This design included a retractable hook on the upper forebody that was to be used in conjunction with a trapeze-equipped B-36. This arrangement was intended to extend the range of the RF-84 by carrying the airplane in a semisubmerged position under the B-36 for release and retrieval as needed. Contributing to this program was an unusual design from McDonnell that was specifically intended to be a parasite fighter for the bomber escort role. The McDonnell XF-85 Goblin, flying in 1948, was a short, stubby swept wing jet designed for carriage by the B-29, B-35, and B-36. While the small fighter displayed good agility, the short duration of flight and the hazards of launch and recovery under combat conditions led to the conclusion that the concept was impractical, so the XF-85 was terminated. The flight experience gained, however, was applied to the Republic RF-84K program, and successful flights were made with trapeze hookup to a B-36. Although 25 hook-equipped RF-84K's were produced, the project did not proceed beyond flight test.

Another Republic venture, the XF-91 Thunderceptor, began in the late 1940's and extended into the early 1950's. Intended primarily for a fast-climb interceptor role, the design called for propulsion from four rocket motors mounted in pairs above and below a jet engine. The fuselage had a nose inlet and a tail assembly similar to the F-84. The swept wing differed from previous designs in that the planform had an inverse taper ratio that, it was conjectured, would maintain wingtip lift at high angles of attack. The wing also featured variable incidence as a means for maintaining lift for takeoff and landing. With a combined thrust of 11 200 lb, the XF-91 exceeded Mach 1.0 in 1952. Two prototypes were built for flight test. One was modified to have an underslung forebody inlet and a pointed nose for radar. The other

was modified to incorporate a V-tail. The program did not proceed beyond flight test.

Still another bold Republic venture was the concept of an all-weather, high-altitude, air defense interceptor that was proposed to the Air Force in 1951. A contract was awarded in 1954 for three prototypes designated the XF-103. The heart of the design was a unique dual-cycle turboramjet engine to be developed by Wright. The engine, which was fed by an underslung variable-geometry scoop inlet, consisted of a turbojet and an afterburner that also served as a ramjet combustion chamber. The intercept conditions called for a Mach number of about 2.2 at an altitude of 75 000 ft with a maximum speed capability of about Mach 4.0. A full-scale mock-up was completed in 1953, and studies were done in the areas of titanium and stainless steel fabrication, high-temperature hydraulics, escape capsules, and periscopic sights for the submerged cockpit. A large folding ventral fin was provided to augment the high Mach number directional stability. After a 9-year development program, and with one airplane under construction, the program was canceled—reportedly for economic reasons.

In a somewhat less imaginative program, Republic began an in-house design in 1951 for a supersonic tactical fighter-bomber to succeed the F-84F. The proposal was given a go-ahead by the Air Force and was designated the F-105 Thunderchief. The configuration, influenced by previous Republic designs, was a conventional swept wing, aft-tail, single-engine, single-seat type. The airplane was designed with an internal bay for carrying nuclear or conventional weapons. Twin side inlets with a horizontal sugar-scoop shape were located in the wing root juncture. While the first three prototypes were under construction, the use of area-ruling for the relief of transonic drag became known and was demonstrated by NACA wind-tunnel tests. Accordingly, the third prototype was modified to make use of the transonic area rule. Flight tests verified the transonic drag effects in that the unmodified airplanes were limited to Mach 1.2 whereas the modified version reached Mach 2.15. Other design changes resulting from the wind-tunnel tests included a more effective vertical tail and the addition of ventral fins for the purpose of alleviating the supersonic stability problems. Later modifications to the F-105 included engine changes, armament changes, avionics changes, as well as a two-seat version. The F-105 was the last of a long line of Republic fighter designs.

Lockheed was able to make a rapid response to a 1948 Air Force requirement for an all-weather jet interceptor by converting their T-33 trainer to include a radar nose, an afterburning engine and four

0.50-caliber machine guns in the forward fuselage. Designated the F-94 Starfire, the airplane was the first operational all-weather jet fighter to enter service and was the first Air Force fighter to use an afterburning engine. Although generally successful, the design was progressively refined and the final production version included such changes as a more powerful engine, a new thinner wing with increased area and a greater dihedral angle, a swept horizontal tail, larger tip tanks, a new nose that allowed the housing of 24 folding-fin rockets, and two midwing-mounted pods that each contained 12 more rockets. The F-94 was the first U.S. fighter to be equipped entirely with missiles.

Lockheed began the design of a somewhat different fighter concept in 1952, knowing that the Air Force, based on the Korean war experiences, needed a new air superiority fighter capable of operating from forward airfields and accelerating rapidly for high-altitude intercepts. The concept, which was the basis for an unsolicited proposal, was a single-seat, single-engine, Mach 2, lightweight fighter with a low-aspect-ratio thin straight wing, a "T"-tail, and a long slender body with semiconical side inlets. The design benefited from the Douglas X-3 research airplane that had been a part of the flight test program of the X-series airplanes. Design information was also gained from the Lockheed X-7 research missile. The Air Force issued an operational requirement similar to the Lockheed proposal and, after competitive bidding, awarded a contract to Lockheed over Republic and North American for a supersonic air superiority fighter that was designated the F-104 Starfighter. Kelly Johnson, Lockheed's chief engineer said, in reference to the F-104 design, "...what we have done is bring to an end the trend toward constantly bigger, constantly more complicated, constantly more expensive airplanes."

McDonnell reactivated the XF-88 in 1951 as the Air Force sought a long-range, high-speed bomber escort fighter. The new airplane was designated the F-101 Voodoo. The general arrangement was similar to the XF-88, but the F-101, with more powerful engines, was larger and heavier and, at the time, was the largest and most powerful combat airplane to be accepted by the Air Force. The F-101 was produced in both a single-seat and a two-seat version and performed the roles of tactical fighter-bomber, reconnaissance, interceptor, and trainer. The interceptor version was armed with missiles carried internally on a rotary launcher. The F-101 had some stability problems, in particular a pitch-up, that were finally alleviated by use of an active inhibitor device.

Convair began studies of high-speed configurations in the late 1940's using the delta wing shape

that had been exploited by the German designer Lippisch. A low-aspect-ratio 60° delta wing was used with a single delta vertical tail and no horizontal tail. It was thought that such an arrangement would have low drag and that the stability might be better than that for aft-tail arrangements. A single jet engine with a nose inlet was used, but the original airplane was underpowered. To augment the thrust, six rocket motors were also to be used. Given the designation of XF-92, the airplane was useful for experimental flight research and, although never achieving supersonic flight, did reach a Mach number of 0.95.

The basic design of the XF-92 was used by Convair in response to an Air Force request in 1949 for a supersonic interceptor with an integrated fire-control system. The airframe award went to Convair with the designation of F-102 Delta Dagger. The first flight in October 1953 indicated that the original airplane was underpowered and had a higher than anticipated drag and that it was not possible to attain supersonic speeds. Production plans were halted pending the correction of performance and stability problems. Wind-tunnel tests at the NACA resulted in the application of the transonic area rule, an extended body, a new canopy, new inlets, an aft fuselage fairing, wing camber modifications, and a larger vertical tail. The revised airplane, with a more powerful engine, flew in December 1954 and reached Mach 1.22. The F-102 was armed with six internally carried missiles.

Further redesign of the F-102 resulted in the F-106 Delta Dart interceptor. While maintaining the basic all-wing delta concept, the F-106 had a more powerful engine, a completely new area-ruled body, shorter intake ducts and a larger, swept trapezoidal vertical tail. The F-106 reached a maximum speed of Mach 2.3.

Bombers. The 1950's saw the development of new advanced jet bombers. Near the end of World War II, Boeing began to explore the use of jet engines in bomber designs to follow their successful piston-engine airplanes. The first Boeing concept in 1944 had a straight wing, but this soon gave way to the newly accepted swept wing concept. Body-mounted engines were replaced by wing-mounted engines and the prototype, ordered in 1946, was designated the B-47 Stratojet. The B-47 had six engines with two in pylon-mounted twin pods located inboard and one snugged under the wing in an outboard position. The airplane was equipped with a body-mounted tandem main gear with outriggers near the wingtips. The B-47 was the first operational swept wing jet bomber in the Air Force. Many modifications involving equipment, engines, and armament resulted in versions

that were used for electronic warfare, reconnaissance, training, and remotely piloted target drones. One version became the first Air Force airplane to incorporate a fly-by-wire primary control system.

In 1945, Boeing was asked by the Air Force to develop a strategic bomber to replace the B-36. The original design had turboprop engines, but through a series of evolutionary changes, the design designated the XB-52 Stratofortress that flew in 1951 had eight jet engines pylon mounted under a 35° swept wing. With various changes to the airframe and engines, the B-52 remained in production through 1961 and is still in operational status with the Strategic Air Command.

Seeking a light jet bomber, the United States made a rare decision in selecting the British-designed English Electric Canberra airplane in 1951. The airplane appeared well suited to the Air Force mission with good range and payload, and it was decided that it would be built under license by Martin as the B-57. The B-57 is a two-seater with twin jet engines mounted in wing nacelles. The wing is unswept and, with a relatively large wing-area, the wing loading is low. In addition to the original mission, the airplane was used in a reconnaissance role.

The Douglas B-66 Destroyer was developed for the roles of tactical bomber and reconnaissance. The airplane, with a high swept-wing and two pylon-mounted jet engines, was a direct development from the Navy A3D airplane, with the same basic layout but without certain Navy shipboard features such as folding wings, strengthened gear, and arrestor hook. The airplane is one of the relatively few examples of the use of a basic design for multiservice roles.

The first supersonic bomber in the United States was the B-58 Hustler design of Convair. The design started in 1949 in response to an Air Force feasibility study for a supersonic strategic bomber weapon system. For Convair it also represented a replacement for their B-36. The design retained the all-wing delta and single vertical tail concept used by the F-102 and F-106 and had four pylon-mounted jet engines under the wing. The configuration was area ruled and had a unique detachable weapons pod attached to the underside of the body. The B-58 demonstrated a maximum speed of about Mach 2 and made a supersonic flight (with refueling) from Tokyo to London in 1963. The B-58 was phased out of SAC in 1970 as the FB-111 was beginning to appear.

Cargo airplanes. Lockheed proposed a turboprop transport in 1951 as the Air Force began a move to replace the conventional piston-engine transports. The airplane, which became the C-130 Hercules, had four turboprop engines mounted on a high

wing. The body sat low on the ground to facilitate loading through an aft ramp. The C-130 is still in service today.

Boeing produced a variation of their early 707-80 commercial transport that was accepted by the Air Force and designated the C-135. A tanker version, the KC-135 Stratotanker, has been widely used.

McDonnell-Douglas produced the C-133 Cargo-master in response to an Air Force requirement for a heavy transport capable of carrying bulky loads. With no prototype, the airplane was ordered into production in 1954. The design had a high wing with four turboprop engines and clamshell doors on the low aft body.

A tactical assault transport designated the C-123 Provider was developed in the early 1950's by Chase Aircraft with a powered version of a Chase cargo glider. The design had two piston engines attached to a high wing. The low body had a rear loading ramp. Chase was acquired by Kaiser-Frazer, who failed to produce the airplane, and Fairchild was finally awarded a production contract.

The 1960's and Beyond

As world events continue to change, the perceived needs of the Air Force continue to change. Changes that occur in economics and politics as well as in technology are reflected in the actual acquisition of airplanes. In general, acquisition of new airplanes has slowed and the design cycle has lengthened. The era of the chief engineer or designer in charge of a project has given way to a management system involving many people with responsibility for various discrete areas of a project.

Fighters. Fighter programs during this period included many diverse programs—some successful, some not. Supersonic VTOL was one of the areas of interest. In the early 1960's, the Bell company, already well known for innovative concepts, undertook the design of a supersonic VTOL airplane at the request of both the Air Force and the Navy. The intent was to provide a high-performance fighter unhampered by basing considerations or gear strength—a design philosophy under study again today. Designated the XF-109, a mock-up completed in 1961 showed a single-seat fighter with a long slender body, a high short-span wing, aft tails, and eight jet engines. Two engines were located conventionally in the rear of the body with twin side inlets under the wing. Two engines were in an upright position in the body just aft of the cockpit and were to be used to provide vertical thrust only. The other four engines were paired in rotating wingtip nacelles to provide either vertical or horizontal thrust as required. Thus, six engines could be used for vertical flight, and six

engines were available for forward flight. Reaction jet controls would be used during vertical or hovering flight, and conventional aerodynamic controls would be used for forward flight. The anticipated weight was to be about 24 000 lb. In addition to vertical and hovering flight capability, the XF-109 was expected to have a maximum speed of Mach 2.3 and a subsonic range of about 1400 miles. Although a full-scale mockup was built, the program was terminated and the airplane was never built.

Following the Century series of fighters of the 1950's, there was a relative dearth of new fighter designs. The Air Force, in looking for a fighter, turned to the Navy McDonnell Douglas F4H-1 Phantom shipboard fighter—a mid-1950's design that entered Navy service in 1960. The F4H-1 design had already been revised in several respects following NACA wind-tunnel tests done to explore problems of stability, in particular pitch-up and roll-yaw coupling. The revised airplane incorporated a wing leading-edge tip extension, turned up wingtips, and a drooped horizontal tail. Compared with the Century series fighters, the F4H-1 had greater load-carrying capability as well as greater range and hence was ordered by the Air Force in 1962 with the designation of F-110. With a change in classification the airplane was redesignated the F-4 Phantom II and, in various forms, has remained in service into its third decade.

The primary fighter development during the 1960's was the Tactical Fighter Experimental (TFX) program that resulted in the production of the F-111 airplane. The main point of the program was to develop a multimission airplane that could be used by both the Air Force and Navy. The anticipated benefit was commonality, which should be conducive to efficiency and lower cost. Technology pertinent to the design was the use of variable wing sweep that should permit good takeoff and landing characteristics, good subsonic range and loiter time, supersonic capability, and low-altitude penetration capability. The concept of variable wing sweep was not new but had been brought to light by German scientists during World War II. Extensive investigations of the variable-sweep feature were conducted in NASA wind tunnels. Flight results were also obtained with the Bell X-5 research airplane (based on a captured German Messerschmitt airplane) and with the Grumman XF10F-1. The TFX program resulted in a request for proposal in 1961 to which nine companies responded. A contract for the airplane, designated the F-111, was finally awarded to General Dynamics in 1962 after several lengthy evaluations. The program was plagued with many problems—technical, political, and economic—and was, in fact, subjected to a

congressional investigation. Technically, the problems were related to such things as excessively high drag, inlet flow distortion, excessive supersonic longitudinal stability, deficient supersonic directional stability, and excessive weight. Thousands of hours of wind-tunnel tests were done by NASA and the USAF to address these problems. In addition, these problems were compounded by some of the constraints imposed by service commonality—for example, some weight, length, and height limitations were dictated by the physical characteristics of Navy carrier elevators and hanger decks. In the end, the Navy canceled out of the program and only about a third of the anticipated production was delivered to the Air Force. While showing little merit as a tactical airplane, a version designated the FB-111 did go to SAC as an interim strategic bomber. The FB-111 had a longer fuselage, a greater wing span, a stronger gear, increased fuel capacity, and more powerful engines. The F-111 and FB-111 are still in service.

Northrop began a company-funded project in 1955 with the intent of producing an inexpensive, uncomplicated, lightweight, single-seat supersonic fighter. The design featured a slender, needle-nosed fuselage with twin jet engines, twin side inlets, a conventional straight wing, and aft tails. Air Force interest in a supersonic trainer resulted in a two-seater version designated the T-38 Talon. The fighter version, designated the F-5 Freedom Fighter, was selected for use by foreign countries under the Military Assistance Program. In addition to its use in allied air forces, the F-5 saw combat service with the U.S. Air Force in Southeast Asia. Because of certain unique features, the F-5 has been used in U.S. aggressor squadrons to simulate such airplanes as the MiG-21.

The McDonnell Douglas F-15 Eagle was the first new fighter design in the U.S. Air Force since the era of the Century series. The Air Force issued a Request for Proposal (RFP) for a fighter in late 1965 to 13 companies. In 1965, bids were again solicited from seven companies in what was called the FX program. In 1967, study contracts were awarded to McDonnell Douglas and General Dynamics while some contenders—Fairchild-Hiller, Grumman, Lockheed, and North American—stayed in the competition at their own expense and Boeing withdrew. In 1969, the field was narrowed to McDonnell Douglas, Fairchild-Hiller, and North American. In late 1969, McDonnell Douglas was declared the winner, and the initial contract for the F-15 was awarded in January 1970. The first flight occurred in July 1972, production was approved in February 1973, and the first operational airplanes were delivered in November 1974. The original F-15 was a single-

seater, but a two-seater version has also been introduced. The airplane is a twin-tail, fixed trapezoidal wing design powered by twin jets with nozzles at the base of the body and twin horizontal ramp inlets just aft of the cockpit. The design makes use of some composite material and some titanium. The combination of a relatively high thrust-to-weight ratio and a relatively low wing-loading is such that the airplane is highly maneuverable. Armament typically consists of eight air-to-air missiles and a 20-mm cannon.

In early 1972, the Air Force issued an RFP to nine companies for a lightweight fighter technology demonstrator. Out of five responses, two were selected—the General Dynamics single-engine design designated YF-16 and the Northrop twin-engine design designated YF-17. After a fly-off between the two, the F-16 Fighting Falcon was selected in January 1975, and the first operational airplane was delivered in January 1979. The YF-16 design was to demonstrate several new technologies that included a fly-by-wire/side-stick flight control system, relaxed static stability, automatic variable camber, high acceleration cockpit, and composite structure. The design also included a blended wing-body with a thin straked wing intended to have both low drag and high lift. The single engine is fed by an inlet on the underside of the body just ahead of the nose gear. Extensive NASA wind-tunnel testing accompanied the development. The Northrop YF-17 design was later incorporated by McDonnell Douglas into what was to become the Navy F/A-18 airplane.

The Lockheed-developed stealth fighter F-117 began in the late 1970's as a highly classified, closely guarded program. The design is intended to provide a configuration with low detectability. The wing is highly swept and has a sawtooth trailing edge. The single-seat fighter has two jet engines with inlets and nozzles designed for minimum detection. The body has a faceted surface designed to reduce the radar signature. Although the airplane has been operational since October 1983, its existence was not acknowledged until late 1988.

Currently under development for the Air Force is an advanced tactical fighter (ATF) to be a follow-on to the F-15. The emphasis is on affordability, maintainability, survivability, and performance and calls for the production of flying prototypes. Lockheed, teamed with Boeing and General Dynamics, is developing the YF-22, while Northrop, teamed with McDonnell Douglas is developing the YF-23.

Bombers. During this period the Air Force continued to seek a follow-on for the B-52 strategic bomber. Potential successor systems included the North American XB-70 Valkyrie. In December 1957,

the North American B-70 was selected over a Boeing proposal in response to an Air Force requirement for a new strategic bomber. The design was a canard and delta wing type with twin vertical tails. A wedge-shaped body on the underside of the wing housed six jet engines and twin vertical-ramp inlets. The underbody was intended to exploit the phenomena of compression lift. The tips of the delta wing could be drooped to reduce longitudinal stability and increase directional stability at supersonic speeds. The B-70 demonstrated Mach 3 flight in October 1965, but there was some concern that the lift-drag ratio was not adequate to provide the required range. Only two B-70's were built to be used as flying testbeds for supersonic flight research. One of these was lost in a midair collision with a chase airplane. Final test work was done by NASA, and the program was terminated in 1969 with the remaining airplane relegated to the U.S. Air Force Museum.

The Air Force began a series of studies in 1962 that culminated in the advanced manned strategic aircraft (AMSA) requirement in 1965 for a low-altitude penetration bomber to replace the B-52. The RFP was issued in 1969, and Rockwell (having absorbed North American) was selected to develop the airframe in June 1970. The airplane, designated the B-1, used a variable-sweep wing to accommodate the range and low-level penetration requirements. A conventional aft tail was used, and power was provided by four jet engines paired in twin pods with bifurcated inlets located below the wing. The flight of the first prototype B-1 occurred in late 1974, and construction of three more prototypes proceeded. However, in June 1977, newly elected President Carter canceled the plans for production of the B-1. The program was reinstated in 1981 by newly elected President Reagan, and the updated version designated B-1B entered the inventory during 1986.

Currently under test for the Air Force is the advanced technology bomber (ATB) designated the B-2. The prime contractor, Northrop, teamed with Boeing and LTV Aircraft Products Group, has produced a design that draws on their flying-wing experience and incorporates stealth technology to reduce detection. The B-2, rolled out in late 1988, began test flights in the summer of 1989.

Attack airplanes. Attack airplanes in this time period included the Douglas A-1 Skyraider. Originally designed in the mid 1940's as the Navy AD dive-bomber, the airplane was conventional for the time period with a piston engine and a retractable gear. Almost 20 years later the Air Force became interested in the airplane for use in the Southeast Asia conflict for close-air support. A number of surplus

Navy airplanes were converted to Air Force use for training Vietnamese pilots and for converting U.S. Air Force jet pilots to piston-engine, tail wheel airplanes.

The Cessna A-37 Dragonfly, intended for light attack and counterinsurgency (COIN) missions, was developed in the early 1960's from the existing T-37 twin-jet trainer. Armed with a 7.62-mm Gatling gun and a variety of wing-mounted stores, the A-37 was used in Vietnam.

The Vought A-7 Corsair II, based on the Vought F-8 design, was originally intended to be a carrier-based attack airplane. The Air Force became interested in the airplane as an inexpensive way to fill the requirement for a heavily armed long-range tactical fighter-attack airplane for close-air support in Southeast Asia. Accepted into service in 1968, only 2 years after Navy service began, the A-7 was the first new jet-powered subsonic fighter to enter the Air Force in almost 20 years.

In the late 1960's, the Air Force initiated an Attack Experimental (AX) program. The purpose of the AX program was to produce a battleproof, heavily armed close-air support airplane to replace the A-1. Six companies entered the competition, out of which a fly-off between the Northrop A-9 and the Fairchild Republic A-10 Thunderbolt II resulted in the selection of the A-10. The A-10 is a straight-wing design with twin vertical tails and twin jet engines pylon mounted on the upper back of the body above the wing.

Cargo airplanes. With worldwide logistic support becoming of increased importance in the 1960's, the Air Force required new dedicated cargo transport airplanes. In 1960, the Air Force issued a requirement for a jet-powered cargo airplane that brought responses from Lockheed, Boeing, and Convair. The winning design was the Lockheed C-141 StarLifter. The design had a high, swept wing with four pylon-mounted engines and a high T-tail. Early use of the load-carrying capability was demonstrated beginning in 1965 when almost daily flights were made across the Pacific to Vietnam.

A requirement for a heavy-lift cargo airplane issued in 1963 resulted in design contracts being awarded to Lockheed, Boeing, and Douglas. A production contract was awarded in 1965 to Lockheed for the winning C-5 Galaxy. The C-5 was geometrically similar to the C-141 but was much larger, with more than twice the payload and twice the power. Some structural and propulsion changes have been made to the airplane to extend the life and improve the performance. The airplane is the largest in the Air Force inventory.

Currently under development is the McDonnell Douglas C-17. This airplane is being designed to combine heavy lift and long-range performance with small, austere airfield restrictions.

Special airplanes. Although many unique airplanes have been developed, only the Lockheed SR-71 Blackbird will be mentioned. Design work for this special high-speed airplane began in about 1959 and the first flight occurred in 1962. The airplane was officially announced in 1964. The airplane was referred to as the A-11 but had a Lockheed designation of A-12. The Air Force designated a proposed fighter version the F-12, and the better-known reconnaissance version was designated the SR-71. With a maximum speed in excess of Mach 3, the airplane represented advancements in aerodynamic shaping, propulsion, materials, and fabrication—some of which had been previously explored in airplanes that never flew, such as the XF-103. Three of the airplanes were allocated for use in the NASA/USAF Advanced Supersonic Technology program.

Epilogue

It is recognized that all events related to the history of Army/Air Force airplane design trends have not been included in this paper. However, it is believed that enough has been presented to permit some observations.

The development of these airplane systems was slow over the first three decades of this century, very prolific during the 1940's and 1950's, and tended to slow once again beginning in the 1960's. These trends seem to be related to perceived needs, to technical capability, to the economy, and to the political atmosphere. Some of the significant design trends can be noted in figure 1, which shows, for the same scale, some of the fighter designs from 1925 to today. The trends include changes from biplane to monoplane, fixed landing gear to retractable gear, open to enclosed cockpits, "tail draggers" to tricycle gear, propellers to jets, unswept to swept wings, and so on. In addition, there have been changes in materials and construction techniques, and other changes, to permit increases in speed and maneuver capability. It can also be noted in figure 1 that the size of the single-seater fighter has increased considerably over the years.

Some U.S. designs were influenced by technology from other countries, and the imminence of war has had a strong influence on design trends. Many current designs employ features that can be found in previous designs, and thus a knowledge of past design history can be useful. Many seemingly good

designs have often failed to reach fruition but have, nevertheless, added to useful knowledge.

The relationship between industry and government has changed considerably. In the early days of military aviation, the industry was often submitting proposals to the government. Today, the industry is generally responding to requests from the government.

Many dramatic changes have been apparent in the design trends of U.S. Army/Air Force airplanes. As technology advances and mission needs change, dramatic design changes in the future cannot be precluded.

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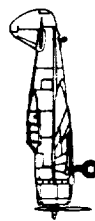
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Curtiss P-1



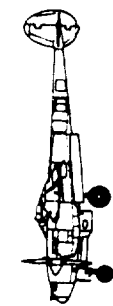
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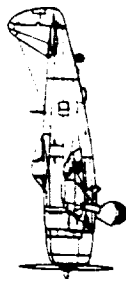
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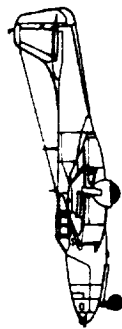
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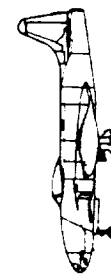
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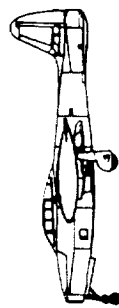
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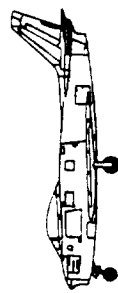
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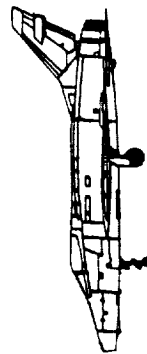
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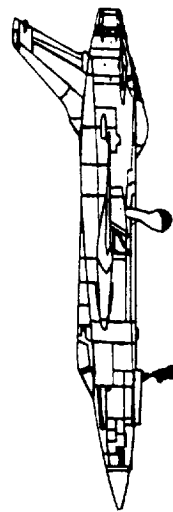
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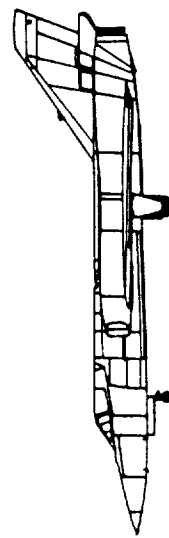
North American F-86



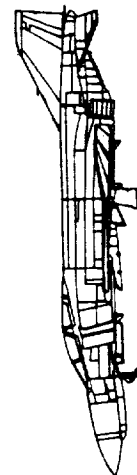
North American F-100



Republic F-105



Convair F-106



McDonnell Douglas F-4



McDonnell Douglas F-15



General Dynamics F-16

Figure 1. Some U.S. Army/Air Force airplane designs from 1925 to today.



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16. Abstract Some design trends in Army/Air Force airplane systems in the United States are traced from the post-World War I era to the present. Various types of aircraft systems are presented with a view toward noting design features that have been used. Some observations concerning the design trends indicate that some may be driven by advanced technology and some by a need for new mission requirements. In addition, it is noted that some design trends are evolutionary and result in an extension of the service life or utility of existing systems. In other cases, the design trends may be more revolutionary with the intent of creating a system with a new capability. Some examples are included of designs that did not proceed to production for reasons that sometimes were technical and sometimes were not.			
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