

# Wright from the start

*The Contributions of Dayton's Science and Engineering Community  
to American Air Power in the Twentieth Century*

**DISTRIBUTION STATEMENT A**  
Approved for Public Release  
Distribution Unlimited

by

James F. Aldridge

20000515 041

DTIC QUALITY INSPECTED 2

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE DECEMBER 1997	3. REPORT TYPE AND DATES COVERED FINAL 1997		
4. TITLE AND SUBTITLE WRIGHT FROM THE START: THE CONTRIBUTIONS OF DAYTON'S SCIENCE AND ENGINEERING COMMUNITY TO AMERICAN AIR POWER IN THE TWENTIETH CENTURY			5. FUNDING NUMBERS	
6. AUTHOR(S) JAMES F. ALDRIDGE				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ASC/HO AERONAUTICAL SYSTEMS CENTER AIR FORCE MATERIEL COMMAND WRIGHT-PATTERSON AFB, OH 45433			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) ASC/HO AERONAUTICAL SYSTEMS CENTER AIR FORCE MATERIEL COMMAND WRIGHT-PATTERSON AFB, OH 45433 POC: JIM ALDRIDGE, ASC/HO, (937) 255-8382, EXT. 2004			10. SPONSORING/MONITORING AGENCY REPORT NUMBER  ASC-TR-2000-5005	
11. SUPPLEMENTARY NOTES U.S.GOVERNMENT PRINTING OFFICE PUBLICATION 1997-550-784				
12a. DISTRIBUTION AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) PROVIDES A HISTORY OF DAYTON, OHIO FROM ITS DAYS IN THE 1920s AND 1930s AS THE FOCAL POINT OF THE U.S. AERONAUTICAL INDUSTRY TO THE END OF THE TWENTIETH CENTURY WHEN IT WAS THE HOME OF THE AERONAUTICAL SYSTEMS CENTER (ASC) AND "SUPER LAB," WRIGHT LABORATORY.				
14. SUBJECT TERMS McCOOK FIELD, OHIO, WRIGHT FIELD, AERONAUTICAL HISTORY, AIR FORCE LABORATORIES HISTORY			15. NUMBER OF PAGES 42	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	



# WRIGHT FROM THE START

*The Contributions of Dayton's Science and Engineering Community*

*to American Air Power in the Twentieth Century*

POSTMARK: DAYTON, OHIO .....	1
HOW WE INVENTED THE AIRPLANE .....	2
MR. DEEDS GOES TO WASHINGTON .....	4
THIS FIELD IS SMALL .....	5
"THE FOCAL POINT WAS DAYTON . . ." .....	9
WORLD WAR II: THE RISE OF "RESEARCH AND DEVELOPMENT" .....	13
TOWARD NEW HORIZONS .....	17
REENGINEERING THE AIR FORCE FOR THE JET AND SPACE AGE .....	19
UNLEASHING A TECHNOLOGICAL DYNAMO .....	24
CREATING TODAY'S AIR FORCE .....	30
OVER THE HORIZON: THE 1990s AND BEYOND .....	35
RETROSPECT: "A STORY THAT . . . OUTFRIVALS THE ARABIAN NIGHTS . . ." .....	37
ACKNOWLEDGMENTS .....	38

# WRIGHT FROM THE START

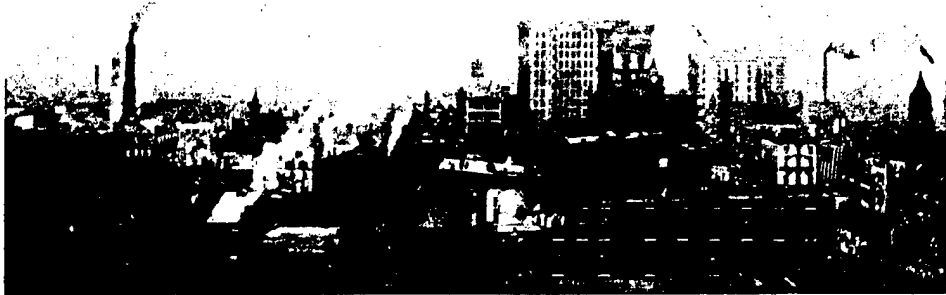
*The Contributions of Dayton's Science and Engineering Community  
to American Air Power in the Twentieth Century*

by

James F. Aldridge

History Office  
Aeronautical Systems Center  
Air Force Materiel Command  
Wright-Patterson AFB, Ohio

# POSTMARK: DAYTON, OHIO



*Bird's eye view of Dayton, around the turn of the century*

In 1899, one hundred three years had passed since Jonathan Dayton lent his name to a pioneer settlement on the banks of the Great Miami River. Thirty-four years had passed since the end of the Civil War—less time than separates the present day from the end of World War II. In 1899 there were men and women still alive who remembered hearing Abraham Lincoln speak from the old courthouse steps in '59. On Decoration Day Dayton schoolchildren recited Lincoln's Gettysburg Address before grandfathers and granduncles who had fought at Gettysburg, and Chickamauga, Bull Run, and Antietam Creek. Among those children were some whose parents and grandparents had been born into slavery, men and women who bitterly appreciated the slain president's observation that "every drop of blood drawn with the lash shall be paid by another drawn with the sword."

In 1899 the tallest building in Dayton was only 13 stories high. Aside from the occasional hot air balloon, the best view of Dayton was reserved for winged, feathered creatures whose ancestors had circled the skies in the days when the Miami and the Shawnee roamed the forests. What the "bird's eye" beheld in 1899 was a growing community of 45,000 souls; a commercial and civic center whose streets only recently had been paved: the "Lincoln" courthouse now dwarfed by larger and

taller, if less elegant business and government buildings. To the south of town was the already sprawling complex of John Patterson's National Cash Register Company. To the east lay the city's railroad yards, Dayton's link to the rest of *terra firma*. To the north was a vacant field just above the confluence of the Mad and Great Miami rivers, property owned by the McCook clan that had lost six sons in the

fight for Union and Emancipation. To the west, beyond the Great Miami, lay Dayton's suburbs: modest brick and frame houses of the city's prosperous middle class, built side by side along shady, tree-lined streets.

In the parlor of one of these houses, a bicycle maker sat down one day in May of 1899 and wrote a letter to the Smithsonian Institution. Several days later the Assistant Secretary of the Smithsonian received the letter, postmarked Dayton, Ohio, requesting information that would advance the writer's "pet theories as to the proper construction of a flying machine." The letter was signed: *Wilbur Wright*.



*Wright family home on Hawthorne Street*



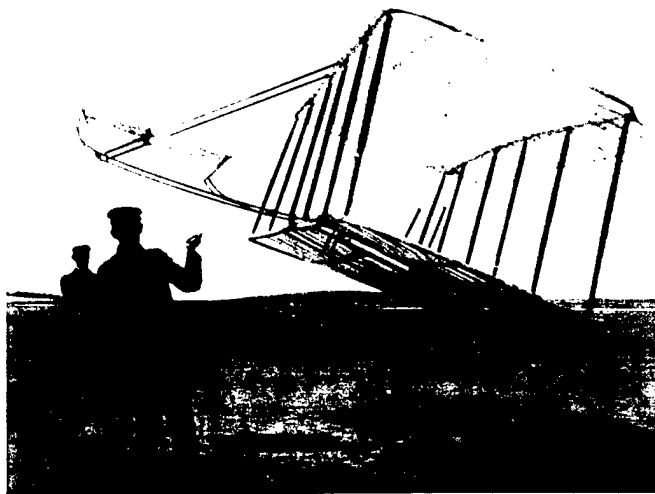
# HOW WE INVENTED THE AIRPLANE



*The Fathers of Aeronautical Engineering*

Four years after writing the Smithsonian, Wilbur and Orville Wright had designed, built, and flown the world's first airplane. How did they do this? To contemporaries, it seemed almost a "miracle," as it does to many even today. How did two bicycle makers from Dayton, Ohio, finally achieve what had eluded so many others,

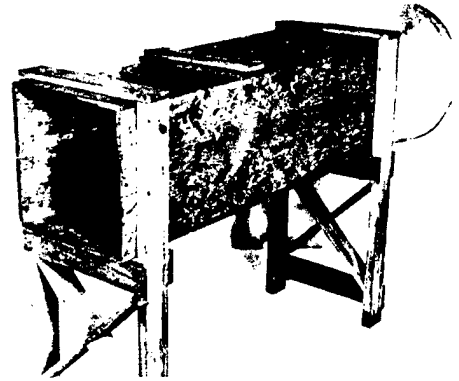
including such distinguished inventors as Da Vinci, Cayley, and Langley? Orville himself marveled in 1903: "Isn't it astonishing that all these secrets have been preserved for so many years just so that we could discover them?"



*Early glider experiments*

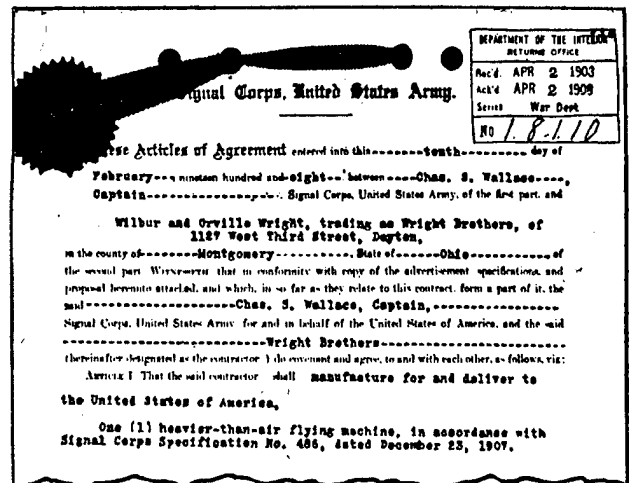
When the Wrights' airplane first lifted off of the ground on 17 December 1903, there was no miracle at work—at least not in the conventional sense of a super-vening "act of God." That first flight was, in fact, the result of the Wright brothers' other great discovery: the discipline of *aeronautical engineering*.

The Wright brothers were the world's first true aeronautical engineers. They combined the partial achievements of their predecessors with their own very original insights. But they added something more: a critical methodology that proceeded carefully and logically from one step to the next, anticipating problems, and constantly testing and critiquing results. Without this method, the Wrights might have stumbled onto success, but they would not have been able adequately to explain it or even, perhaps, to repeat or improve upon it. In fact, on the basis of their calculations and three years of grueling ground and flight testing, the brothers were confident *at the end of 1902* that they had solved the problem of flight.



*The Wrights used a primitive wind tunnel to gather data on airfoil characteristics*

Armed with this confidence, they proceeded to develop a propulsion system (another marvel of engineering insight) and over the next several years, improve upon

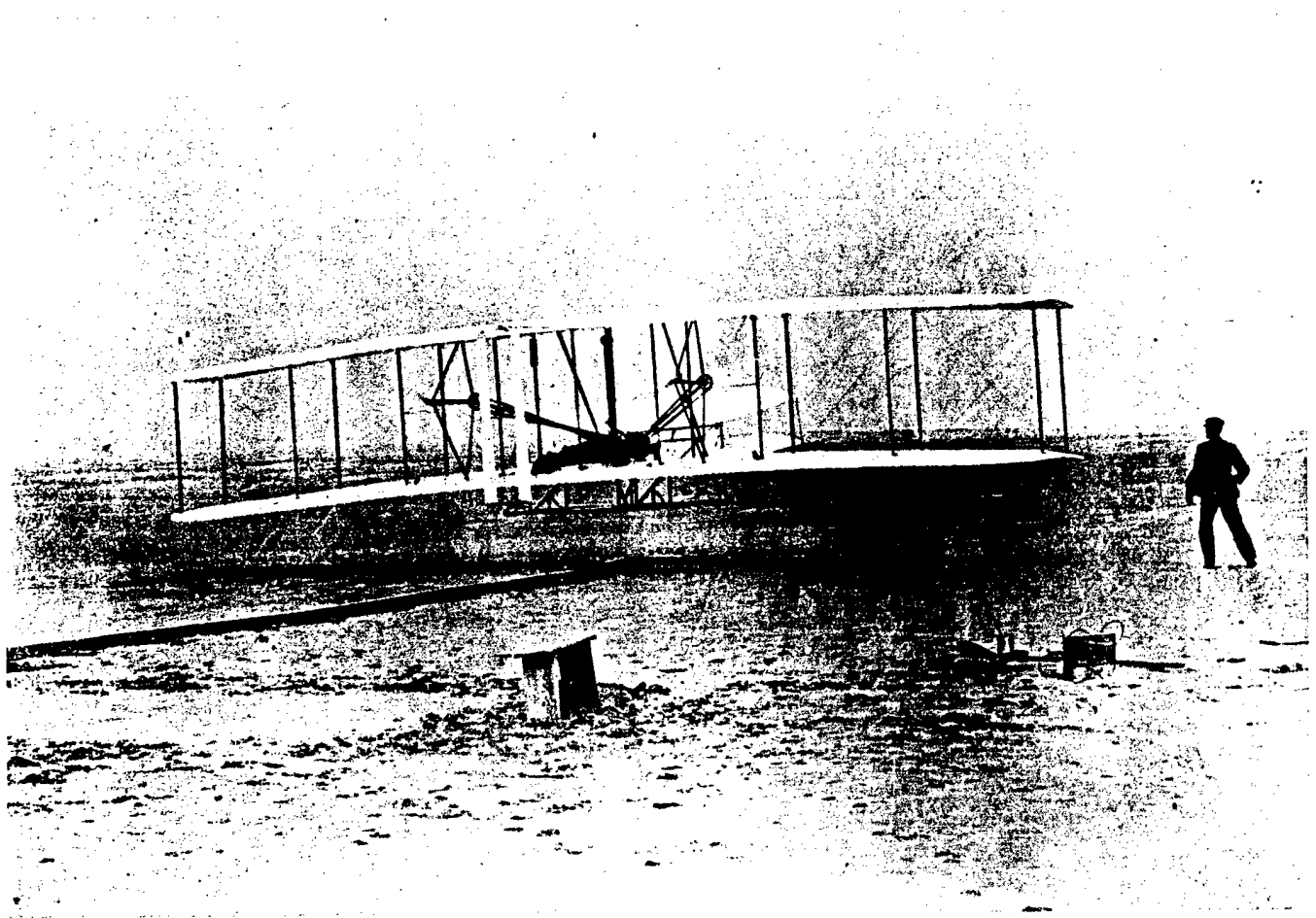


*Wright's contract with the U.S. Army Signal Corps*



the airplane until it had reached a stage where they offered it to the government. Initially rebuffed, the brothers proved, into the bargain, to be shrewd *aviation entrepreneurs*. In the course of a series of exhibition flights, in 1908 and 1909, they sold all Europe—and finally the U.S. military—on their invention.

The Wrights left in their wake a world transformed. As one British military observer remarked: “That [the Wright brothers are] in possession of a power which controls the fate of nations is beyond dispute.”



*17 December 1903*



# MR. DEEDS GOES TO WASHINGTON

The fate of nations soon hung in the balance when on 28 June 1914 a Serbian terrorist gunned down the heir to the Austro-Hungarian throne and his wife in the little Bosnian town of Sarajevo. Before long all Europe was at war. King, prime minister, *Kronprinz*—the Wrights had met them all and shown them their machine. The message was not lost. Between 1908 and 1914 the nations of Europe expended over \$81,750,000 in building up military air forces. The First *World War* was fought on land, sea, and *in the air*.

The Wrights' machine shortly transformed not only the fate of nations but also the future of Dayton, Ohio. This, however, was not all the doing of Wilbur and Orville. The Wrights had put Dayton on the map as the "birthplace of aviation." There was nothing writ in the heavens, however, that the Gem City should become the lodestone of aeronautical research and development for the balance of the twentieth century. This circumstance was owing to a handful of remarkable Dayton businessmen and community leaders, including John and Frederick Patterson, Charles Kettering, and Edward Deeds. First among them was Mr. Deeds.



Edward Deeds



John Patterson



Charles Kettering

*They brought military aeronautics to Dayton*

When the United States entered World War I, on 6 April 1917, Deeds was already in Washington, invited to serve on the Munitions Standards Board by men acquainted with his business acumen and engineering know-how. Deeds had got his start in business and engineering in the employ of John Patterson's NCR. There he met Charles Kettering, inventor extraordinaire, and the two formed a fast friendship. Deeds had an abiding interest in aeronautics dating from his early association with the Wrights. Together with Kettering, he had established, in 1916, an installation for aeronautical experimentation south of Dayton and purchased land for

a cross-country air field to the north of downtown, on land once owned by the McCook family.

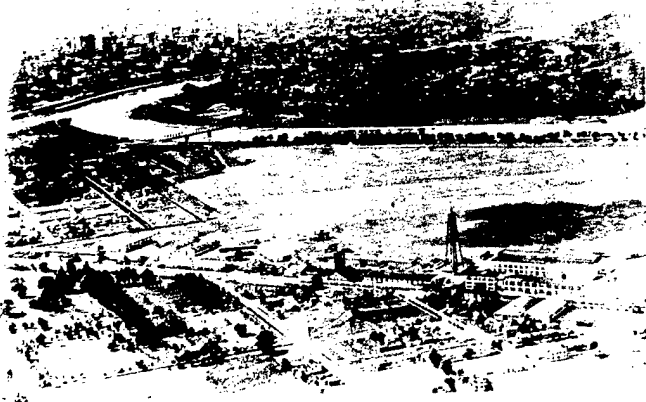
Deeds thus needed little prodding, after the dissolution of the Munitions Standards Board, to join the Aircraft Production Board and from there to become chief of the Signal Corps' Equipment Division. The Division was charged with managing the Army's aircraft production and procurement program. When the Army was looking for a site to set up an experimental and engineering field to assist industry design and produce military aircraft, Deeds was well-positioned to suggest Dayton: first south field and, when this proved unsatisfactory, north field. After both he and Kettering divested their interest in the north field site, the Aircraft Production Board selected it in September 1917 and named it in honor of the McCook clan.

The first spadeful of earth was turned for McCook Field early in October 1917. Over the following weeks, into November and December, workers labored furiously, laying out streets, raising the first wooden buildings, and preparing the aerodrome. While they toiled, new faces detrained at Dayton's rail terminal, passing the familiar faces of local boys heading to mustering and training camps before going "over there." As the weeks and months went by, new names were added to McCook's personnel roster: Vincent ... Clark ... Verville ... Klemin ... Fales ... Boulton ... Myers ... Carr ... Johnson ... Bane ... . A new episode had opened in the history of Dayton ... and American aeronautics.



*Dayton goes to war*

# THIS FIELD IS SMALL



*McCook Field from the air*

speech. “It was nice to be honored by my peers and superiors,” recalled Doolittle many years later. “But it was a greater honor to receive an assignment to . . . McCook Field.”

When Doolittle reported to McCook, the field was at the halfway point in its short history. The Army was already looking for another, larger and more permanent location for its experimental facilities—a search that would result five years later in the dedication of Wright Field, to the east of Dayton. Since first opening its gates in December 1917, McCook despite its constrained size (THIS FIELD IS SMALL, proclaimed a sign over the main hangar doors) had chalked up a remarkable record of achievement, a record that would make it near legendary in the annals of American aeronautics.

McCook operated, from the very first, as no other Army installation. It employed primarily a civilian workforce: scientists, engineers, and support personnel, who themselves were exempted from many of the ordinary civil service rules, including



*Lt Colonel Thurman Bane, Chief of the Engineering Division*

In 1922 Lieutenant Jimmy Doolittle flew from Florida to California—the first man to fly coast-to-coast in less than 24 hours. On his way back to Kelly Field, where he was stationed, he received orders transferring him to McCook. At Kelly, he was greeted by the commander and a reception committee that escorted him to the nearby city hall, where he received congratulations and made a short



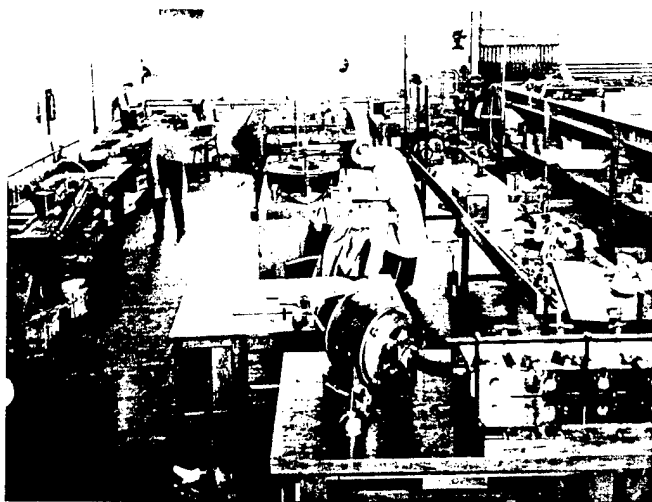
*Lt Jimmy Doolittle*



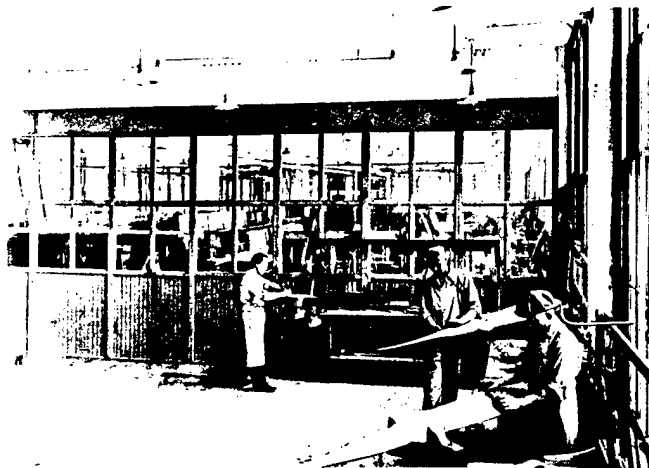
*Main gate of McCook Field*



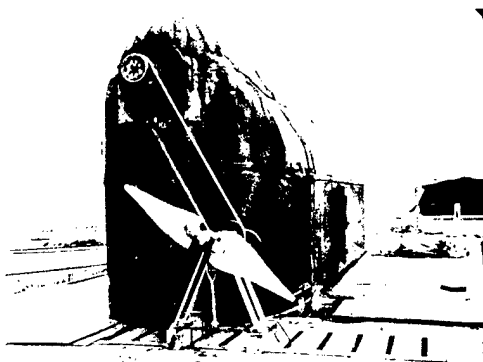
*Laboratory and shop facilities at McCook Field*



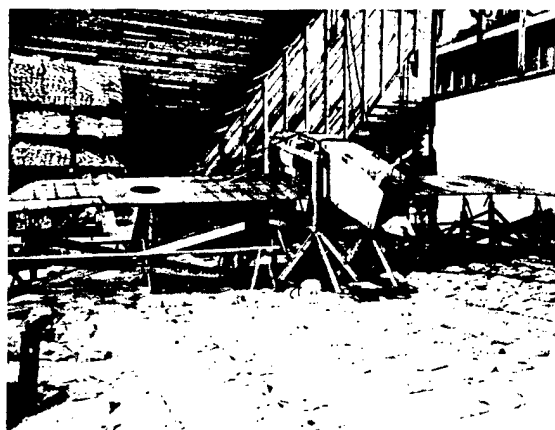
*Powerplants*



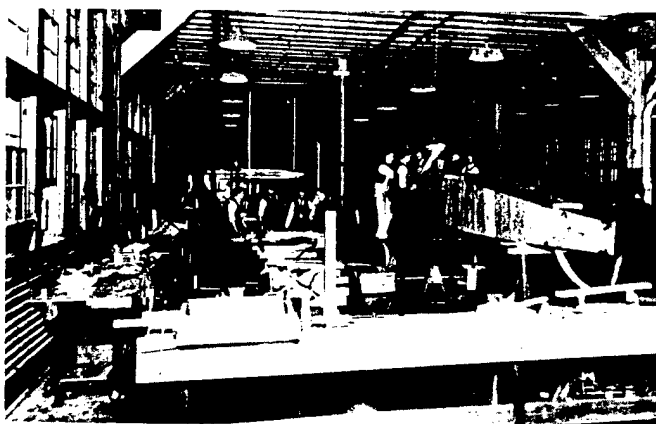
*Propellers*



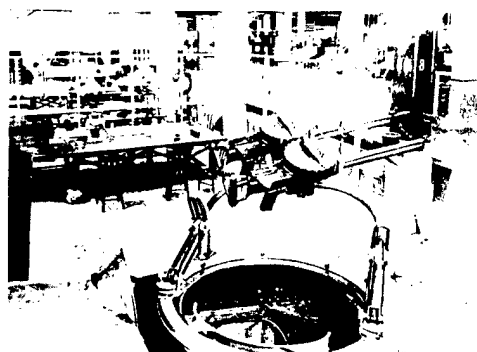
*Test rig*



*Static test*



*Aircraft assembly*



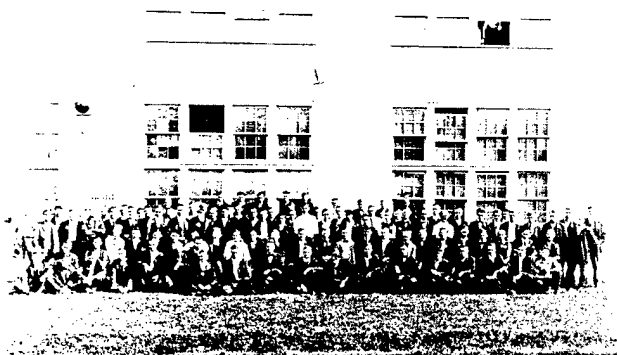
*Armament*



those on hiring. It welcomed some of the best and brightest engineers in the country, both from industry and academe, both seasoned professionals and youngsters newly degreed.

What they found on arrival in Dayton was a collection of temporary wooden buildings, running along Keowee Street, on the “land” side, and a small air field, including a short, paved runway, along a bend in the Great Miami River. The buildings included laboratories for research in materials, power plants, equipment, armament, airplanes, and (after 1920) lighter-than-air craft. Research facilities included propeller and engine test rigs, two small wind tunnels, a foundry, and a collection of fabrication shops, for metals, wood, and machines, collectively called the “Factory.” The Factory built everything from the Field’s two wind tunnels to airplanes, designed by McCook’s engineering staff. Indeed, one of the most remarkable—and controversial—activities conducted by McCook’s engineering staff was the design, construction, and testing of its own prototype airplanes and equipment, including engines. (McCook reluctantly gave up this activity in the mid 1920s, following complaints from industry of unfair competition.)

McCook, in short, was the place to be in the early 1920s for anyone interested in aeronautical science and engineering. It was the place to discover how to build

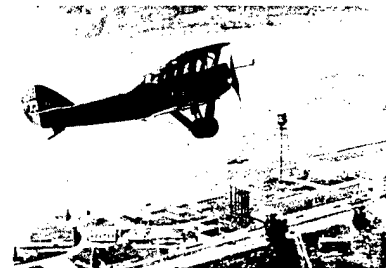


*McCook personnel*

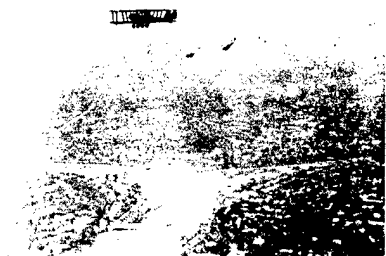
military aircraft, something that no one in the United States knew how to do before 1917. It offered opportunities to rub elbows with many outstanding engineers and researchers: to advance one’s own education both

practically and professionally. (While at McCook Jimmy Doolittle served as a test pilot, but was also given leave to earn both master of science and doctoral degrees from the Massachusetts Institute of Technology.) In the larger sense, therefore, McCook served as a “learning laboratory” for the first generation of American military aeronautical engineers.

Following the war, the Engineering Division at McCook experienced the first of several postwar “downsizings.” As a result, McCook “alumni” were scattered throughout the aircraft industry and academe, where many of them held top positions from which they influenced the direction of American aeronautics for nearly half a century. (Following his resignation from active duty in the Air Corps, Jimmy Doolittle himself joined the Shell Oil Company in 1930, where he was influential in the development of 100 octane aviation fuel that gave American fliers a decided edge in World War II.)



*Packard-LePere Lusac II over McCook Field, 1919*



*Parachute testing over McCook*



*Blimp flying over McCook Field*



An essential element that these men took with them when they left government service, were the friendships and camaraderie that so exemplified the professional atmosphere at McCook. An example is the friendship of Joseph Shipley Newell and Alfred Salem Niles. While at McCook, they coauthored a book on aircraft structures, which they continued to update for a quarter century. After leaving McCook, they became professors of aeronautical engineering: Newell at MIT and Niles at Stanford. Newell died before Niles published the fourth edition in 1954. In the introduction, Niles remembered his colleague: "Joe Newell and I worked together at adjoining desks at McCook Field for five years, and were closely associated in the writing and revision of this book for the following twenty-five. No one could ask for a better collaborator or personal friend . . ."

*That was the abiding legacy of McCook Field.*

# AIRPLANE STRUCTURES

VOLUME I

ALFRED S. NILES, A.B., S.B.

Professor of Aeronautic Engineering  
Stanford University

JOSEPH S. NEWELL, S.B.

Late Professor of Aeronautical Structural Engineering  
Massachusetts Institute of Technology

FOURTH EDITION

New York · JOHN WILEY & SONS, Inc.

London · CHAPMAN & HALL, Ltd.

1954

*Title page of 1954 edition of Niles and Newell, Airplane  
Structures*

# “THE FOCAL POINT WAS DAYTON...”

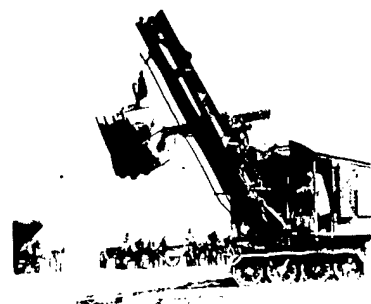


A retired engineer, looking back on his years in industry before coming to work at Wright Field in the mid-1930s, reminisced that in those days “the focal point was Dayton, Ohio.” Dayton’s McCook Field set the standards for the entire U.S. aeronautical industry. Publication of the Air Service’s *Information Circulars* was keenly awaited by engineers in industry and academe throughout the country. McCook’s engineering staff exercised great influence over what aircraft and equipment the Army would accept and what it would not. They were in a position to survey the entire industry as well as foreign aeronautical developments—indeed, they were charged to do this. It was not only their job, but in the words of one Chief Engineer, it was their *duty*.

By the early 1920s, however, it was unclear that the aviation industry would continue to revolve around Dayton. The National Advisory Committee on Aeronautics’ (NACA’s) Langley Field began operations in 1920 and soon began performing the bulk of the basic aeronautical research sponsored by the government. McCook Field, moreover, was too small and its site unsuitable for an experimental aeronautical center. The Army began to look for another site.

The citizens of Dayton were determined that their city would continue to be the focal point for advanced aeronautics. In 1922 they formed the Dayton Air Service Committee. John Patterson initially headed this body. After his death, his son Frederick took over the campaign. Behind the scenes Edward Deeds wielded his usual influence. In 1922 the citizens of Dayton made the Army an offer it couldn’t refuse: 4,520 acres of land to be donated for the construction of a flying field and experimental facility. In October 1922 the Army accepted.

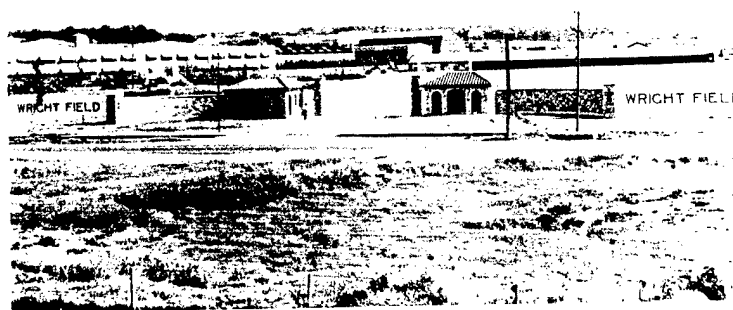
The ground was broken for the new facility, named Wright Field, in honor of the “fathers of aviation”, on 16 April 1926. The Field was dedicated on 12 October 1927. Orville Wright hoisted the flag and Jimmy Doolittle led the aerial acrobatics.



*Wright Field under construction*



*Raising the flag at Wright Field dedication,  
12 October 1927*

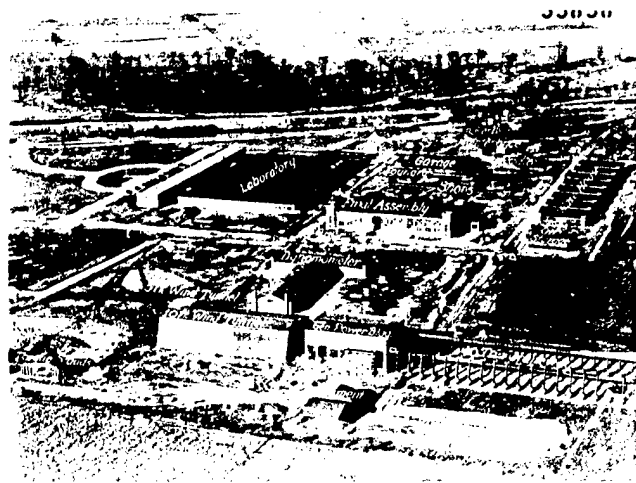


*Wright Field main gate*

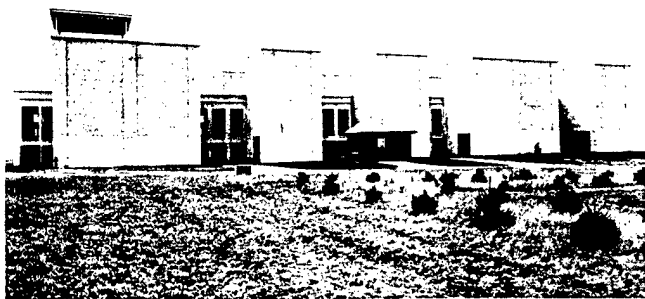


Unlike McCook, Wright Field was built to last. The original complex included an administration building, a vast building to house the laboratories, an aircraft assembly building with attached shops, a foundry, garages, hangars, warehouses, laundry, and power generation buildings. Among the test facilities were dynamometers and torque stands for engine testing, an enormous propeller test stand (the largest in the world), the two wind tunnels from McCook Field, and a firing range. The airfield, though unpaved, provided far more room than had McCook's. Wright Field, located eight miles from the center of Dayton, also provided more safety and security for flight testing than had McCook.

More important than the physical dimensions was the expanded mission of Wright Field. In 1926,



*Wright Field experimental facilities*



*Engine torque stands*

McCook's Engineering Division was superseded by the Materiel Division. The Materiel Division was formed not only to conduct experimental engineering, but also procurement, and maintenance and support of Air Corps aircraft and associated materiel. Henceforth, an increasing part of the engineering staff's duties was to include not only experimental research but also the service testing of aircraft and equipment destined for procure-



*Wright Field: display of aeronautical equipment*

ment and production; thus the amount of space given over to test facilities at Wright Field. During the 1930s, Wright Field would "write the book" on aeronautical test and evaluation.

The Field's engineering staff also continued to pursue original research, although with a diminished budget. The Materials Laboratory made some particularly significant contributions in metals and synthetic materials in the years before World War II. The Physiological Research Unit of the Equipment Laboratory pioneered research in aeronautical medicine, including the use of new facilities such as an altitude chamber. The Aircraft Laboratory continued to make important discoveries in aerodynamic problems, such as flutter; as well as in aircraft structures, where it made pioneering contributions in static testing techniques.

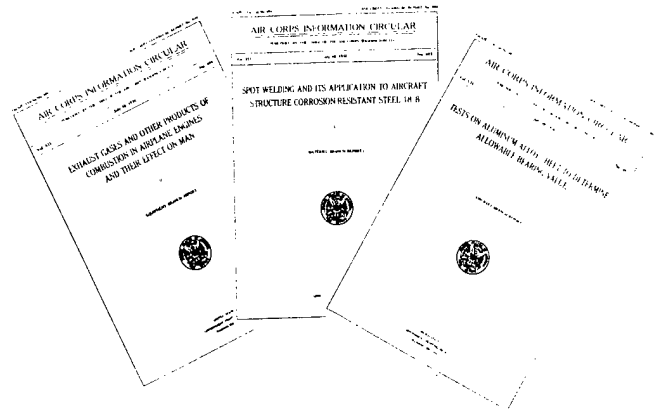
The laboratories were, however, small. None comprised more than a hundred personnel. Their staffs, moreover, performed multiple duties: everything from formulating specifications and standards to test and



evaluation of the resulting aircraft and equipment, and in-service support of fielded aircraft.

Despite the outflow of individuals to industry and academe in the 1920s, Wright Field still possessed a core of outstanding engineers. These included civilians as J. B. Johnson and C.J. Cleary of the Materials Laboratory, Weldon Worth and Opie Chenoweth of the Power Plant Laboratory, and E. R. Weaver of the Aircraft Lab. The Field was also home to military officers of outstanding technical merit: Paul Kemmer of the Aircraft Laboratory, Edwin Page of the Power Plant Laboratory, Harry G. Armstrong of the Physiological Research Unit of the Equipment Laboratory, and Franklin O. Carroll, who served at Wright Field almost uninterruptedly, from the late 1920s through the end of World War II, rising to

become chief of the Engineering Division with the rank of major general. Throughout this period Wright Field engineers authored numerous articles in influential journals, such as *Aviation Magazine*. The laboratories also continued publication of the *Information Circulars*, although their number diminished as the 1930s wore on.



*Air Corps Information Circulars*



*Radio Lab personnel*

Wright Field also welcomed a number of promising young engineers during the 1930s from industry and academe. These individuals were to make outstanding contributions during World War II and provide the laboratories with leadership from the late 1940s through the 1970s.



*Flying Branch personnel*

Despite the many contributions made by Wright Field to American aeronautics in the years before World



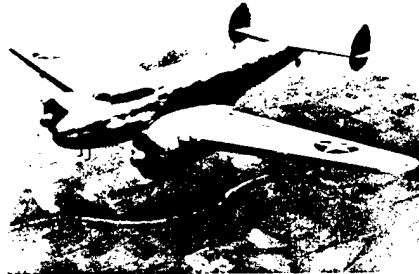
*Equipment Lab personnel relax*



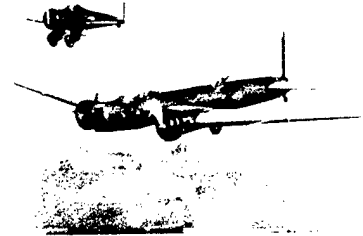
*Demonstrating gun from Curtiss A-3B Falcon, 1930*



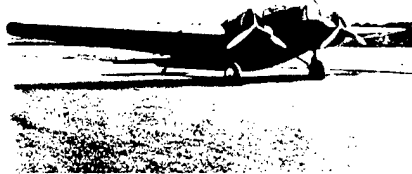
*Keystone B-3A, 1930*



*Lockheed XC-35 won the 1937 Collier Trophy for demonstrating pressurized cabin*



*Boeing Y1B-9A, early 1930s*



*Martin B-10B, 1934*



*Detroit Y1C-12 had monocoque aluminum fuselage, 1931.*

War II—everything from component research to developing the specifications and testing of heavy bombers like the B-17—it was often criticized (both by contemporaries and those coming later) for failing to accelerate such developments or to anticipate truly revolutionary technologies: the jet engine, ballistic missiles, and microwave radar.

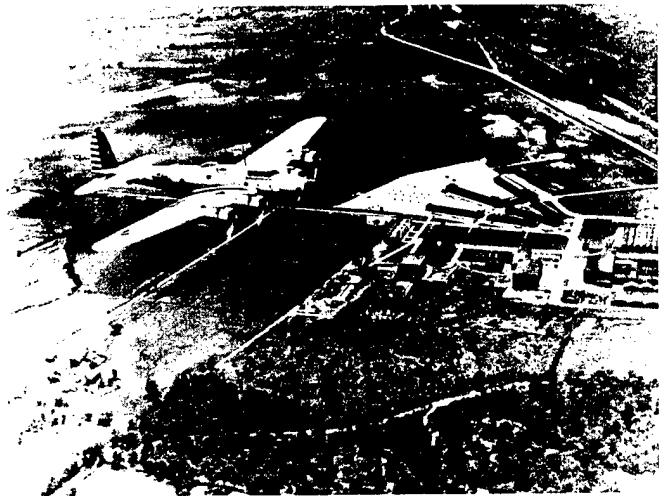
At the end of the 1930s, Hap Arnold and Ira Eaker co-authored a book called *Winged Warfare* in which they responded to this criticism. In the book they surveyed the various aeronautical laboratories and research centers around the nation, including those of the Navy, the NACA, and Wright Field. They wrote:

The History of the Materiel Division at Wright Field, Dayton, Ohio, is the history of military air progress in this country. There have been those who have charged that this progress could have been faster. The principal answer to these harping critics is to point out that in spite of the lean years, when this country made very little money available for our experimental division, we can point with pride to the results achieved and improvements made. No critic has ever been able to show that maximum effort was not obtained from the funds which the country was

willing to devote to aeronautical experimental development as expressed in the annual appropriations from Congress.

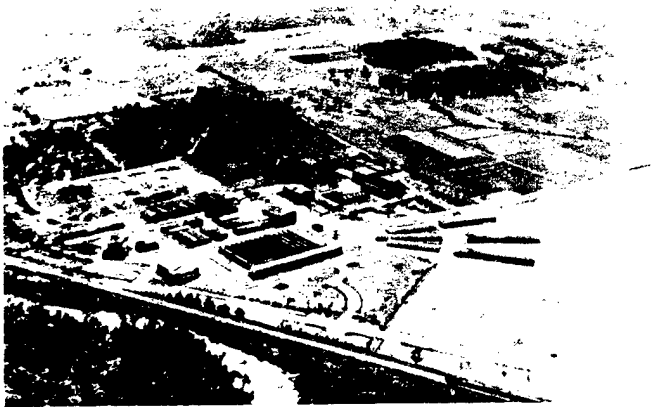
They concluded:

It is not a personal bias, but personal knowledge that permits the statement that America owes more to the Army's Air Corps experimental division at Wright Field for its present high place in world air leadership than to any single institution or group in this country.

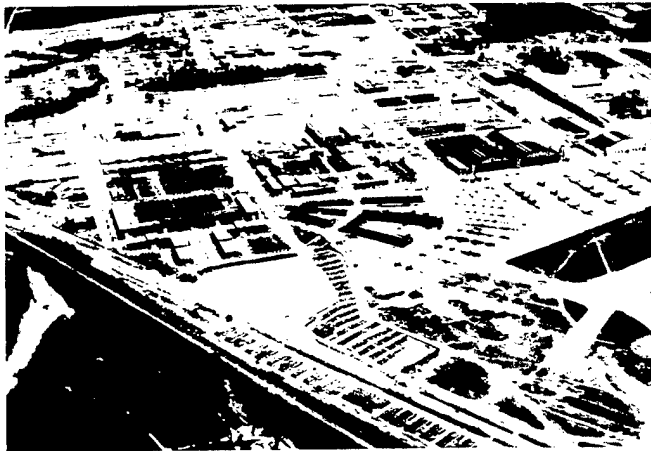


*Boeing B-17 in flight over Wright Field*

# WORLD WAR II: THE RISE OF "RESEARCH AND DEVELOPMENT"



*Wright Field on the eve of World War II*



*Wright Field at the end of World War II*

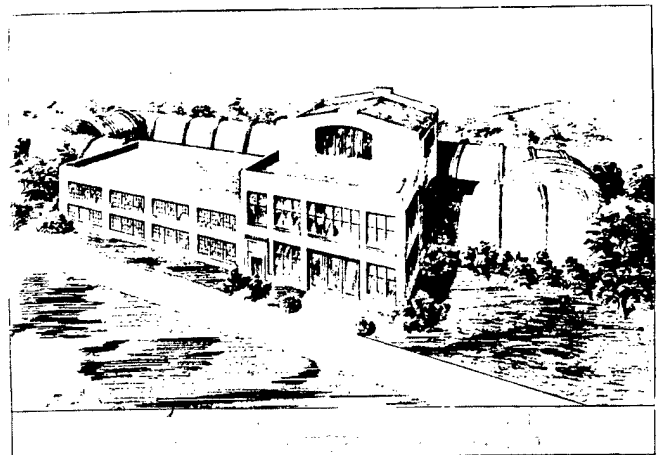
The first real hint of things to come at Wright Field was on the day in June 1941 when workers and equipment from the Price Brothers Company of Dayton drove through the main gate. They had come out from town to begin laying the Field's first concrete runways. The old turf field had initially sufficed as wooden biplanes gave way to metal stressed-skin cantilever monoplane in the early 1930s. The giant long-range bombers—some of intercontinental range—planned for development by the Materiel Division, however, would be too big and heavy for sod alone to support. Wright



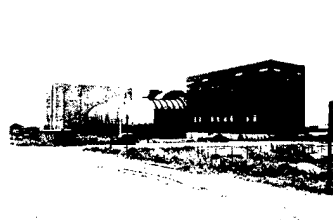
*Laying Wright Field's first concrete runways*

Field's first growing pains in over a decade were to accommodate this new reality. It was only the beginning.

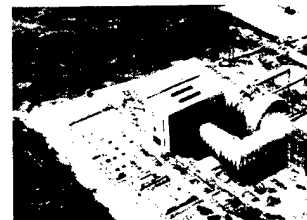
Another sign of change was outwardly less dramatic if no less portentous. In 1939 Frank Wattendorf visited Wright Field. He had just returned from China where he had designed and overseen construction of the Chinese' first major wind tunnel complex. Wattendorf was an associate of Theodore von Karman, an aerodynamicist of international stature and since 1930 professor of aeronautical engineering at the California Institute of Technology. Wattendorf came to the Field to survey the site of a giant new wind tunnel. The tunnel was to have a test section 20 feet in diameter and a drive system that would make it the most powerful in the world. Von Karman had suggested such a facility after discussion with General Henry H. "Hap" Arnold, who wanted to upgrade Wright Field's technical facilities. It was the beginning of a long association between Von Karman and Arnold—an association that would soon transform the physiognomy of Wright Field and the future course of Air Force RDT&E.



*Preliminary design*



*The tunnel as built*



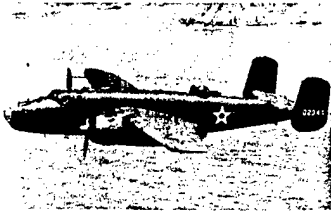
*Aerial view of the tunnel*

*The 20-foot wind tunnel*

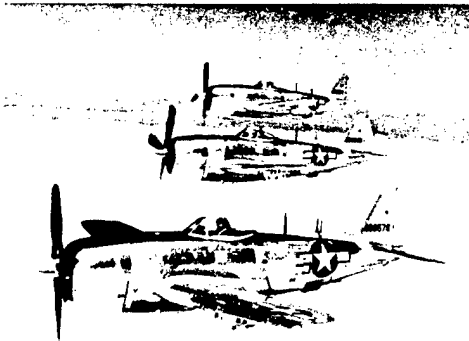


This buildup of facilities was undertaken partially in response to needs of European nations engaged in the opening stages of World War II. The Materiel Division was already filling orders, and the laboratories had already begun a modest expansion of their technical program. Then in May 1940, President Franklin Roosevelt called upon the nation's industry for the greatest production of warplanes in history: 50,000 airplanes for the Army and Navy with an annual production capacity of 50,000. For Wright Field's laboratories this meant abruptly shifting their research program to accommodate full-time support of the aircraft production effort. It also meant

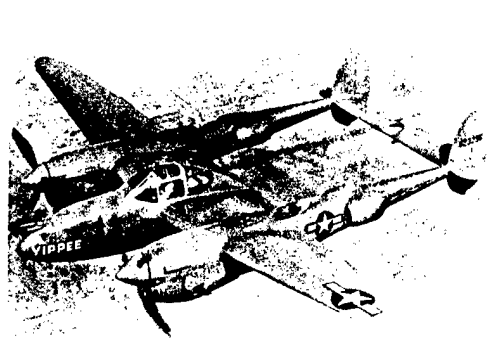
the end of the prewar method of airplane development, where the Materiel Division would test prototype aircraft experimentally and then for service use before recommending a model for production. Henceforth, aircraft development would be *concurrent* with production. Under this arrangement, the laboratories were kept busy testing production aircraft and recommending "fixes" and modifications or the incorporation of advanced equipment, such as radars, as these became available. These modifications would be incorporated on subsequent production aircraft and *retrofitted*, as necessary, on aircraft already produced.



*North American B-25D Mitchell (Photo courtesy of USAF Museum)*



*Republic P-47 Thunderbolt*



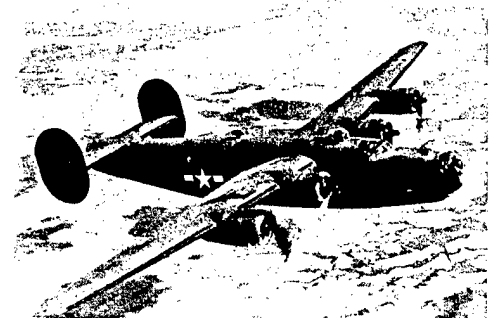
*Lockheed P-38 Lightning*



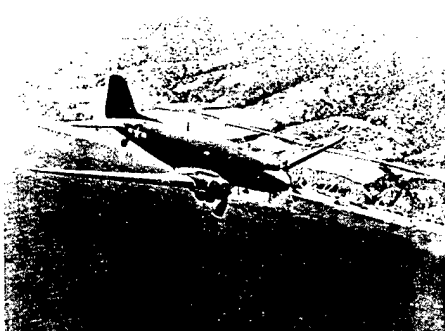
*Northrop P-61 Black Widow*



*North American P-51 Mustang*



*Consolidated Vultee B-24 Liberator*



*Douglas C-47 Skytrain*



*Boeing B-29 Superfortress*



Following U.S. entry into World War II, in December 1941, Wright Field experienced a phenomenal expansion in personnel, facilities, and projects. The laboratory workforce increased over eightfold in four years. This expansion consisted mainly of younger engineers, for the most part in uniform. The number of laboratories also increased, from seven before the war, to about a dozen by 1945, including new labs for aero medical research, communications and navigation, and radar. The number of facilities also increased, from 40 before the war to nearly 300 by war's end. In addition to the 20-foot wind tunnel, Wattendorf oversaw construction of a smaller 10-foot transonic tunnel and, before war's end, a supersonic tunnel. Nearby was a new vertical wind tunnel. New hangars were built for aircraft modification and assembly

and a vast new complex was added for in-house shop activity. A number of smaller laboratory buildings also sprouted up here and there among the larger facilities. These buildings characteristically housed both laboratory workrooms and offices. Work was also begun on a massive new structures testing facility, completed in 1946. Funding all this activity was an increase in expenditures for experimental work, from \$3,525,000 in 1939 to over \$121,647,605 by 1944.

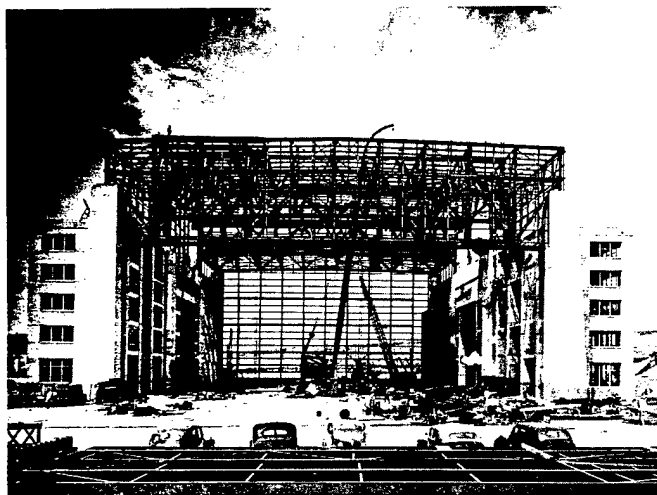


*Engine test stands under construction*

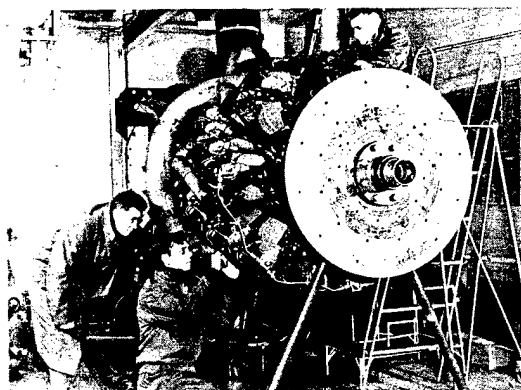


*Looking "up the hill", with vertical wind tunnel under construction (top center)*

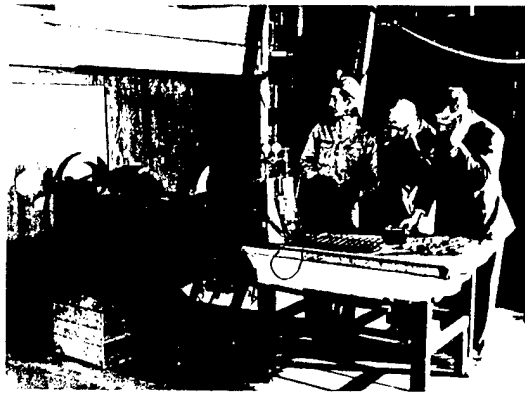
All this buildup was in response to an exponential increase in projects. For the most part, these consisted of Wright Field's prewar stock-in-trade: airplanes with piston engines, and associated equipment. Among these were some of the most important aircraft of World War II and immediate postwar period, including pursuit planes and giant, long-range bombers, such as the B-29 and the



*New static test facility (Building 65) under construction*



*Preparing engine for cold chamber tests*



*Firing tests of an experimental gun charger*

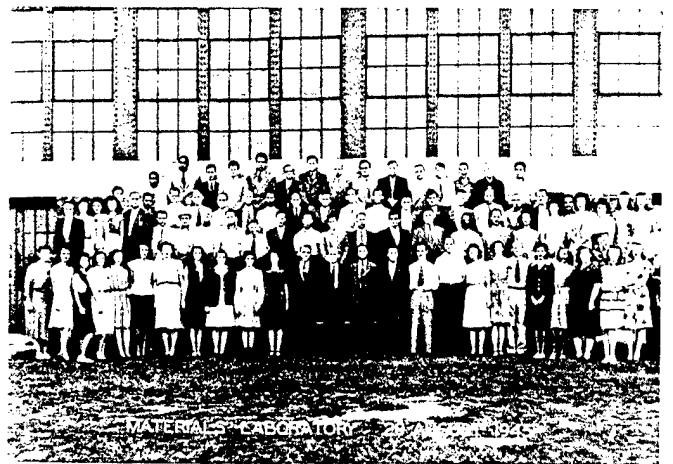


*Personnel posing before captured foreign aircraft at Wright Field*

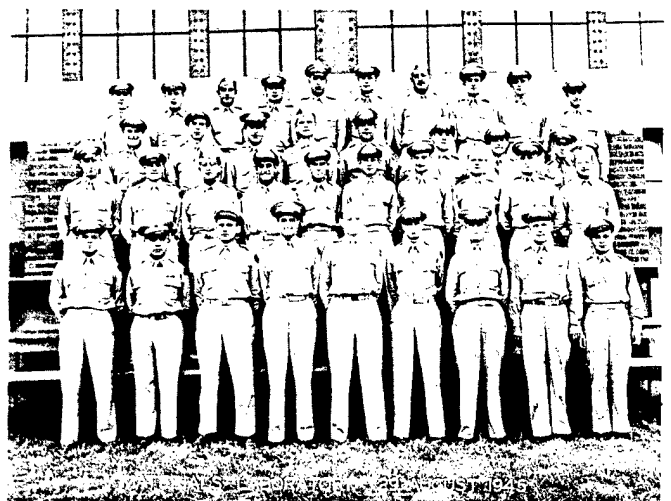
B-36. However, these projects also included development of revolutionary new technologies: jet and rocket motor propulsion, advanced aerodynamics, gun and bomb sights, radars and communications equipment, and synthetic materials.

The war thus brought change of all kinds to Wright Field. The most important change, however, was that which began to take hold in the minds of its engineers and technical planning staff. Wright Field had been caught by surprise by the technical advances of the British and Germans. It was determined that this should never happen again. The change is best expressed in the term *research and development*, which increasingly replaced the older *experimental engineering* as time wore on. Experimental engineering described an aircraft development process with heavy emphasis on test and evaluation. It was experimental largely in the sense of "trial and error." Research and development, on the other hand, encom-

passed a full-spectrum *science and technology* development program, beginning with investigations of a theoretical and fundamental nature and advancing toward full-scale development of a final product. This approach, which had been common in Europe since the turn of the century, began to enter American university engineering curricula during the 1920s and 1930s, aided by emigre scientist/engineers like Von Karman. It was this orientation that young engineering recruits brought with them to Wright Field, beginning in World War II. It was no accident that before the war, the Wright Field laboratories resided in the *Experimental Engineering Section* of the Materiel Division. Following the war, in 1946, they were part of the Air Materiel Command's *Directorate of Research and Development*.



*Civilian staff*



*Military staff*

*Materials Laboratory, 1945*

# TOWARD NEW HORIZONS



An Army Air Forces staff car parked at the end of a runway at New York's La Guardia Airport was an unlikely place for one of most momentous encounters for the future of Air Force R&D. The time was September 1944. The two figures inside the car were Commanding General of the Army Air Forces Hap Arnold, and his scientific advisor, Dr. Theodore von Karman. "What I am interested in," confided Arnold, "is what will be the shape of the air war, of air power, in five years, or ten, or sixty-five." He then directed von Karman to "gather a group of practical scientists for



**General Henry H. "Hap" Arnold**

all the new things. I want to know what the impact of jet propulsion is, of atomic energy, of electronics. Get a group and study that . . . and make me a report." Arnold was a man well ahead of his time, a man not hide-bound by tradition or given to sentimentality. (On one occasion, thinking out loud to Von Karman and his group, he remarked: "For twenty years the Air Force was built around pilots, pilots and more pilots. . . . The next Air Force is going to be built around scientists—around mechanically minded fellows"! He had learned to fly on Huffman Prairie at the Simms Station school run by the Wrights. During World War I he had served in the Technical Section of the Division of Military Aeronautics, which was responsible for determining Air Service requirements and translating them into airplanes, equipment, and other materiel. During the interwar years, he had served in numerous assignments in the Air Corps, rising gradually to the top. During those years he had authored several books on air power, ever stressing the importance of aeronautical research.

Von Karman was no less remarkable a figure. He was born in the Austro-Hungarian Empire before World War I to a father "enobled" by the emperor for his efforts on behalf of education. Von Karman was estab-

lished as one of the leading aerodynamicists in Europe when Robert Millikan invited him to the U.S., to join the faculty of the California Institute of Technology, in 1926. There he headed up the Guggenheim Aeronautical Laboratory of the California Institute of Technology



**Dr. Theodore von Karman**

(GALCIT) and gathered about himself a coterie of student proteges, including Frank Wattendorf, Frank Malina, and H.S. Tsien, among others. These now formed the nucleus of the team Von Karman put together for General Arnold. Over the next year, the team visited Europe where it examined facilities and spoke with

personnel of Allied and enemy research centers, including Ludwig Prandtl of Goettingen (Von Karman's *doctorvater*), General Walter Dornberger and Wernher von Braun of Peenemuende, Hans von Ohain of Heinkel, and Bernhard Goethert, among many others. Except for the aged Prandtl, who remained at Goettingen, these men formed the core of scientists and engineers later invited to the U.S. under *Project Paperclip*. Their service on behalf of the U.S. Air Force, the other services, and the U.S. space program in coming decades was inestimable, in some cases legendary. Von Karman's team also gathered scientific data on swept-wing aircraft (used by Boeing in its design of the B-47) and arranged for the transfer of entire facilities (including a wind tunnel complex, crated up and shipped to Wright Field). But most importantly, Von Karman's team issued a report, containing insights and recommendations that would influence the subsequent course of Air Force science and technology planning.

The report, sent to General Arnold in December 1945, consisted of 34 monographs in 12 volumes. The title *Toward New Horizons* was a compromise arrived at after some last minute haggling. But it expressed admira-



bly the content and thrust of the whole. *New Horizons* outlined developments and opportunities in areas of high speed aerodynamics; aircraft materials and structures; power plants, including gas turbines, pulse jets, and ramjets; the design and development of solid and liquid fuel rockets; high temperature materials; aircraft fuels and propellants, including hydrocarbon fuels and atomic power; guided missiles and “pilotless” aircraft; automatic



*First meeting of the Scientific Advisory Board (Von Karman is seated at the head of the table; Frank Wattendorf is the first man, seated, on the left)*

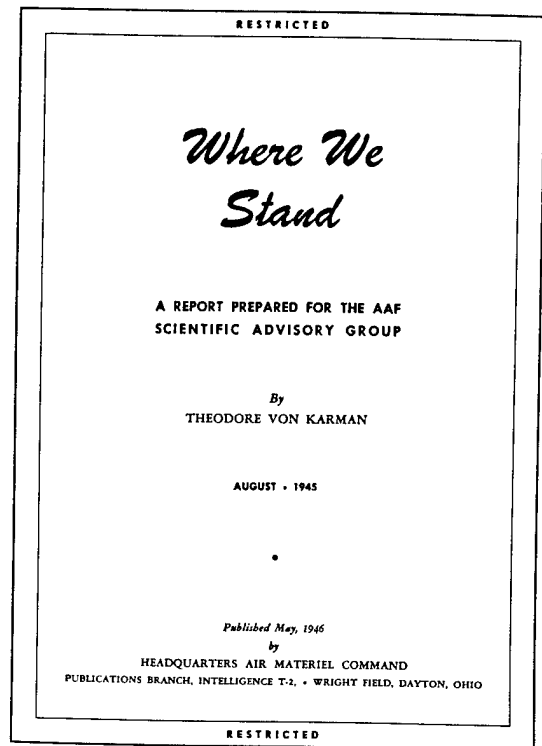
flight controls; heat, television guided, and radar homing missiles; explosives and terminal ballistics; radar and communications; and aviation medicine, including psychological research. Von Karman authored two of the monographs: “Science, the Key to Air Supremacy,” and “Where We Stand.” He advocated a vigorous research program for the future Air Force, including the technical education of officers and the establishment of research and development centers to conduct work in specialized areas. He recommended—somewhat optimistically, if not naively—that future R&D funding account for *one fourth to one third* of the peacetime Air Force annual budget.

What followed was anticlimax—at least in the short term. General Arnold, suffering ill health, was forced to retire. The demands of demobilization following the war, put R&D in third place behind maintenance and supply, and procurement in the priorities of the Air Materiel Command (AMC), headquartered at Wright Field. Von Karman, however, persisted with his program. In 1948,

he got the Air Force to create an Office of Air Research (OAR) in the Air Materiel Command’s Engineering Division. This office was to become the basis for the Air Force’s subsequent program in *basic* research, including the future Air Force Office of Scientific Research (AFOSR), and at Wright Field, the Aerospace Research Laboratories (ARL).

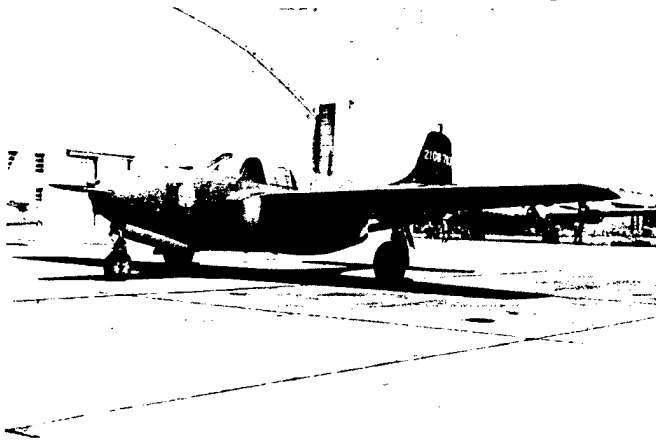
Then in 1951, in midst of the Korean War and Soviet technical successes, including the development of atomic weaponry, the Air Force created an independent command for R&D, the Air Research and Development Command (ARDC). At Wright Field, ARDC’s field unit was the Wright Air Development Center (WADC), established along the lines of R&D centers envisioned by Von Karman in *New Horizons*. (Other centers, created at this time, were the Arnold Engineering Development Center, Tullahoma, Tennessee, and the Rome Air Development Center, Rome, New York.)

In this way *New Horizons* formed the *magna carta* of postwar Air Force R&D. Under its aegis the Air Force and Wright Field entered upon a new era of *aerospace* science and technology development.



*Where We Stand [title page]*

# REENGINEERING THE AIR FORCE FOR THE JET AND SPACE AGE



*Bell P-59A Airacomet powered by the General Electric I-A jet engine*

What Power Plant Lab engineer Cliff Simpson called the “changeover” began with the arrival of the first “Whittle engine” at Wright Field in 1941. Wright Field engineers had been aware of British development of the gas turbine engine. Earlier in the year General Arnold paid a visit to British military installations and had a look for himself. What he saw so impressed him that he convinced the British to send an engine to Wright Field so that the U.S. might begin its own program in “jet” engine development.

Throughout the 1920s and 1930s Wright Field had led the world in piston, or reciprocating, engine technology. The Field both conducted significant in-house research and underwrote extensive industry efforts in building larger and more powerful piston-driven power plants. By the outbreak of World War II, however, American reciprocating engines had reached a technological plateau that seemed to limit aircraft speed and performance forever to the *subsonic* flight regime.

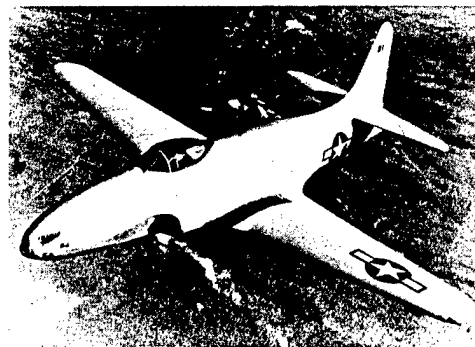
The center of engine development at Wright Field was the Power Plant Laboratory, made notable by such men as Sam Heron, Weldon Worth, Captain Edwin Page, and Opie Chenoweth. The Laboratory’s dynamometers and torque stands tested the best engines industry had to offer—to destruction—to determine their limits and reliability for Air Corps airplanes. Beginning in 1941 one of the most remarkable (and unremarked) transitions in the history of U.S. military technology occurred as men and machines finely honed for one branch of technology

development performed a virtual “left flank” and began to march down another road. It is testimony to the adaptability of this group that the changeover occurred relatively quickly, in the midst of a world war still being waged with the older technology.

The arrival of the jet engine transformed at a stroke a technical community grown comfortable with a mature propulsion technology and the air vehicle built around it. With the new means of propulsion, not only the power plant but every aspect of the airplane was affected: its aerodynamics and hence airframe, including materials and structures; landing gear; radomes and canopies; fuels and lubricants; electronics and controls; cockpit and ejection systems. Jet aircraft raised a host of new problems for aero medical research. They opened up whole new areas of operations as well, as aircraft were now capable of flying higher and faster than ever.

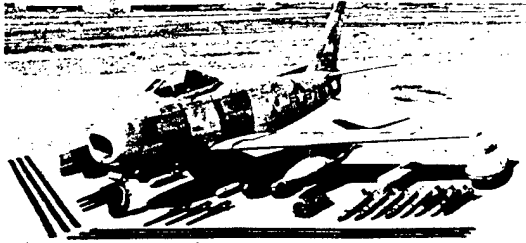
Gas turbine engines were not the only new means of propulsion. World War II also brought to Wright Field pulsejet and ramjet propulsion, as well as rocket motor research. For the first time since Mr. Kettering sold his “bug” to the Army during World War I, the Air Force began to undertake serious research and development of “pilotless” aircraft: both cruise and ballistic missiles that would require sophisticated guidance and control apparatus. For the first time in history, moreover, the exploration and exploitation of “outer space” seemed more than sheer fantasy.

Thus by the end of World War II the Wright Field laboratories found themselves in the midst of one of the greatest efforts of “reengineering” of all time. They had



*Lockheed P-80 Shooting Star*

to accomplish this task with drastically reduced budgets and personnel in the first postwar years, assisted somewhat by *Paperclip* scientists and



*North American F-86A Sabre*

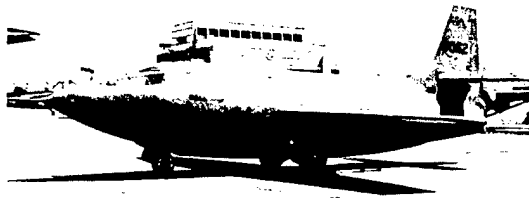


*Convair B-36 Peacemaker flying over Wright Field*



*Boeing B-52 Stratofortress*

engineers. These years saw the introduction of the first operational jet aircraft, both fighters and bombers, such as the P-80 and F-86, the B-47 and the B-52. They also witnessed the conquest of the so-called “sound barrier” by a new genre of experimental craft, the X-plane, a concept itself pioneered by Wright Field professor of aeronautical engineering Ezra Kotcher with help from the Aircraft Laboratory.



*X-1 at Wright Field (June 1946)*

The outbreak of the Korean War in 1950 and the creation of ARDC the following year brought some relief to the laboratories’ funding and manpower shortfall. Under WADC, the laboratories were now part of an organization dedicated to research and development. However, they still expended the bulk of their funding and manpower on near-term engineering development of new systems (often developed, as in WW II, *concurrently*) and in-service engineering in support of AMC’s depots. “Over the horizon” technology projects still took a decidedly back seat.

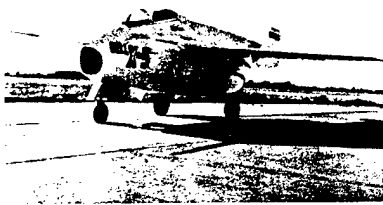


*Northrop YB-49 “flying wing”*

The 1950s was nevertheless an exciting time in technology development at Wright Field. The Air Force was lead sponsor on most of the early X-planes during this period. In addition to supersonic flight, these vehicles also explored guided missile technology, “swing wing” aircraft for both high and low



*X-3*

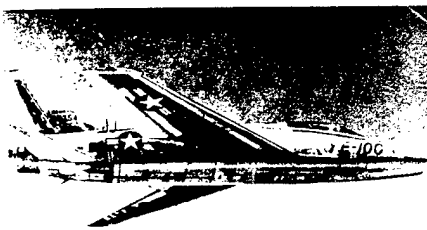


**X-5**

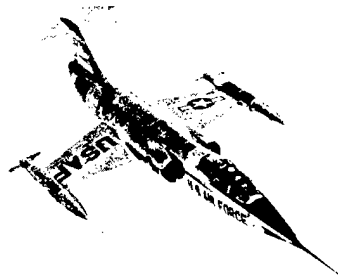
altitude operations, nuclear powered aircraft, ramjet propulsion, and ballistic missiles. Meanwhile, the "century series" fighters (F-100, F-102,

*et al.*) experimented with a variety of airframe configurations (e.g., swept and "delta" wings) to achieve ever better high speed performance in operational aircraft. WADC's Materials Laboratory was kept busy exploring high temperature materials, especially advanced aluminum alloys (one of which was named in honor of the Laboratory), for both airframe and propulsion systems. The

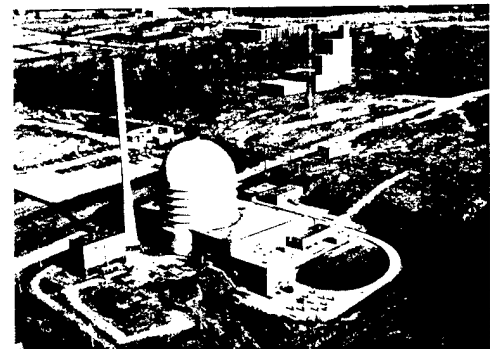
Equipment Laboratory, too, was busy developing everything from advanced clothing for pilots to specialized instrumentation. So complex had aircraft guidance and control technology become that in 1955 WADC created a separate laboratory solely to explore and monitor developments in this area. Meanwhile, the Aeronautical Research Laboratory undertook more fundamental work across a wide spectrum of technical areas. Finally, some of the most interesting and portentous research was conducted by the Aircraft Radiation Laboratory, from the "barn" at the top of the hill at Wright Field: research aimed at exploring the radar cross section of air vehicles, research that very soon turned to means of "reducing" radar detection. This was the beginning of "stealth" technology development at Wright Field.



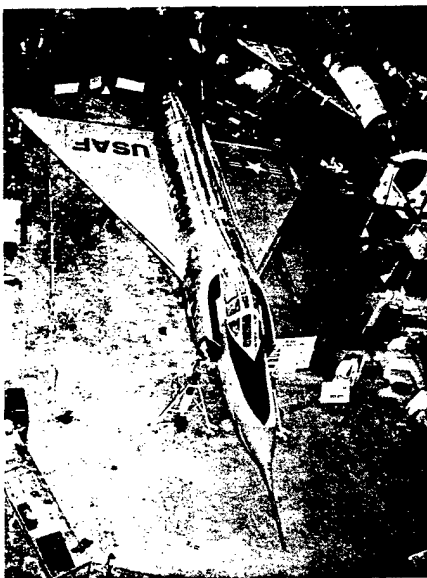
**North American YF-100 Super Sabre**



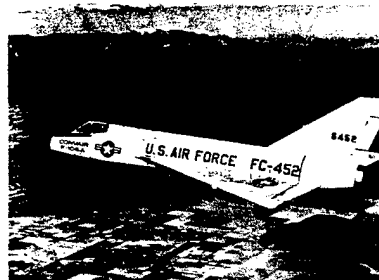
**Lockheed F-104 Starfighter**



**Nuclear Engineering Test Facility, Building 470**



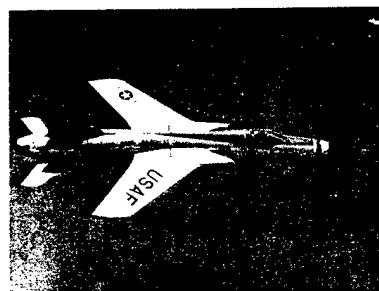
**Convair YF-102 Delta Dagger**



**Convair F-106A Delta Dart**



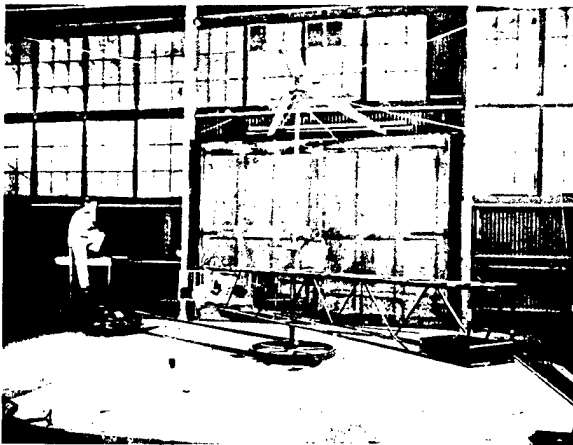
**Radar "barn," Building 821, where early experiments in "stealth" technology were conducted during the 1950s and 1960s**



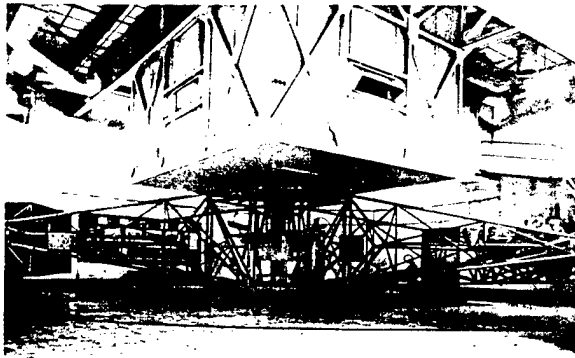
**Republic F-105 Thunderchief**



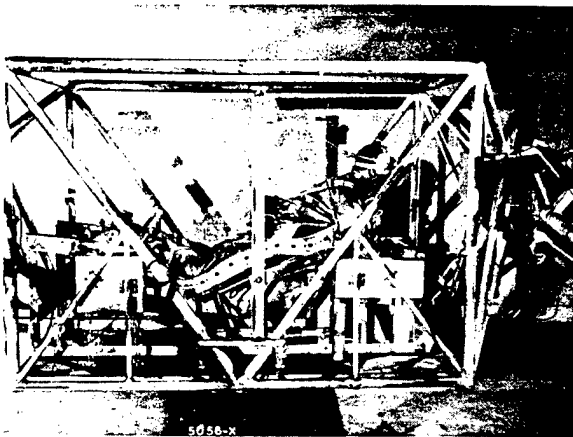
**Centrifuge development at Wright Field**



**First centrifuge in U.S., at Wright Field**



**Later, larger centrifuge, Wright Field**

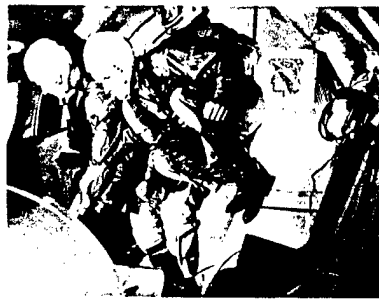


**Human subject in centrifuge**

One of the most important areas of research was human physiology in the new high altitude, high speed flight regime. Major contributions were made early in this area by the Aero Medical Laboratory. The Aero Medical Laboratory was building on the prewar work of its predecessor, the Physiological Research Unit of the Equipment Laboratory. Under the direction of Captain Harry G. Armstrong, this group had pioneered aeronautical medicine, particularly the effects on the human body of high altitudes. Armstrong had built in the basement of Building 16 one of the first altitude chambers in the nation to conduct this research. He and his team devised special oxygen equipment for high altitude flight and

**Pioneering work in zero gravity simulation at Wright Field later aided America's space program**

pioneered development of aircraft with pressurized cabins for operation at high altitudes. The results of this research were first used in World War II, most notably in the B-29, but became especially important after the war in the development of new jet aircraft and plans for space vehicles.



**Gemini-Apollo weightless training**



**Wernher von Braun goes "zero g"**



**Neil Armstrong prepares for tests**

Jet and space flight opened up whole new areas of research. First was the need for new facilities and means of testing the human body's behavior under the stress of rapid acceleration and deceleration; its maneuverability under conditions of weightlessness; human behavior and psychology when subjected to stressful conditions or



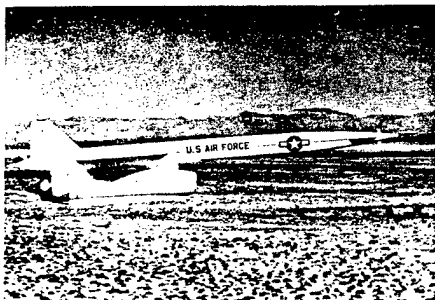
confinement in space-restricted environments. All this was unknown territory in the late 1940s and early 1950s when the Wright Field laboratories began research into these areas. Centrifuges were constructed to test multiple gravity (g) loads on pilots—and potential “astronauts”. WADC researchers devised an ingenious method of simulating weightless (zero-g) conditions by flying “parabolas.” WADC also constructed a mockup “space capsule” in which several human subjects lived for days on end. (The only major problem experienced by this project was when the experimental waste disposal system malfunctioned and had to be replaced by another, more conventional device.) The laboratories also developed new, stronger, and more heat resistant materials for jet powered and space vehicles. (Heat shield research included development of ablating materials as well as a “rotating” heat shield that would act like a whirling propeller blade, allowing space travelers reentering the earth’s atmosphere to view their descent through the “blades.”) Personal equipment was another important area of research: pressurized pilot suits that would prevent “blackouts” under multiple g’s and cockpit ejection systems that went far beyond the simple parachute.

Wright Field also conducted pioneering research into missile systems, beginning in the 1940s. Initially, this research included studies of ballistic missiles and rocket motors. In the mid 1950s responsibility for ballistic

missile development was transferred to the new Western Development Division (WDD), where it was placed under the management of a rising young officer, Brigadier General Bernard Schriever. Most missile work at Wright Field in the 1950s centered on what came to be known as “pilotless aircraft” or cruise missiles and air-to-ground, air-to-air, and ground-to-air missiles. (Von Karman confided to his biographer that the term “pilotless *aircraft*” was coined by AAF officers during the war to prevent missile research from becoming the province of the “ground” Army.) This work was not uniformly successful: difficulties were particularly encountered in developing adequate guidance and control technology. Even failures, however, contributed to the technology experience base on which more successful weapon systems in subsequent decades built.

Indeed, as the 1950s progressed there was increasing dissatisfaction with ARDC and WADC as organizational concepts. In many ways WADC was the “last hurrah” for the old laboratories at Wright Field and their way of doing business. In 1957, the Soviets placed the first artificial satellite in orbit around the earth. The shock to the U.S. public caused by *Sputnik* was profound. Reverberations were felt to the uppermost echelons of the Air Force and the Department of Defense. As the year 1960 approached, there was a growing sentiment to “get America moving again.” Wright Field would soon find itself in the forefront of this new course.

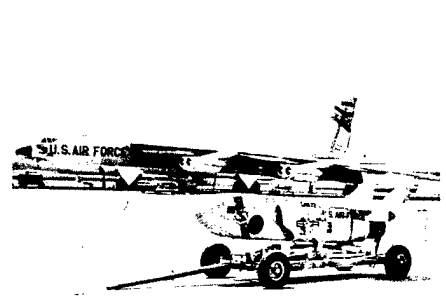
### *Early missile systems*



**North American GAM-77 (AGM-28)  
Hound Dog**



**Martin TM-76 Mace**



**McDonnell GAM-72 (AGM-20A)  
Quail**



# UNLEASHING A TECHNOLOGICAL DYNAMO

**B**ernard Schriever was a man with a mission and a man with a *vision*. Born in Germany in 1910, the year after Orville Wright demonstrated the *Flyer* to the Kaiser and crown prince at Tempelhof Field, near Berlin, Schriever emigrated to the United States with his parents in 1917 and became a naturalized citizen in 1923. He began service in the U.S. Army field artillery, but transferred to the Air Corps in 1932, winning his wings the following year. In 1939, he came to



*General Bernard Schriever*

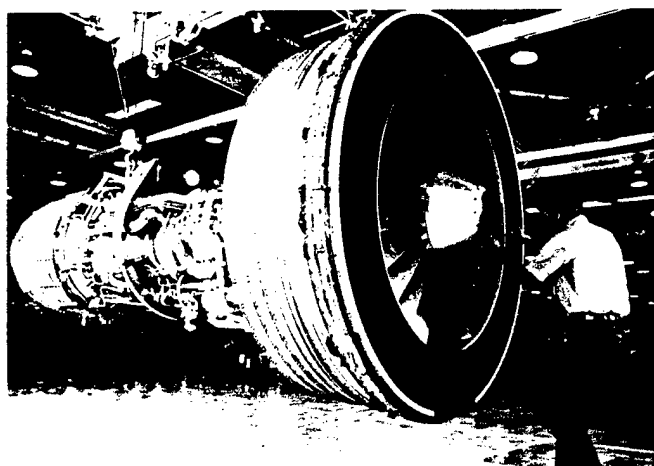
Wright Field as a test pilot and attended the Air Corps Engineering School (later, reorganized as the Air Force Institute of Technology). During World War II Schriever fought in campaigns throughout the Pacific. But war on the battlefield left him unprepared for the postwar bureaucratic infighting leading to the creation of an independent R&D command. "There was lots of blood on the floor," he recalled many years later. And that was only *half* the battle.

When ARDC was set up in 1951, it incorporated the R&D Directorate of the Air Materiel Command (AMC). AMC retained possession of its two other directorates, for Procurement and Production, and Maintenance and Support. More importantly, AMC retained control of all materiel funding, *including* that for R&D. A number of senior officers, like Schriever, came to believe that the R&D process was incomplete, however, without including procurement and production. On becoming commander of ARDC in 1959, Schriever began to lobby for such a change. He won his point, and in 1961, ARDC and AMC were reformed into two new commands: Air Force Systems Command (AFSC) that incorporated the entire weapon systems development process, from research through production, and the Air Force Logistics Command (AFLC) that was responsible for AMC's depot maintenance and support of fielded systems.

As the first commander of AFSC, General Schriever was in a position to implement the second part of his agenda: remaking the Air Force research and technology process and chartering it to forge ahead with truly advanced science and technology work. At Wright Field this agenda spelled the end of the laboratories as they had operated since 1917 and the creation of something new. As a first step in this process, General Schriever separated engineering development from the advanced technology mission of the laboratories and formed two separate organizations to handle each end of the R&D process. The labs themselves, shorn of considerable manpower that was transferred to systems engineering, were consolidated into six organizations for Aero Medical Research, Aero Propulsion, Avionics, Materials, Flight Dynamics, and Aerospace Research. More importantly, the laboratories were placed under HQ AFSC: first its Research and Technology Division (RTD) and, after 1967, under a Director of Laboratories. Under this arrangement, the laboratory commanders and their technical chiefs were given considerable latitude in developing their own technical programs, complete with considerable discretionary funding.

Finally, in 1963 General Schriever convened *Project Forecast*. *Project Forecast* was the largest and most ambitious postwar science and technology forecasting enterprise and second only to Von Karman's *Toward New Horizons* as a model for Air Force planners and strategists. *Project Forecast* comprised nearly 500 participants from the Air Force, other federal agencies, 26 institutions of higher learning, 70 corporations, and 10 non-profit organizations. Its final report ran to over thirty volumes and recommended candidates for both technology and systems development for the next 10 to 25 years.

At Wright Field, the new laboratories set about implementing their mandate to perform advanced technology research. Over the next decade and a half, the *Aero Propulsion Laboratory* introduced several new programs for solving development problems with gas turbine engines. First was the Advanced Turbine Engine Gas Generator (ATEGG) program (1965), which systematically developed engine core technologies; the Aircraft Propulsion Subsystem Integration (APSI) program (1968), which addressed problems of engine-



*High by-pass turbofan engine development was sponsored by the Aero Propulsion Laboratory*

airframe interface, particularly troublesome in design of advanced fighter aircraft; and sponsored the Joint Technology Demonstrator Engine (JTDE) (1975) with the Navy to test full-scale demonstrator engines. During the 1950s the laboratory had promoted development of turbofan technology. In 1964 this sponsorship bore fruit in development of the first high-bypass turbofan engine, for the Air Force's first wide-body jet airlifter, the giant C-5A. The Laboratory also undertook development of ramjet and scramjet power plants for potential application in hypersonic aerospace planes. The Laboratory, moreover, continued its in-house development of jet propulsion (JP) fuel and lubricants, not only for the Air Force (JP-4) but also for the Navy (JP-5) and member states of the North Atlantic Treaty Organization (NATO) (JP-8). Finally, the Laboratory pursued an aggressive program to develop aircraft and spacecraft electrical power systems, including longer-lived and lighter-weight fuel cells and solar cells and cell arrays.

During this period, the *Materials Laboratory* continued pioneering a host of advanced materials and processes, including manufacturing methods. Since World War II, the Laboratory had sponsored development of plastics and advanced composite materials for aircraft and spacecraft application. These materials had advantages over conventional structural materials due to their durability and lighter weight. The Laboratory almost single-handedly sponsored the development of carbon-carbon for use in structures subject to extremely high



*Materials Laboratory, Building 32*

temperatures, such as jet and rocket engine nozzles and leading edges of aerospace vehicles. The Laboratory also continued development of newer and lighter metal alloys with both high temperature and high tensile properties, for use in both airframes and engines. So, too, the Laboratory investigated the properties of high temperature ceramics, for use in powerplants and the thermal protection systems of space vehicles. The Laboratory inherited AMC's Manufacturing Technology (Man Tech) program in the late 1950s. Under Man Tech, the Laboratory pioneered the application of computers to manufacturing processes, beginning in the early 1970s. Finally, the Laboratory explored the development and "manufacturability" of improved substrate materials—such as gallium arsenide—for the new science of microelectronics.

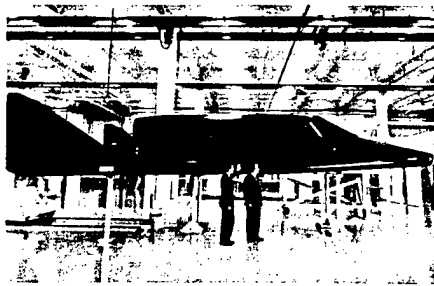
The *Avionics Laboratory* was the organization most profoundly affected by the microelectronics revolution that burst upon the world in the late 1940s with the invention of the transistor by Bell Labs and then the integrated circuit (IC) nearly a decade later. The term "avionics" (= aviation electronics) was itself only first applied to Wright Field's electronics development program activity in 1959. The Avionics Laboratory united several smaller labs, including those for Electronic Technology, Aerial Reconnaissance, Guidance and Control, and Communication and Navigation. The Laboratory's mission was essentially fourfold: development of defensive systems (electronic warfare), offensive systems, communication and navigation systems, and device technologies. In the 1960s and 1970s, the Avionics Laboratory continued pioneering development of low observable (stealth) technology; initiated research into revolutionary active phased array radars; airborne lasers; electronic warfare jammers; terminally guided laser



weapons; airborne forward looking infrared (FLIR) technology; and anti-jam radio communications, among many others. Finally, the Laboratory began to undertake studies in the *integration* of avionics systems that would bear fruit in the 1980s and 1990s.

The *Flight Dynamics Laboratory* inherited the missions of the Aircraft Laboratory, the Flight Controls Laboratory, and the Aeronautical Accessories Laboratory of WADC. These missions included aerospace vehicle design studies, flight control research, aircraft structures research, aeronautical equipment development, and aeromechanics. The Laboratory became the *integration laboratory* par excellence of the Wright Field laboratories and over the years sponsored a variety of its own and Air Force demonstrator vehicles, including support of several X-planes, such as the X-21, the X-24A, and the X-24B.

During the 1960s and 1970s the Laboratory conducted programs for improving aircraft tires, oxygen systems, subsonic and transonic flutter prediction, improved gasdynamic instrumentation, a functionally integrated throttle control system, improved flight control systems, improved fuel tanks, tactical weapon delivery, stall/post-stall/spin requirements, integrated air-frame-nozzle performance prediction techniques, flutter safety evaluation



**X-20 Dyna Soar**



**X-21A**



**X-24A**

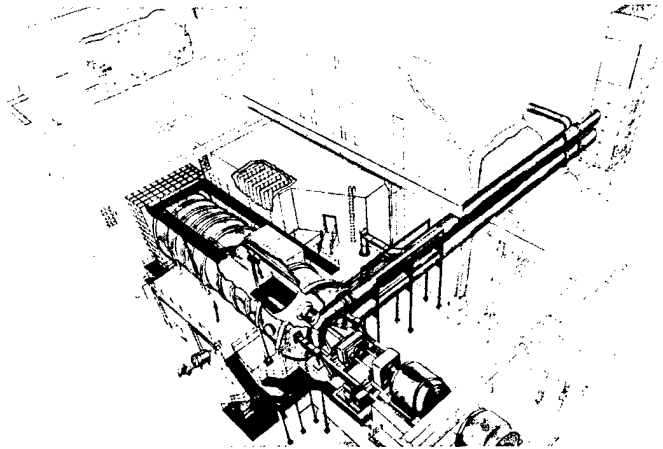
for aircraft with external stores, cryogenic cooling for spacecraft, transonic wind tunnel wall interference reduction, graphite epoxy landing gear, and the study of acoustic fatigue at elevated temperatures. Particularly notable during this period was the Laboratory's sponsorship and advocacy of *fly-by-wire technology*, which revolutionized aircraft maneuverability and control. The Laboratory also developed several new facilities and diagnostic techniques. These included the Total In-Flight Simulator (TIFS) for simulation studies of the proposed B-1 strategic bomber; the Re-entry Nose Tip (RENT) facility for evaluating severe aerodynamic heating of reentering spacecraft; improved in-house capability for gasdynamic instrumentation; and the Dynamic Taxi Simulation Facility for testing landing gear.

The *Aerospace Research Laboratories* specialized in *basic* research. The Laboratory was a direct descendent of the Office of Air Research established by Von Karman in 1948 at Wright Field. During the 1950s the laboratory was called first the Flight Research Laboratory and then the Aeronautical Research Laboratory. When the Wright Field laboratories were reorganized in 1959-63, the ARL was assigned to the Office of Aerospace Research (OAR), in Washington, although its buildings and personnel remained at Wright Field. The Laboratory conducted studies in the areas of chemistry, energetics, fluid dynamics, plasma physics, applied mathematics, thermodynamics, general physics, hypersonics, solid state physics, and metallurgy and ceramics. The ARL was no "sandbox" organization. Its researchers worked closely with other laboratories in formulating solutions to Air Force problems. It numbered among its members some of the most gifted scientist-engineers at Wright Field.

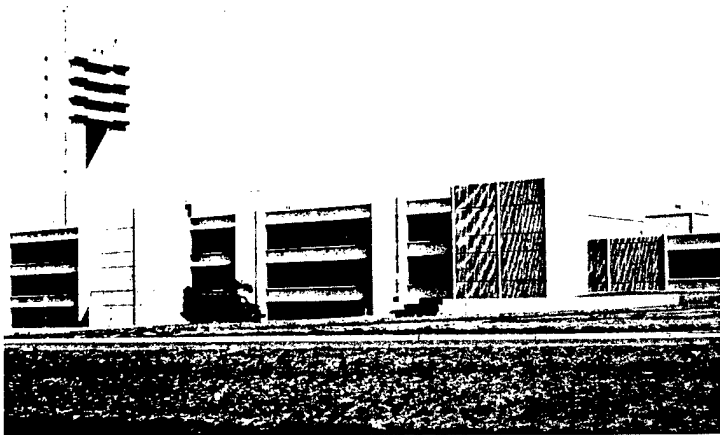
In support of this expanded advanced technology mission, the Air Force sponsored the most significant facility construction at Wright Field since World War II. This included the beginnings of a vast five-building complex for materials research; a new fuels and lubes laboratory; two new buildings housing simulators for work in aircraft controls and cockpit design; and a new structure for conducting sensitive work in avionics. In addition to these were numerous smaller facilities, either built anew or from parts of earlier facilities (very little went to waste at Wright Field). Many of these facilities



*New Materials Laboratory complex under construction*



*Compressor Research Facility (schematic)*



*New Avionics Laboratory complex (Building 620)*

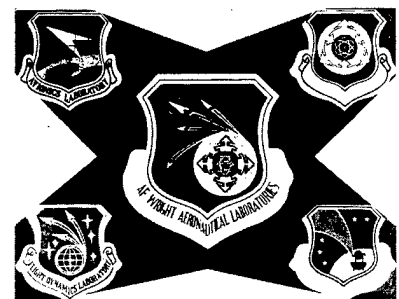


*New fuels and lubes facility (Building 490), foreground, with other buildings of the Aero Propulsion Laboratory complex*

were unique in the nation and placed the Wright Field laboratories squarely on the cutting edge of aerospace research and development.

U.S. involvement in Southeast Asia, from the mid 1960s through the mid 1970s, presented the Air Force R&D community with a two-edged sword. On one side, the war diverted funding from far-term research to support near-term Air Force combat needs, particularly in the area of "limited" or counterinsurgency warfare. On the other side, as the war began to wind down, in the late 1960s and early 1970s, overall reductions in the Defense budget caused funding for R&D to drop as well. Consequently, the Air Force directed reductions in

laboratory manpower and the consolidation of laboratory organizations where possible. At Wright Field, the four applied research laboratories for Materials, Aero Propulsion, Avionics, and Flight Dynamics were consolidated under a new organization, the Air Force Wright Aeronautical Laboratories (AFWAL), in 1975. At the same time, the Air Force disestablished the Aerospace Research



*AFWAL emblem with those of its four constituent laboratories*

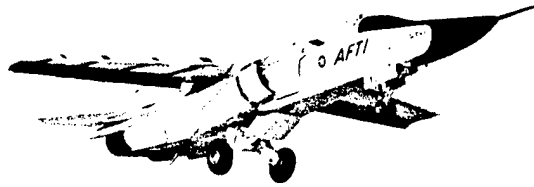


Laboratories and distributed its personnel and facilities among the four other AFWAL laboratories.

Despite post Viet Nam cutbacks, the Wright Field laboratories continued to make significant technology contributions. By the end of the 1970s, defense expenditures again began to rise, first modestly and then in the early 1980s dramatically resulting in the largest peacetime military buildup in American history. This buildup fueled a host of major program efforts by the laboratories, particularly advanced technology demonstrator efforts, with the purpose of hastening the transition of technology to developmental weapon systems. This push for technology transition was institutionalized in 1982, when AFWAL was assigned to the Aeronautical Systems Division (ASD).

The programs undertaken by the laboratories in the late 1970s and 1980s were numerous and significant. AFWAL fielded a number of technology demonstration aircraft, among them, the Advanced Fighter Technology Integration (AFTI)/F-111 that experimented with variable camber wings; the AFTI/F-16 that demonstrated integrated aircraft flight and fire control technology; the Short Take Off and Landing (STOL)/F-15, outfitted with thrust vectoring nozzles to enhance STOL operations; and the X-29 that demonstrated the advantages of forward swept wings on modern fighter aircraft for high angle-of-attack and other difficult maneuvers.

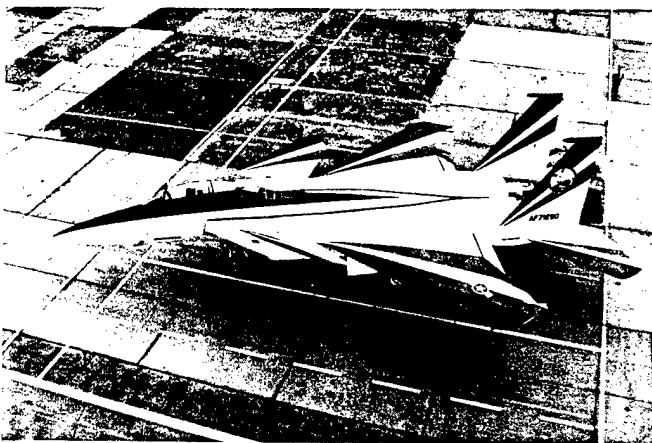
Also during the 1980s AFWAL made significant progress in the development of advanced structural alloys, composite materials and their applications, non-



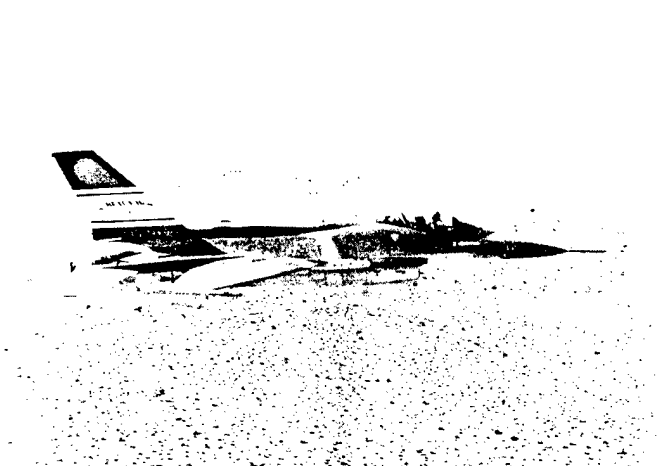
*AFTI/F-111 explored effects of variable wing camber on aircraft performance*



*X-29 exploited forward-swept wings for high angle of attack maneuvers*



*STOL/F-15 employed ducted nozzles to demonstrate short takeoff and landing maneuvers*



*AFTI/F-16*



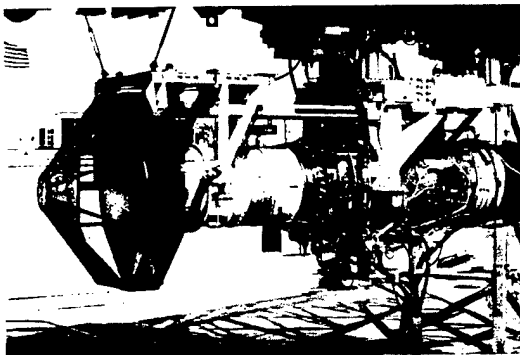
flammable hydraulic fluids; and semiconductor substrate materials, such as gallium arsenide.

In addition to materials, AFWAL directed a number of important efforts supporting advanced avionics development. These efforts included Very High Speed Integrated Circuits (VHSIC); Integrated Communication, Navigation, Identification Avionics (ICNIA); Pave Pillar advanced avionics architecture; solid state phased array radar technology; and advanced guidance for cruise missiles, among many other programs. AFWAL also led a government-industry-academic consortium for the development of artificial intelligence technologies and their exploitation.

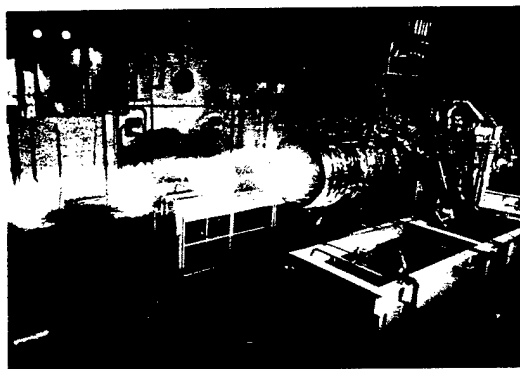
In the area of propulsion technology, AFWAL spearheaded a major national effort to double the performance of gas turbine engines by the turn of the century. This effort, called the Integrated High Perform-

mance Turbine Engine Technology (IHPTET) program, included participation by the Army, Navy, the National Aeronautics and Space Administration (NASA), and all major U.S. turbine engine manufacturers. IHPTET combined propulsion, materials, design, and instrumentation technologies in what has become a model advanced development program.

AFWAL also made major contributions in the areas of propulsion, materials, and diagnostic technologies to the National Aero Space Plane (NASP) program. NASP explored the development of suitable technologies and designs for an "aerospace plane," i.e., a vehicle capable of taking off from a runway like an airplane, accelerating to orbital velocity, flying into space, and returning to land like an airplane. The program revived the nation's hypersonic technology base, which had atrophied since the early 1960s when the Wright Field laboratories had initially explored the hypersonic frontier. The NASP program was cancelled, however, before building a demonstrator vehicle (designated the X-30), a victim of defense reductions at the end of the "Cold War."

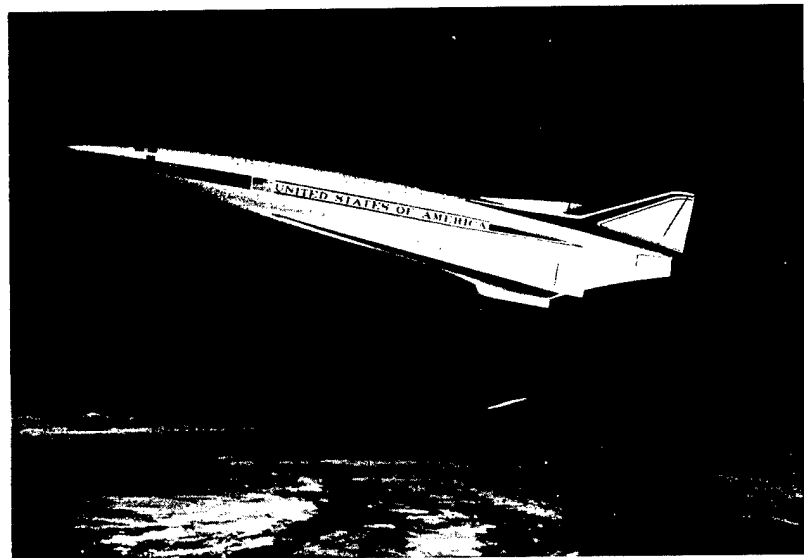


*XTE 43 Joint Technology Demonstrator Engine  
(General Electric)*



*XTE 65-1A Joint Technology Demonstrator Engine  
(Pratt & Whitney)*

*IHPTET developed advanced gas turbine  
engine technologies*



*National Aero Space Plane—X-30 (artist's concept)*



# CREATING TODAY'S AIR FORCE

The ultimate recipients of advanced technology were modern aerospace weapon systems. Since 1961 the organization charged with the development and acquisition of these systems was the Aeronautical Systems Division (ASD). ASD was formed by combining the Air Materiel Command's Aeronautical Systems Center (ASC) with the Air Research and Development Command's Wright Air Development Division (WADD). At the heart of ASD was the *system program office (SPO)*. The "SPO concept" had arisen gradually since World War II as the development of aircraft and associated components became more complex and expensive. The first large aircraft project office to anticipate the later SPO was the B-29. During the 1950s major aircraft and missile programs were managed by *weapon system project offices (WSPOs)* that combined expertise from WADC and AMC. The SPO went one giant step farther than these earlier arrangements. Building on General Schriever's experience in managing the Air Force's ballistic missile development program, the SPO consisted of a dedicated engineering and procurement cadre together with representatives from the using command(s), including the logistics command. The SPO, in short, attempted to anticipate *all stages in the development and deployment and operational life cycle* of a weapon system. This approach to weapons acquisition was made necessary with the increased expense of weapons and their longer service use.

The organization that formed the bridge between the laboratories and a completed weapon system was ASD's *Deputy for Engineering (EN)*. Initially set up as the Deputy for Systems Engineering, under the Wright Air Development Division (WADD), 1959-1961, it comprised engineers taken from the laboratories to form an organization dedicated to *engineering development* of weapon systems. In 1961, it became part of ASD. From 1963 to 1967, however, it reported to Air Force System Command's Research and Technology Division (RTD) as the Systems Engineering Group (SEG). When RTD was disestablished in 1967, Engineering returned to ASD. The Deputy for Engineering was responsible for a multifaceted mission at the heart of which was the evaluation through analysis, test, and validation of technologies before they were transitioned to weapon

systems. Without EN's *fiat* advanced technology quite literally "wouldn't fly."



**Lockheed C-130A Hercules**



**KC-135 refueling B-52**



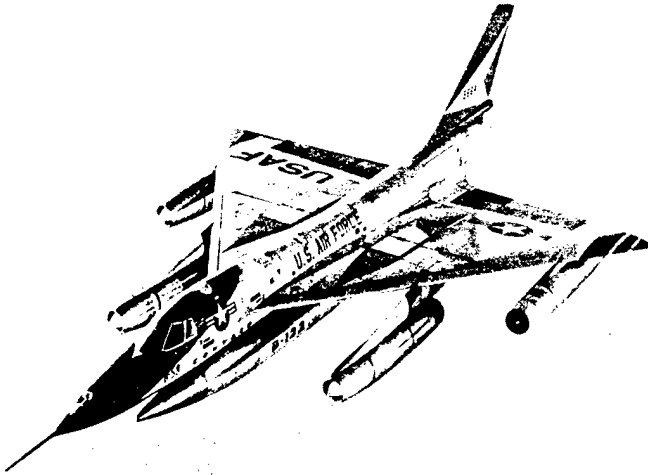
**Northrop YF-5A Freedom Fighter**

stealth fighter/bomber. In addition, there are a number of aircraft which saw service through much of this period, but are currently retired from the Air Force's inventory or are in the process of retirement. These include the F-111 fighter/bomber, the F-5 fighter, and the A-10 attack aircraft. Some, such as the SR-71 reconnaissance aircraft, have been retired and "resurrected."

When ASD began operations in the early 1960s, the Air Force had for a decade and a half been pursuing the twin aims of greater speed and altitude for both its

At the outset of the 1960s, the Air Force had a handful of aircraft whose service would continue to the end of the century. Most notable among these aircraft were the C-130 airlifter, the B-52 strategic bomber, and the KC-135 tanker/transport. However, today's Air Force is largely a product of weapon systems developed since the formation of ASD. These include the F-15 and F-16 fighters, the B-1B and B-2 strategic bombers, the C-141, C-5A and C-5B, and C-17 airlifter aircraft, the KC-10 tanker, and the F-117

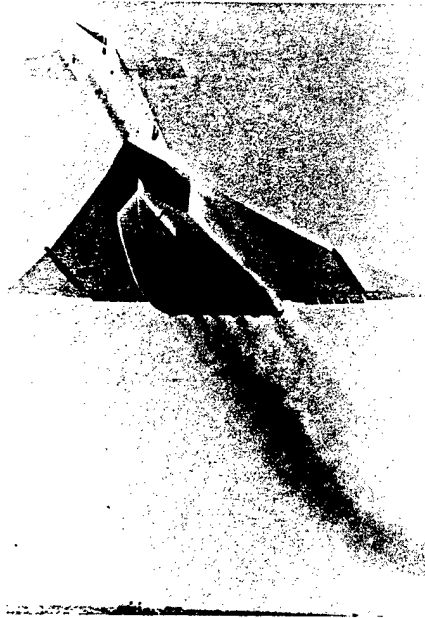
fighter and bomber aircraft. These were the objectives behind the Century Series fighters. It was the motive behind the development of the Air Force's first supersonic bomber, the B-58, and the B-70 strategic bomber that would be capable of flying at Mach 3. The reason



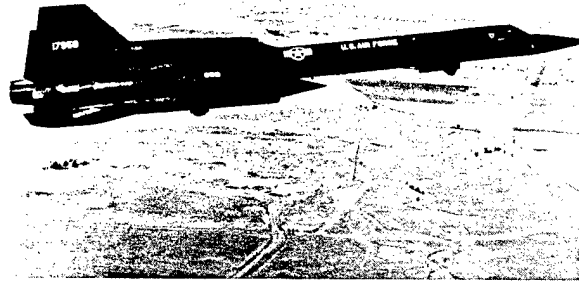
**Convair B-58 Hustler**

for the emphasis on speed and altitude was penetration of enemy air defenses. However, a series of incidents, such as the downing of the high-flying U-2 reconnaissance aircraft over the Soviet Union in 1960, demonstrated the vulnerability of even high-flying aircraft to surface-to-air missiles. Furthermore, the development of ballistic missiles provided an alternative means of delivering nuclear warheads against a foe's home territory. Moreover, the Korean War had demonstrated the need for more emphasis on tactical aircraft and weapons. This need was reemphasized as the U.S. became increasingly engaged in Southeast Asia, from the mid-1960s.

Because of these shifting priorities, ASD was charged with a number of major actions in the early 1960s. First, development of the B-70 was transformed into an "experimental" program and then cancelled. The Division remained committed to transitioning technology to the high-altitude, high-speed regime, however, in development of the SR-71 reconnaissance aircraft and its support of the X-15 in cooperation with the National Aeronautics and Space Administration (NASA). The Division began development of the F-111 "swing wing" fighter/bomber that would be capable of both high and low altitude operations. The Division also began plan-



**XB-70 taking off**



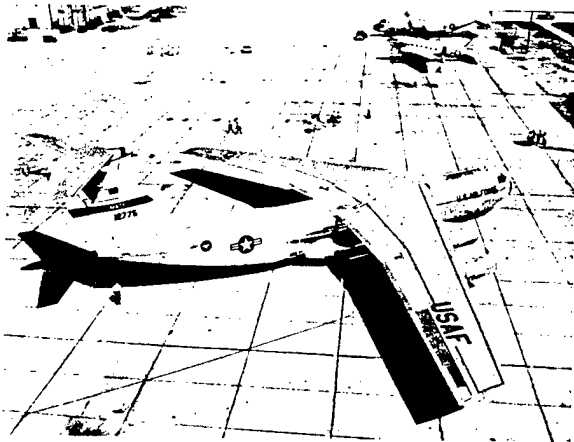
**Lockheed SR-71 Blackbird**



**General Dynamics FB-111**



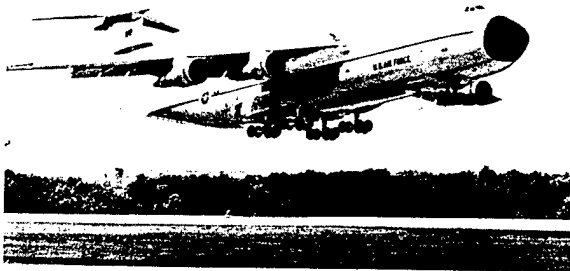
ning development of an advanced twin-engine multi-role fighter aircraft, the F-15, and by the end of the decade a smaller, single-engine fighter, the F-16. The F-16 became the first fighter aircraft fully to exploit fly-by-wire



*Lockheed C-141 Starlifter*



*General Dynamics F-16 Fighting Falcon*



*Lockheed C-5A Galaxy*

technology. At the same time, the Division undertook development of the Air Force's first large jet-powered airlift aircraft, the C-141 and the C-5A. The wide-body C-5A was powered by revolutionary high-bypass turbofan engines.

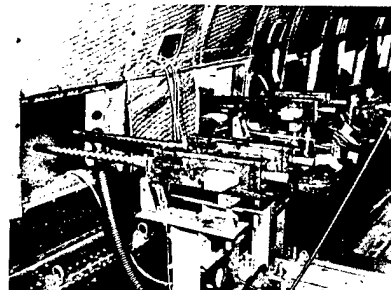
These programs were for the most part in the early development stages when U.S. involvement in Viet Nam began to escalate. Viet Nam presented a different kind of war for the Air Force, one marked by so-called counterinsurgency or "limited war" tactics and objectives. In response, ASD established a Limited War Office in the mid 1960s to coordinate development of weapons suitable to this new kind of aerial warfare. Many of these developments were *ad hoc* and acquired in limited quantities for the war emergency. In several cases, however,

#### *Gunship development*

they resulted in new weapon systems that soon became mainstays of the Air Force's operations.



*AC-47 gunship*



*AC-47 interior*



*AC-130 gunship*

Perhaps the most notable example is the gunship. The first gunship was an all-house prototype effort developed in cooperation between ASD and the Avionics Laboratory. The prototype consisted of a C-47 airframe mounted with side-firing canon and a synchronizer that allowed activation of the gun from the cockpit. Combat trials proved the value of the gunship and more were ordered. Eventually, both the C-119 and the C-130 aircraft were also converted to gunship configuration.



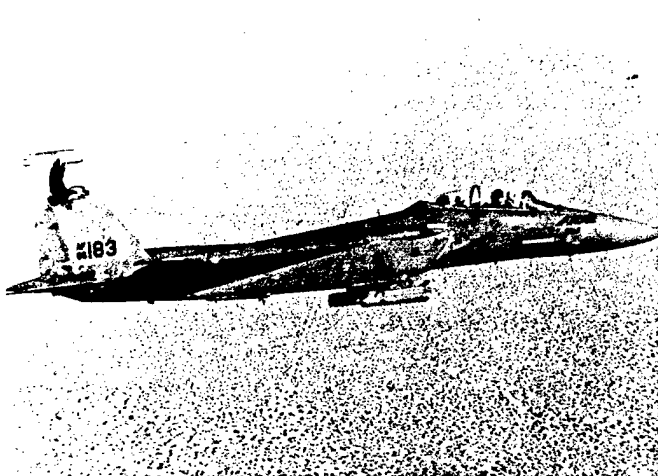
During the 1970s, ASD underwent a major management reform under Lt General James T. Stewart. Under General Stewart's long tenure (1970-76)—the longest in ASD history—the Division developed the “super SPO” by combining, e.g., all engine programs in one organization. This resulted in more efficient and effective strategies for developing and procuring aircraft subsystems. The new *Propulsion SPO* devised what became known as the “great engine war,” which sought to reduce acquisition costs while increasing performance and reliability by bringing



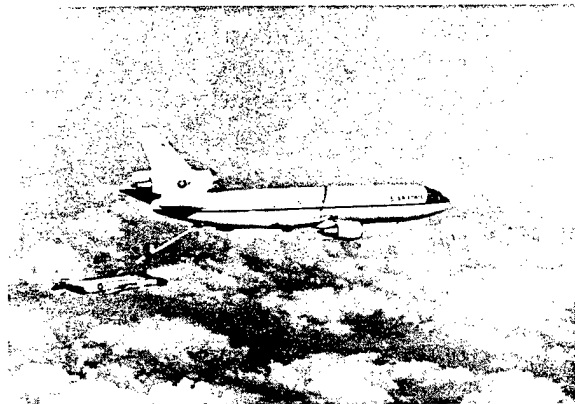
***Lt General James T. Stewart, ASD Commander 1970-1976***

more competition between the nation's chief jet engine manufacturers. A similar SPO was established for the development and procurement of aircraft simulators.

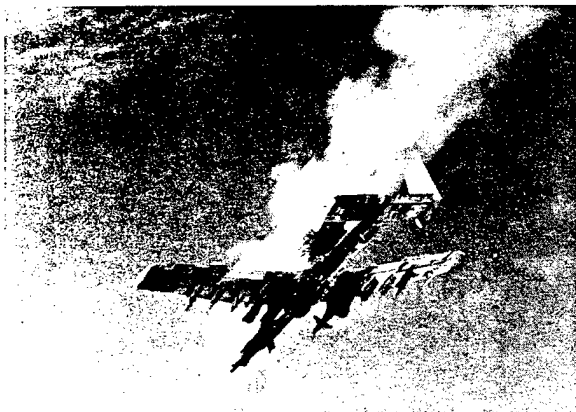
ASD also forged ahead during the 1970s with acquisition of the F-15 and F-16 as well as a new close air support aircraft, the A-10. Work also continued on the B-1A strategic bomber until its cancellation in 1979. One of the most portentous developments during the 1970s was the insertion of low observable or “stealth” technology into operational aircraft systems. During the mid 1970s work began on what was to become the F-117 fighter/bomber, which entered Air Force operations in the mid 1980s. During the 1970s, ASD also explored the use of “propulsion lift” technology in the design of short landing field heavy airlift systems. This technology would later be applied to design of the C-17 airlifter. Finally,



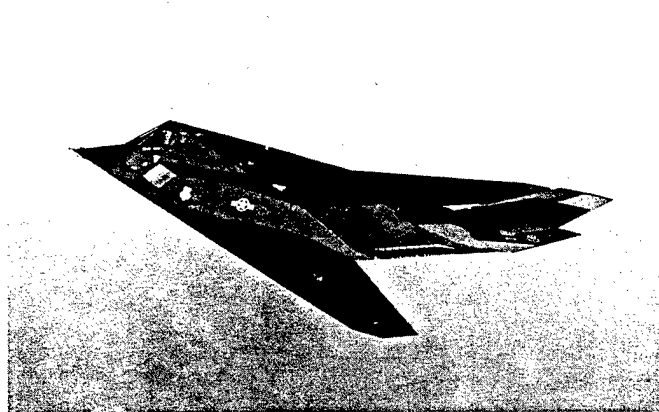
***McDonnell Douglas F-15E Eagle***



***KC-10***



***Fairchild Republic A-10A Thunderbolt II***

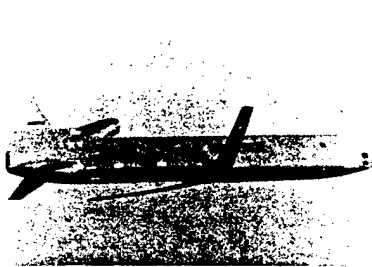


***Lockheed F-117***

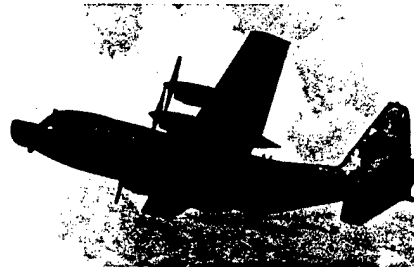


during this period, ASD continued development of major missile systems, including the Air Launched Cruise Missile (ALCM) and the Short Range Attack Missile (SRAM).

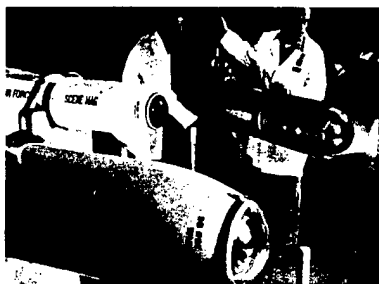
The decade of the 1980s witnessed the greatest peacetime increase in the defense budget in history. ASD was a principal beneficiary of this largesse, forging ahead with a variety of major weapon system developments. At the outset of the decade, ASD resumed work on the B-1 strategic bomber, revived by the Reagan Administration, as the B-1B. Early in the decade the Division also began procurement of an upgraded version of the C-5 airlifter, the C-5B, and began engineering development of an all-new heavy airlifter, the C-17. The C-17 was notable for incorporating both the ability to fly strategic *intertheater* missions and tactical *intratheater* missions, combining the C-130's short, rough field capability, and the long-distance and large capacity characteristics of the C-141 and the C-5. At the same time, the Division unveiled the Air Force's first "stealth" fighter, the F-117 and accelerated development of a "stealthy" strategic bomber, the B-2, and continued planning for a new generation air superiority fighter, called initially the Advanced Tactical Fighter (ATF), later designated the F-22.



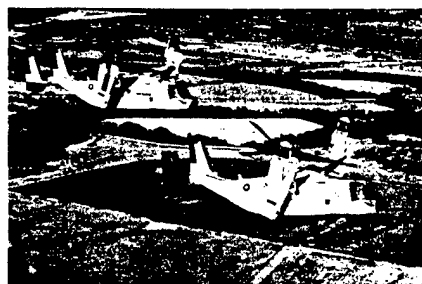
*Air Launched Cruise Missile*



*MC-130H Combat Talon II*



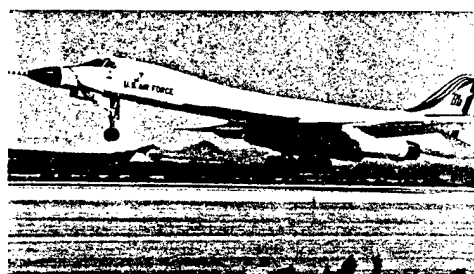
*AGM-65A Maverick*



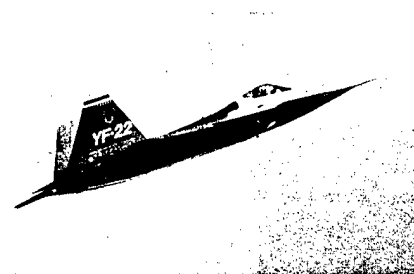
*CV-22A Osprey*

Special operations aircraft were also developed and acquired by ASD during the 1980s. These systems included an upgrade to the gunship, the AC-130U; an upgraded combat talon aircraft, the MC-130H Combat Talon II; support for joint service development of a unique tiltrotor aircraft, the CV-22A

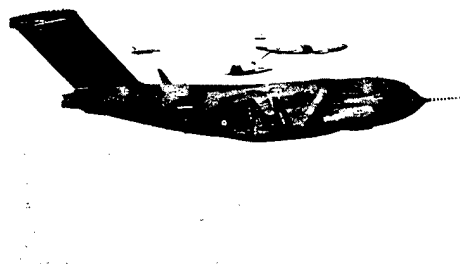
Osprey; and acquisition of two new *Air Force One* airliners to provide transportation for the President of the United States and other high government officials. In addition, ASD also acquired a number of smaller, commuter aircraft for executive airlift of Air Force and other dignitaries, as well as smaller airlift aircraft, and a new trainer aircraft, the T-1A.



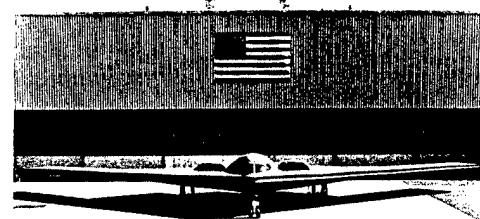
*Rockwell International B-1B Lancer*



*Lockheed YF-22*



*McDonnell Douglas C-17 Globemaster III*



*Northrop B-2*

# OVER THE HORIZON: THE 1990s AND BEYOND



In 1985, the commander of the Air Force Systems Command, General Lawrence A. Skantze, initiated a systems and technology forecasting exercise. Called *Project Forecast II*, it looked back to the precedent established under General Schriever in the 1960s. Its purpose, however, was to look forward to an uncertain, perhaps revolutionary future in technology and systems development. A former commander of ASD, General Skantze was well-versed in the capabilities of the laboratory and program office operations at Wright Field, and *Project Forecast II*'s final report reflected the dominant role played by the Wright Field science and engineering community.



**General Lawrence A. Skantze, AFSC Commander**

*Project Forecast II* attempted to provide not only guidance but funding as well for future aerospace developments. However, it did not, indeed could not, anticipate the revolutionary change in world geopolitics that occurred in the latter half of the 1980s.

Nineteen eighty-five, the year that *Project Forecast II* convened, saw the rise to power in the Soviet Union of a reformist leadership, headed by Mikhail Gorbachev. Within five years, under the slogans *glasnost* and *perestroika*, the Soviet empire in eastern Europe was liquidated and the Union of Soviet Socialist Republics (USSR) itself came undone. The "cold war" that had persisted for forty years between the democratic west and the communist east effectively and symbolically ended with the tearing down of the Berlin Wall in November 1989.

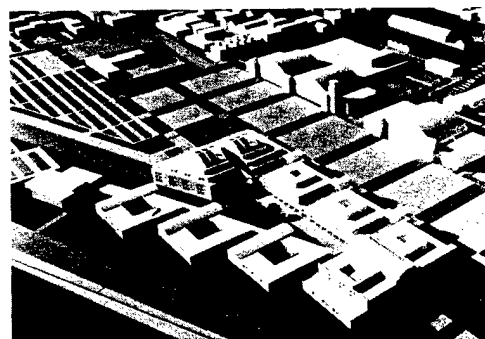
The "new world order" issuing from these events left the United States as the world's sole superpower. This new status was almost immediately put to the test in 1990/91 when Iraq invaded Kuwait, violating the national sovereignty of a peaceful neighbor and threatening the world's middle east oil supply. The United States led a coalition of powers under the general auspices of the

United Nations to reverse Iraqi aggression and restore the mideast balance of power. The United States Air Force played a dominant role in this action, codenamed *Operation Desert Storm*. For the first time in a generation the nation and the world witnessed the USAF's arsenal of advanced weaponry let loose—with devastating consequences for the enemy.



**Allied warplanes of Operation Desert Storm fly over burning Kuwaiti oil fields**

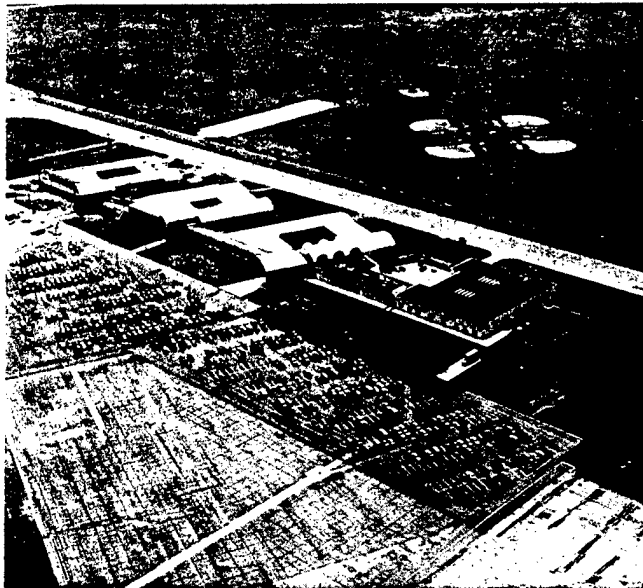
The end of the Cold War had other consequences including considerable domestic pressure on the Department of Defense to downsize its force structure; the alleged savings would constitute a "peace dividend." Reductions in defense spending, already begun in the 1980s, accelerated precipitately in the early 1990s. Concomitantly, the Air Force initiated a major reorganization of its command structure. Included in this reorganization, in 1992, was the disestablishment of Air Force Systems Command and Air Force Logistics Command and the formation of the Air Force Materiel Command (AFMC). Under this arrangement, at Wright Field the Aeronautical Systems Division was reorganized as the Aeronautical Systems Center (ASC). ASC extended ASD's scope beyond technology and weapon systems development to include the operation of



**James H. Doolittle Acquisition Complex (artist's concept)**



*Lt General James T. Stewart Hall*



*James H. Doolittle Acquisition Complex, 1996*

Wright-Patterson Air Force Base, including the Wright-Patterson Medical Center. Meanwhile, ASC began construction of a major complex for acquisition management, the General James H. Doolittle Acquisition Center. The first building in the complex was dedicated in the summer of 1994 in honor of former ASD commander Lt General James T. Stewart. (Three additional buildings were dedicated in 1997, to General K. B. Wolfe, Mr. Fred Rall, and Major General William "Billy" Mitchell.)

Changes had also occurred within ASC's laboratory community. In 1990, the Air Force consolidated its laboratories nation-wide to form four "super labs." Under this arrangement, the Wright Field laboratories for Materials, Aero Propulsion and Power, Electronic Technology, Avionics, and Flight Dynamics combined with the Armament Laboratory at Eglin AFB, Florida, to form the *Wright Laboratory*.

The Air Force, meanwhile, proceeded on several fronts to map out its technology and systems future. In the early 1990s it inaugurated a new "technology master process" for coordinating technology development with customer requirements. At the same time, it initiated a new round of forecasting exercises. The first major exercise, *Spacecast 2020*, which convened in the summer of 1993, forecast the Air Force's space technology and systems requirements well into first quarter of the twenty-first century. Early in 1994 the Air Force also began preliminary studies leading to a more comprehensive forecasting exercise, *Air Force 2025*, which issued its report in 1996. At the same time, the Air Force Scientific Advisory Board conducted a similar study called *New World Vistas*, which it issued on the 50th anniversary of Von Karman's *Toward New Horizons*.

What these studies foresaw was a future Air Force that increasingly would become an Air and Space Force and ultimately a Space and Air Force: a force structure that would rely increasingly on unmanned vehicles and weapon systems "internettted" by a complex information system consisting of ground, air, and space platforms, that would allow nearly instantaneous action anywhere on the face of the globe in response to hostile actions against the interests of the United States and the peace of the world community.

**NEW WORLD VISTAS**  
AIR AND SPACE POWER FOR THE  
**21ST CENTURY**

# RETROSPECT: "A STORY THAT... OUTRIVALS THE ARABIAN NIGHTS..."



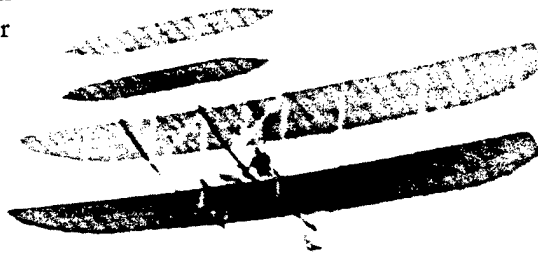
In 1904 Amos Ives Root traveled from his home in Medina, Ohio, to Dayton. He came to see if the rumors he had heard were true: that two Dayton brothers had solved the problem of manned flight. He came. He saw. He wrote it all down. His account appeared the following January in *Gleanings in Bee Culture*. "I have a wonderful story to tell you," Root began, "a story that, in some respects, outrivals the Arabian Nights fables." He continued solemnly: "God in his great mercy has permitted me to be, at least somewhat, instrumental in ushering in and introducing to the great wide world an invention that may outrank the electric [street] cars, the automobiles, and all other methods of travel, and one that may fairly take a place beside the telephone and wireless telegraphy."

Root was an apiarist by vocation, an intensely curious man by nature, and a poet at heart. "It has often been remarked that one of the most beautiful sights in the world is a ship under full sail," he observed. "But to me the sight of a machine like the one I have pictured, with its white canvas planes and rudders subject to human control, is one of the grandest and most inspiring sights I have ever seen on earth. . . Its highway is God's free air . . ."

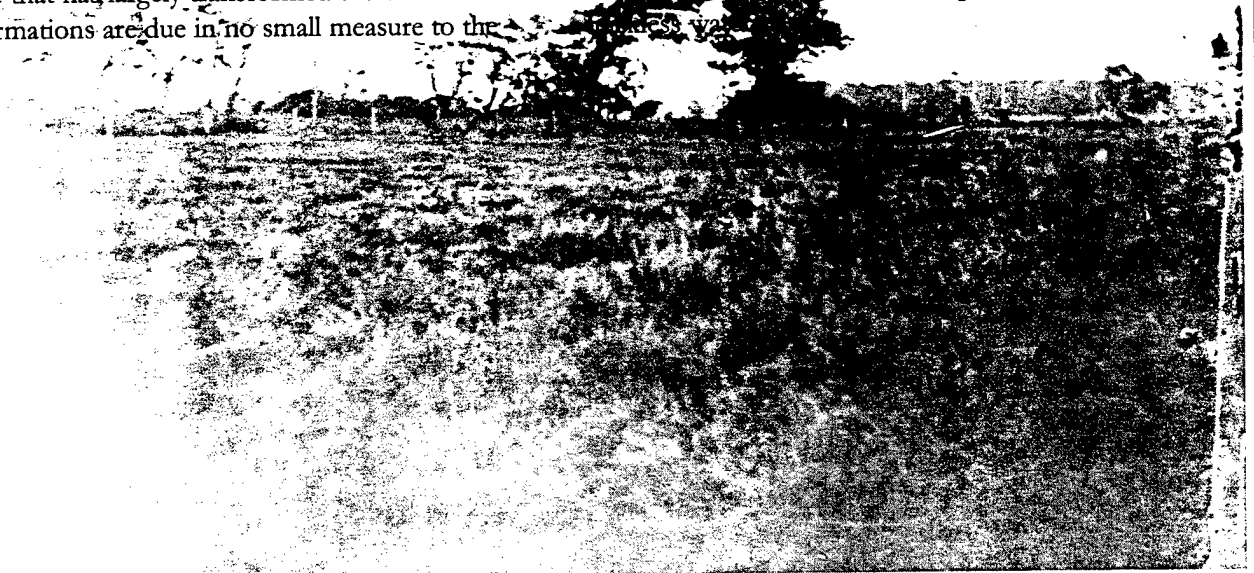
Nearly a century has passed since Root first stood in awe of the airplane. In that time both the airplane and the world have been transformed; indeed, it is the airplane that has largely transformed the world. Both transformations are due in no small measure to the

community of scientists and engineers who for the better part of the twentieth century have stood at the center of aeronautical—and now aerospace—development, here in Dayton, Ohio. The community was born in the throes of the first *great* war of the century. Due in large part to its efforts, human civilization survived a second *world war* twenty years later. For the last fifty years—throughout the so-called Cold War—the members of that community have kept active vigil in the laboratories and program offices at Wright-Patterson Air Force Base, beside the very field where Wilbur and

Orville Wright first demonstrated the possibilities of human flight.



What the future might hold is anyone's guess. Peering over the horizon we can do no better than borrow the words with which Root concluded his account: "When Columbus discovered America he did not know what the outcome would be, and no one at that time knew; and I doubt if the wildest enthusiast caught a glimpse of what really did come from his discovery. . . No one living can give a guess of what is coming along this line [manned flight], much better than any one living could conjecture the final outcome of Columbus' experiment when he pushed off through the





## ACKNOWLEDGMENTS

The author would like to acknowledge those individuals without whose help this booklet could not have been completed in timely fashion. Ms. Laura N. Romesburg, ASC History Office archivist, selected the photographs accompanying the text. Mr. Curtis Alley of the 88th Air Base Wing Communications Group Multimedia Center designed the booklet's layout and cover. The engraving of the Wright brothers appearing on the cover is reproduced with kind permission of Mr. August Brunsman. Ms. Helen Kavanaugh, ASC Public Affairs Chief of Media Relations, and Mr. Jack Jones reviewed the preliminary draft of the text and offered much cogent advice and insight. Mr. David Menard of the USAF Museum's Research Division reviewed the text and photographs and offered kind advice and encouragement. Mr. Don Yates, Air Force Printing Liaison 88th ABW Communications Group/Visual Information Group, guided the final product through printing. Ms. Diana G. Cornelisse, Chief of the ASC History Office, gave encouragement and insight at every stage in this project's completion. To all these individuals the author owes a debt of thanks. The author is responsible for any errors of fact and interpretation that may remain.