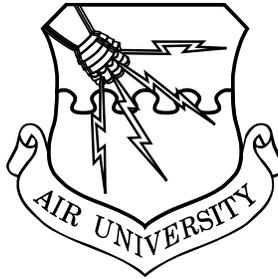


AIR WARFARE

WILLIAM C. SHERMAN



Reprint Edition



Air Warfare

WILLIAM C. SHERMAN

Major Air Corps, United States Army; Airplane Pilot; Instructor in
Air Tactics at the Command and General Staff School,
Fort Leavenworth

Reprint Edition

Introduction

by

Col Wray R. Johnson

**Air University Press
Maxwell Air Force Base, Alabama**

March 2002

Air University Library Cataloging Data

Sherman, William Carrington, 1888-1927

Air warfare / William C. Sherman ; introduction by Wray R. Johnson.

--Reprinted ed.

p. cm.

Originally published: New York : The Ronald Press Co., 1926.

With a new introduction.

Includes index.

Contents: Some principles in air warfare--The characteristics of aircraft--Individual combats and defensive formations--The service of observation--Pursuit aviation--Attack aviation--Bombardment aviation--Antiaircraft defense--Notes on air logistics--Naval aviation.

ISBN 978-1-58566-104-6

1. Aeronautics, Military. 2. Air warfare. I. Johnson, Wray R. II. Title.

358.4--dc21

First Printing April 2002
Second Printing August 2008

Disclaimer

Opinions, conclusions, and recommendations expressed or implied within are solely those of the author and do not necessarily represent the views of Air University, the United States Air Force, the Department of Defense, or any other US government agency. Cleared for public release: distribution unlimited.

Air University Press
131 West Shumacher Avenue
Maxwell AFB AL 36112-5962
<http://aupress.maxwell.af.mil>

Introduction

In the iconography of early American airpower history, certain figures stand out: William "Billy" Mitchell, Henry H. "Hap" Arnold, and Carl A. "Tooe" Spaatz perhaps foremost. But lesser-known figures, some virtually forgotten today, had considerable influence on the development of airpower thought, doctrine, and organization. One of these men was William C. Sherman, the author of *Air Warfare*. Sherman was present when the foundations were laid and played a significant if not a major role in the construction of the United States (US) Army Air Corps until his tragic death in 1927—a year after his book was published. Sherman was more intellectual in his advocacy and less zealous in his approach, which may account for his lack of notoriety. Not surprisingly then, although not as well known as Mitchell's *Winged Defense*, Sherman's book was more rigorous in its approach and balanced in its argument. In that light it is interesting to note that the only American work quoted by marshal of the Royal Air Force, J.C. Slessor, in his benchmark 1936 airpower study, *Air Power and Armies*, was William C. Sherman's *Air Warfare*.

William Carrington Sherman (or "Bill" as he was typically known) was born on 5 May 1888 in Augusta, Georgia. He graduated from high school at age 15, and after two years at the University of Georgia, he received an appointment to the US Military Academy at West Point in 1906. Characterized as quiet and unassuming, Bill Sherman was also described as having one of the "keenest minds" in his class. His motto was, "If anything is worth doing at all it is worth doing well." He once upbraided a fellow underclassman for insubordination—for which he became famous in the Corps of Cadets. But he had a rebellious side also and was reported to have walked more than the average number of punishment tours. He was an officer of the Dialectic Society and served on the board of governors of the 1st Classman's Club, played polo, and sang with the chorus and Glee Club. As related in his class year-

book, Bill Sherman expressed an early interest in "aerial navigation." While at West Point, he struck up a friendship with another cadet, Thomas DeW. Milling, who would, years later, introduce Sherman to the thrill of powered flight. Sherman graduated third in a class of 83 on 15 June 1910, after which he was assigned to the Corps of Engineers. He served for a little over a year as an apprentice of sorts to civilian engineers at Rock Island, Illinois; Memphis, Tennessee; Pittsburgh, Pennsylvania; and, in Panama. In 1911, he was ordered to the engineer school at College Park, Maryland, whereupon he renewed his friendship with Milling, who was then posted to the fledgling aviation school located there. Thus, upon his arrival at College Park, Sherman appeared on the scene at a time when military aviation was still in its infancy and yet poised on the brink of explosive growth.

Military aviation had begun in the United States early in the Civil War when Federal forces used captive balloons for observation. During the war, balloons were under the control, at one time or another, of the topographic engineers of the Army, the quartermaster, the Corps of Engineers, and for one day at least, the Signal Corps. Between 1863 and 1889, there were no military balloon operations in the United States, but in 1890, the Congress gave specific responsibility for collecting and transmitting information for the US Army to the Signal Corps. Shortly afterward, the chief signal officer, Brig Gen Adolphus Greely, requested funding to establish a balloon corps to support this purpose, and in 1892, a balloon section was created. Following the loss of the lone balloon purchased from the French in 1891, a second balloon was constructed at Fort Logan, Colorado, by Sgt William Ivy (a well-known stunt balloonist) and his wife. This balloon was used on several occasions during the Spanish-American War, to include adjusting artillery fire at the battle of San Juan Hill. By 1906, when Bill Sherman entered the military academy, the Signal Corps possessed eight balloons. Two years later, the Army would acquire its first rigid airship and that same year its first heavier-than-air flying machine.

Orville and Wilbur Wright had successfully inaugurated motor-driven, heavier-than-air flight on 17 December 1903 at

Kitty Hawk, North Carolina. Although ignored by the Army despite repeated attempts by the brothers to attract their attention, President Theodore Roosevelt took note of the brothers' accomplishment in 1906 when foreign governments expressed serious interest in the Wright machine. The president ordered Secretary of War William Howard Taft to investigate the military potential of the Wright flyer. The Wrights offered the use of a similar machine and instructions on how to fly it for \$100,000, which they later reduced to \$25,000. Convinced of its potential, the Signal Corps chief, Brig Gen James Allen, subsequently issued specifications for a military heavier-than-air craft and solicited additional bids. Forty-one bids were received, but only three complied with the specifications stipulated, and the Wright brothers secured the contract after the other two bidders failed to deliver a machine on the date specified in the solicitation. The Wright Army airplane was delivered at Fort Meyer, Virginia, on 20 August 1908. On 9 September 1908, Lt Frank Lahm, an experienced balloonist, became the first Army officer to fly as a passenger in an airplane, lifting off from the parade ground at Fort Meyer. Eight days later, Lt Thomas Selfridge, who had himself earlier designed and flown an experimental aircraft for the Aerial Experiment Association, became the first military aviation fatality when the Wright airplane crashed with Orville Wright at the controls.

In 1909, the Wright brothers delivered an improved machine to the Army, the Wright A airplane. Trials continued until the final test flight was conducted on 30 July 1909, with Orville Wright at the controls and Lt Benjamin Foulois, another balloonist, as observer and navigator on what has been billed as the first cross-country flight—from Fort Meyer to Alexandria, Virginia, a distance of 10 miles. Afterward, Lieutenants Lahm and Foulois were selected by General Allen to be trained as the first Army pilots at the civilian airfield at College Park, Fort Meyer's small drill field being regarded as unsafe for beginners. Foulois, however, was later selected as an official delegate to the International Congress of Aeronautics in Nancy, France, and was replaced by 2d Lt Fredric Humphreys of the Corps of Engineers. Humphreys would make the first military

solo flight on 26 October 1909, but Lahm was the first military flyer to receive a Fédération Aéronautique Internationale (FAI) Airplane Pilot Certificate (No. 2, the first being issued to the civilian aviation pioneer, Glenn Curtiss. Ironically, Orville and Wilbur Wright, who had designed, built, and flown the first successful airplane, were issued certificates No. 4 and No.5, respectively).

At the time, Army regulations permitted line officers to be detached to other duties for only four consecutive years. As a result, Lieutenants Lahm and Humphreys—the only two officers to have soloed thus far—were forced to return to the cavalry and the engineers, respectively. This left only one pilot: Lieutenant Foulois, a Signal Corps officer who had not soloed and had only a few hours of flight time under his belt. In the winter of 1910, the year Bill Sherman graduated from West Point, Signal Corps airplane No. 1, Foulois, and several enlisted men moved to Fort Sam Houston in San Antonio, Texas, in search of better flying weather. Earlier in 1907, an Aeronautical Division had been established within the Office of the Signal Corps, but during Foulois' tour in Texas, the division was unable to generate sufficient funding for aviation, and flying operations were suspended after only a few flights. Early in 1911, however, Robert Collier, owner of Collier's magazine, bought a new Wright Type B airplane and "leased" it for \$1.00 per month to the Army. Flight operations in San Antonio resumed in February 1911. A month later, Congress made its first appropriation for Army aviation: \$125,000 for the year 1912 (that same year the Congress appropriated \$25,000 for the US Navy which provided for the purchase of three airplanes, the beginning of naval aviation). With adequate funding secured, the Signal Corps promptly ordered five airplanes—three Wright Type Bs and two Curtiss types. Both companies provided instructors as part of the package.

At the time, Congress approved the appropriation for Army aviation, 18 officers had volunteered for aeronautical duty and began receiving instruction at Fort Sam Houston. They were not, however, relieved of their regular duties and were required to fly in their spare time. But following an accident in which Lt G.E.M. Kelly was killed, the Maneuver Division commander

suspended flying. Nevertheless, the Signal Corps had renewed flying training back at College Park, whereupon a Curtiss plane and a Wright B plane were transferred from Texas to the new school. Fortunately, for the officers soon to be assigned to the College Park school, flying would be a full-time occupation.

In May 1911, when Bill Sherman was concluding his engineering apprenticeship in Panama, 2d Lt Arnold and 2d Lt Milling were ordered to the Wright Company's flying School in Dayton, Ohio, for instruction. Shortly after soloing, both officers reported for duty to College Park, where they received FAI certificates No. 29 and No. 30, respectively. Bill Sherman left Panama and, after a brief stay in Pittsburgh, arrived at the Engineer Corps special service school at College Park. Sherman and Milling renewed their friendship from West Point, and although the chief of engineers attempted to dissuade him, Sherman began flight instruction with Milling during off-duty hours and on Saturdays.

With winter approaching, the War Department selected Augusta, Georgia—Bill Sherman's hometown—as the winter site of the aviation school. In November, five officers, including Lieutenants Milling and Arnold, 20 enlisted soldiers, and four airplanes were moved to Augusta. The officers were quartered in a hotel, the enlisted men in a nine-room house on a local farm, and the airplanes were sheltered in canvas tent hangars. Flying began in December. During this period, Sherman took Christmas leave and traveled to Augusta, where he received further flight instruction from Lieutenant Arnold. Thoroughly bitten by the flying bug, and having graduated from the engineer School in June, Sherman promptly applied for aviation duty, whereupon he was detached from the Engineers and reported to College Park in September 1912. Although Sherman had passed the FAI test in July and received his certificate on 7 August 1912 (No. 151), he arrived at College Park as a student. By the end of 1911, the Army had concluded that a military aviator rating was required to reflect a standard of skill higher than that of the FAI test. Instructions were subsequently published stating that only when a student had passed the military test was he to be awarded the rating of military aviator and considered to be a graduate of the school.

The first certificates were issued in July 1912 to Lieutenants Arnold and Milling and to Capt Charles DeF. Chandler, another pioneer aviator. Regrettably, owing to his later wartime and other staff service, Bill Sherman was unable to fulfill his flight instruction and never tested for the military aviator rating.

In November 1912, flying training moved again to Augusta, but poor weather prevented flight operations, and mechanical problems plagued the five airplanes that had been moved to the winter site. Flight instruction resumed in February 1913, but that same month Captain Chandler was ordered to move all personnel and equipment as quickly as possible to Texas City, Texas, near Galveston, because of increased tensions between the United States and Mexico stemming from the revolution that had erupted there in 1910, when the government of Porfirio Díaz Mory had collapsed. Employing a special train of 11 cars, five officers, including Sherman, 21 enlisted men, all of the airplanes, and associated equipment were moved to Texas City, arriving on 2 March 1913. Attached to the Army's 2d Division, this "concentration" of aviation for tactical purposes prompted the chief signal officer, Brig Gen George Scriven, to suggest to the chief of staff that a provisional unit be formed. The War Department approved this measure, and on 5 March 1913, the First Aero Squadron was organized at Texas City. The squadron later would become the first air combat unit in the US Army when, under the command of Captain Foulois, the squadron took part in Brig Gen John J. Pershing's punitive expedition against Francisco "Pancho" Villa in 1916- 17.

It was during his stay in Texas City that Bill Sherman entered the record books. Early in March, he and Milling had flown to Houston and returned (some 80 miles) in a Burgess airplane. On 28 March, Sherman and Milling flew another Burgess airplane to San Antonio, a distance of over 200 miles, starting at 2:15 P.M. and arriving at 5:35 P.M. Upon arrival, they circled for over an hour, thus establishing a new American endurance record of four hours and 22 minutes. The return flight was made in three hours and 40 minutes. During this record-breaking flight, Sherman sketched a map, including all of the essential military features such as railroads,

bridges, roads, towns, and other topographical points of interest. The map was made in sections six inches long, unrolled as an interval was traversed every 10 minutes, and used bearings taken from a compass. The entire map was 10 feet in length and was the first map ever to be made from an airplane from a pilot's perspective and to cover such a distance. Aerial operations continued, but with tensions between the United States and Mexico reduced, the squadron was disbanded, and most of the personnel and equipment moved to North Island, near San Diego, California.

In December 1913, General Orders 79 designated the facility at North Island the Signal Corps Aviation School, placing it among the Army's service schools. However, in October, before he could resume his training, Bill Sherman, along with Captain Chandler and Lieutenants Lahm and Arnold, were returned to troop duty. Milling remained attached to aviation duty and was sent to France to observe European aviation. Having returned to the Corps of Engineers, Sherman served as a company commander and as the adjutant of an independent Engineer Battalion in Texas and Mexico. In July 1916, he organized and commanded Company A, 1st Battalion of mounted engineers, and acted as the division engineer of the Cavalry Division. When the United States entered the war in Europe in 1917, Sherman was sent overseas in July as the aide-de-camp to Maj Gen W. L. Sibert, commander of the 1st Division. While in France, he attended the General Staff College of the American Expeditionary Force (AEF) in November, subsequently served a brief stint with British forces, and then returned to the 1st Division as Assistant Chief of Staff, G-2. He remained in this post until July 1918, when he was promoted to the temporary grade of lieutenant colonel and was detailed to 3d Corps as assistant chief of staff. He served on the Marne, the Vesle, and in the Meuse-Argonne until October, when he was reassigned to aviation duty as the chief of staff, First Army Air Service, under his old friend Milling, who was now a colonel succeeding Brig Gen Billy Mitchell as chief of Air Service, First Army.

In February 1918, the War Department created a historical branch of the general staff to write a history of American

involvement in the World War. Shortly afterward, General Pershing, commander in chief of the AEF, established a historical unit in his general headquarters (GHQ) located at Chamount-en-Bassigny. Subordinate units followed suit, including the First Army. Senior aviation leaders believed a comprehensive history of the Air Service in the war would serve as a foundation for the future development of military aviation in the Army. Col. Edgar S. Gorrell, who had graduated two years after Sherman from West Point and had flown with the First Aero Squadron during the punitive expedition in Mexico, was chosen to head up the effort. Various histories were produced—corps air services, wings, groups, and squadrons—but these narratives concentrated on such additional mundane matters as personnel and scheduling as opposed to combat operations. Gorrell believed a combat history was needed and appointed Lt Col Sherman to the task.

The "Tactical History" was written by several unidentified contributors and edited by Sherman. It comprised 157 single-spaced and typewritten pages, including 16 pages of appendices. The document was divided into six major sections. With some minor modifications, the first part, "The Achievement of the Air Service," ultimately served as the introduction to the First Army Air Service "Final Report." The second part, concerning corps observations, was later published as an "Air Service Information Circular" in 1920. The remainder of the document concerned army observation, pursuit, bombardment, and balloon operations. The "Tactical History" was a detailed examination of how combat operations were planned and executed by the Air Service, with comments and criticisms added by the authors. It remains useful today for students of aerial operations during World War I.

At about the same time that he prepared the "Tactical History," Sherman also wrote a "Tentative Manual for the Employment of the Air Service," reflecting the experience gained by the Air Service during the war and advancing the first doctrinal work regarding aerial operations produced in the United States. The "Tentative Manual" was revised as "Notes on Recent Operations" and was forwarded to GHQ AEF for publication. Although GHQ never published these notes, in

April 1919, a copy was sent to Washington, D.C., where it was reproduced by the Information Group, Air Service, under the same title. A year later, the notes were published as an "Air Service Information Circular." With the success of the "Tactical History" and "Notes on Recent Operations," Sherman established himself as a thinker as well as a competent airman. Following the Armistice, he returned from France in March 1919 and was posted to Washington, D.C., as chief of training in the Office of the chief of the Air Service.

From the end of World War I to July 1926, when the US Army Air Corps was created, the Air Service, at first headed by Maj Gen Charles T. Menoher and later Maj Gen Mason M. Patrick, labored to institutionalize aviation as an integral arm of the Army by expanding the organization, formulating policy and doctrine, and devising a training system. The Air Service was organized along divisional lines consisting of Supply, Information, Training and Operations, and Administrative Groups, each headed by first through fourth assistants. The Training and Operations Group was headed by Brig Gen Billy Mitchell who had emerged from the war as a notorious and zealous proponent for airpower and who had returned from France believing that he would be the chief of the Air Service. Mitchell's subordination to General Menoher, an infantry officer, is often viewed as analogous to the subordination of military aviation to operations on the ground, a view that Mitchell and others—including Sherman—were beginning to challenge.

In a memo to Mitchell in 1919, Sherman astutely noted that organizational structure influenced doctrine and therefore training. Given that operations and training both resided in the same group, Sherman expressed concern that any ambiguity regarding the distinction between the two functions would have a deleterious effect on the wartime capability of the Air Service. As it developed, the Training Division under Sherman was made responsible for training of tactical units, and the Operations Division prepared war plans. Subsequently, the 1st Wing, formed at Kelly Field in San Antonio, Texas, in the summer of 1919, received guidance and information from the Training Division in the form of manuals, pamphlets, and other materials, including Sherman's "Notes

on Recent Operations." Inevitably, however, some overlap occurred, particularly with respect to writing training regulations, but the tight-knit nature of the Training and Operations Group (which included Sherman's old friend, Colonel Milling) obviated the factionalism that would in all likelihood have developed in a larger organization. Moreover, the officers were for the most part veterans of the war and they regularly exchanged views with one another in a manner that provided the ferment for emergent airpower thinking in the coming years. Not surprisingly, many of these ideas were contrary to the official positions of the War Department, and officers not similarly inclined took note. At one point, General Menoher's executive officer even suggested that Mitchell either sign a loyalty statement or relieve all of the division heads of their responsibilities.

Nevertheless, Mitchell and his associates continued to explore the possibilities of aviation as an instrument of war, and Sherman was perhaps the first to articulate the indirect nature of airpower. For Sherman, aviation forces had a twofold mission: to attack the moral and material resources of the enemy. Sherman reasoned that the key to victory on land was to shatter the enemy's morale. Victory in naval warfare, on the other hand, was the product of destroying the enemy's fleet through the application of firepower. Aviation would play a vital role in shattering the enemy army's morale, thereby winning the ground war. Along with submarines, aircraft could be used to attack and sink the enemy's fleet, thereby gaining command of the sea. In either case, aviation would prove decisive. Drawing in large measure upon Sherman's thesis, Mitchell met with the Navy's General Board on 3 April 1919 and stated that aircraft could successfully attack warships and further suggested that the defense of the United States could be better accomplished by land-based aircraft. At the same time, he urged the creation of a ministry of defense comprising an army, navy, and an independent air force under a single head. Not surprisingly, Mitchell's ideas were dismissed, and he was not invited again to appear before the Navy's General Board. Regardless, Mitchell had laid down the gauntlet, and stimulated by the ideas generated by his officers, he

had proceeded to inundate members of Congress and the press with proposals regarding the future of aviation in the United States.

Reportedly under pressure from the War Department general staff, General Menoher reorganized the Office of the Chief of Air Service in 1920, relieving Mitchell as chief of the Training and Operations Group and appointing him as assistant chief of the Air Service—but giving him no specific duties. Meanwhile, because of the rapid demobilization that had occurred in 1919, the number of Air Service officers had dropped from 20,000 to a small number of officers holding regular commissions including many members of Mitchell's former staff. While Mitchell retained his rank by occupying a statutory assignment, most Air Service officers were returned to their permanent grade. Foulois, who had been promoted to a wartime rank of brigadier general, was reduced to a captain (but within a few months was promoted to major). At the same time, Milling was reduced to the rank of Major, and Sherman was reduced to his permanent grade of captain on 15 April 1920. Shortly afterward, Milling and Sherman were reassigned to the new Air Service Field Officers School, which the War Department had authorized at Langley Field, Virginia, on 25 March 1920.

Under the direction of Major Milling, the Field Officers School was charged with preparing field grade Air Service officers for higher command duty. But, owing to a shortage of field grade officers, junior officers attended as well. On 1 July 1920, Sherman was transferred from the Corps of Engineers to the Air Service and on that same date was promoted to major. Upon his arrival at Langley Field, he was initially appointed adjutant and chief of staff, 1st Provisional Air Brigade, but in April, he was reassigned to the Field Officers School, where he became Major Milling's assistant. However, he was later detached, and from 30 November 1922 to 22 February 1923, he served as a military advisor on aviation to the Rules of War Commission of Jurists at The Hague, Netherlands, after which he returned to the school at Langley Field. Regarding Sherman's service in Holland, in March 1923 the secretary of war received a letter from Judge John Bassett

Moore commending Sherman for his mastery of the topic of aviation in both its practical and theoretical dimensions.

During its early years, the Air Service Field Officers School remained small and only seven students graduated from the first class. But the decision was made to send every air officer to the school, and the numbers increased over the next several years. Reflecting its new role as a primary training ground for Air Service officers, the school underwent a name change in November 1922, when it became the Air Service Tactical School, and again in 1926, when the Air Service officially became the US Army Air Corps, it became the Air Corps Tactical School, which subsequently moved to Maxwell Field near Montgomery, Alabama.

Throughout the existence of the school, Mitchell's ideas and writings strongly influenced its curriculum development. In 1942, Brig Gen Laurence Kuter recalled that Milling and Sherman had participated in Mitchell's celebrated sinking of the former German battleship *Ostfriesland* in the summer of 1921 and were dedicated "Mitchellites." Although true in the main, as evidenced in the discussion of the *Ostfriesland* "experiment" in his book *Air Warfare*, Sherman was in fact considerably more judicious in his treatment and advocacy of airpower concepts and there is some evidence that Mitchell took Sherman's ideas and enlarged upon them—often to the point of hyperbole.

During his tour at the Air Corps Tactical School, Sherman played a prominent role in developing the curriculum and addressing tactics and techniques of pursuit, attack, and bombardment aviation, but more importantly, he wrote the foundation curriculum for lessons concerning the employment of air forces. Sherman wrote the first textbook on these subjects in 1921. It was forwarded to Washington, D.C., and was issued later as a policy statement in mimeographed form by the Air Service as Training Regulation 440-15, *Air Tactics*. In a slightly edited form in 1923, Sherman's text was again issued as *Fundamental Principles for the Employment of the Air Service*. Finally, on 26 January 1926, after having been revising the text to bring it more in line with mainstream Army thinking on the

matter, the War Department officially issued Training Regulation 440-15 as Army doctrine on aviation matters.

The original text was composed of six sections: "Characteristics of Aircraft," "Fundamental Doctrine of the Air Service," "Observation," "Attack," "Bombardment," and "Pursuit Aviation." Reflecting Sherman's earlier thoughts regarding the moral dimension of land warfare, the text's main emphasis was on the human element in war and the psychological impact of airpower on enemy troops. Although the text generally accepted the principle that air activity was in support of the ground battle, it also revealed Sherman's emerging strategic conception of airpower when it stated that Army aviation was composed of two distinct components: air service aviation, essentially an auxiliary of the ground forces; and air force aviation (bombardment, pursuit, and attack aviation), which would seek to gain and exploit control of the air. To that end, Sherman wrote: "In deriving the doctrine that must underlie all principles of employment of the air force, we must not be guided by conditions surrounding the use of ground troops, but must seek out our doctrine . . . in the element in which the air force operates" (*Air Tactics*, sec. 2, p. 7). But, in the end, Sherman, like many other airmen of the time, was sensitive to the political pitfalls of expressing these views too forcefully—especially following Mitchell's court-martial in 1925—and he found it necessary to generally conform to the official views of the Army's senior leadership regarding aviation, even though his own theoretical views were more akin to those of Mitchell. This is not surprising when one considers that as early as his plebe year at the academy, Sherman was known for his subjection to higher authority.

The key to control of the air for Sherman was pursuit aviation. Pursuit aviation would seek out, and to the extent possible, destroy the enemy's air force, especially enemy pursuit aviation. Having achieved control of the air, the mission of the air force was then to destroy the most important enemy targets on the surface. Sherman's emphasis on pursuit aviation and control of the air would later be echoed in Mitchell's 1925 book, *Winged Defense*, in which Mitchell claimed, "It is upon pursuit aviation that control of the air depends" (*Winged*

Defense, p. 164). It was also Sherman's views on pursuit aviation that received the laudatory attention of J.C. Slessor in his 1936 book, *Air Power and Armies*. Mitchell's emphasis on bombardment aviation came later, when it became clear that long-range bombardment was the key to achieving institutional independence for the air arm.

In September 1923, Major Sherman was ordered to the Army's Command and General Staff School at Fort Leavenworth, Kansas. After graduating on 30 June 1924, he was retained at the school as an instructor. Over the years, Sherman had developed a reputation as not only an expert in aviation topics but in military history as well. He put his expertise to good use at the school as an instructor and later when he set about to write his book, *Air Warfare*. As he states in the preface, the book is based upon notes he wrote while an instructor at the Air Service Tactical School and at the Command and General Staff School. In that sense, *Air Warfare* is the mature expression of Sherman's thinking regarding military aeronautics. The first chapter capitalizes on Sherman's command of military history, revisiting the moral dimension of war and linking the established principles of war to the emergent character of modern air warfare. The remaining chapters address technical and tactical details regarding the primary aviation missions of the time (observation, pursuit, attack, and bombardment) but also include a discussion of anti-aircraft defense (generally dismissed by other airpower theorists of the time) and air logistics, as well as arguably the finest treatment of naval aviation to emerge during the interwar period. The book was published in 1926 by the Ronald Press Company of New York as part of its Aeronautical Library. The editor of the series was Charles DeF. Chandler, with whom Sherman had served at Augusta and Texas City. The series included other works on aeronautical topics, including *Airmen and Aircraft*, by one of Sherman's former instructor pilots, H. H. Arnold. The book was groundbreaking in many ways and amounted to a synthesis of Sherman's experience and thinking on the subject of airpower, analyzing the full spectrum of tactical and strategic applications of aviation, and thus mark-

ing Sherman as one of the more intellectually flexible of the early airpower theorists.

The year that *Air Warfare* was published, Sherman was struck by an unspecified and yet apparently painful illness. On 22 November 1927, only six months after Charles A. Lindbergh made his famous solo flight across the Atlantic and ushered in a new age of aviation, Sherman died at the age of 39 and was buried in the National Cemetery at Fort Leavenworth. His widow, Dixie Milling Sherman of New Orleans, whom he had married only three years earlier, survived him. He was posthumously promoted to the permanent grade of lieutenant colonel on 21 June 1930, retroactive to 22 November 1927. In 1928, his book was listed in War Department Bulletin No. 44, "Reading Course for Officers." His obituary in the Sixtieth Annual Report (1929) of the Association of Graduates of the US Military Academy perhaps best summed up the loss to the continuing development of military airpower: "In spite of the brilliance of his record, those of us who knew him best, felt that he was only at the threshold of his career The Army undoubtedly lost a brilliant officer, one whose future promised much."

Thus, the life of Bill Sherman spanned the genesis of heavier-than-air flight in the United States to the creation of the US Army Air Corps. Along the way, Sherman served with and under the command of some of the truly outstanding figures in American military aviation history. The culmination of his thinking on the subject of airpower on the eve of his sudden death can be found in his book, *Air Warfare*. With that as introduction, there is no better place to understand Sherman's thoughts on the subject than to read his work.

Wray R. Johnson
Marine Corps University
Quantico, Virginia

THIS PAGE INTENTIONALLY LEFT BLANK

AIR WARFARE

By
WILLIAM C. SHERMAN

Major Air Corps, United States Army; Airplane Pilot; Instructor in
Air Tactics at the Command and General Staff School,
Fort Leavenworth

RONALD AERONAUTIC LIBRARY
C. DEF. CHANDLER, EDITOR



THE RONALD PRESS COMPANY
NEW YORK

Copyright, 1926, by
The Ronald Press Company

All Rights Reserved

EDITORIAL PREFACE

Rudyard Kipling has been quoted as saying of aerial navigation: "We are at the opening verse of the opening page of the chapter of endless possibilities." No longer is there doubt as to the practicability of flying. That was demonstrated by the United States Air Mail; the commercial airlines in Europe and South America; the crossings of the Atlantic Ocean by airplanes, seaplanes and airships; and finally the circumnavigation of the earth by airplane.

While the consequences to flow from man's new power cannot yet be estimated, of this we may be certain: As the development within a few generations of railway, steamship, and automobile has altered every relation of the world's life, so the possession at last of aircraft, enabling us to utilize the free and universal highway provided by nature, must lead to effects upon human activity no less wide and profound.

The need is widely felt already for a progressive literature of aerial navigation. We need technical information for designers, engineers, and pilots and for the growing army of students. We need also discussions of the practical implications of air navigation, for statesmen, economists, and representatives of industrial and commercial organizations whose interests and operations are affected by the new mode of transit. The Ronald Aeronautic Library, a series of volumes by specialists able to speak with authority, supplies this information. It is the purpose of the editor to keep the Library continually abreast of every phase of aerial development.

The division into separate volumes is governed by the needs of each branch of aeronautics. At the same time this permits of frequent revisions to keep pace with the progress of an expanding art. The arrangement of the text facilitates reference almost to the extent found in the standard engineering handbooks. Information is not limited to American experience; foreign sources are drawn upon freely.

C. DEF. CHANDLER,
Editor, Ronald Aeronautic Library

THIS PAGE INTENTIONALLY LEFT BLANK

AUTHOR'S PREFACE

In a work, which attempts to cover as broad a field as that of air warfare, it is obviously impossible to give credit to the many men whose ideas are embodied in the text. The author has been fortunate enough to be thrown in contact with many officers whose interest in air tactics has been profound. Immediately following the Armistice in 1918, a group of such men, all of whom had distinguished themselves in the various branches of the air force in the World War, was assembled at the headquarters of the American Expeditionary Force, for the purpose of making a permanent record of their experiences, and of their opinions on matters tactical. To these men the author is indebted for giving generously of their time and of their thought.

In the less strenuous days that have followed the war, interest in air tactics has by no means been allowed to die out. At the military service schools this subject is one of continuous study and investigation. For several years various assignments have brought the author into close association with officers who were devoting much of their time to a study of the many phases of the many phases of air warfare. To these he ascribes whatever merits this volume may contain.

While the material in this book has been prepared, in large part, from the notes made by the author while an instructor at the Air Service Tactical School and at the Command and General Staff School, they are to be considered as purely personal opinions, and in no sense an official publication.

W. C. SHERMAN.

Fort Leavenworth, Kansas,
September 10, 1926.

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

CHAPTER I

PAGE

SOME PRINCIPLES OF AIR WARFARE	3
Human factor in war - Distinctive characteristics of air combat - Shock action - Mass psychology - Principles of economy of force, of the offensive, of security, and of simplicity.	

CHAPTER II

THE CHARACTERISTICS OF AIRCRAFT	34
<i>The Airplane</i> : Design compromise - Speed - Useful load - Strength - Speed and human factor - Rate of climb and ceiling - Maneuverability - Performance factors - Power - Visibility - Maintenance - Weather and darkness effects. <i>The Balloon</i> : Description and operation. <i>The Airship</i> : Non-rigid, semi-rigid and rigid types - Comparisons with airplanes.	

CHAPTER III

INDIVIDUAL COMBATS AND DEFENSIVE FORMATIONS	65
Individual and mass air fighting - Aircraft machine guns and ammunition - Fundamentals of airplane gunnery - Dead spaces - Vulnerability - Single-seater combat - Loop - Tail-spin - Roll - Immelman turn - Single-seater versus two-seater - Defensive formations - Chains of formations.	

CHAPTER IV

THE SERVICE OF OBSERVATION	89
<i>Airplane Observation</i> : General effect on war - Influence and les- sons of World War - Qualifications and position of the observer - Tactical objectives - Effect of altitude and visibility - Reconnaissance - Liaison, contact, artillery, and exceptional mis- sions. <i>Balloon Observation</i> : Compared with airplane - Missions. <i>Airship Observation</i> : Balloon and airship - Airplane and airship.	

CHAPTER V

PURSUIT AVIATION	117
Basic Mission - Control of the air - Cooperation - Air barrages - Objectives - Formations - Attack of single airplane by a flight - Combat between two pursuit flights - Pursuit flight versus defensive formation - Squadron in attack - The group - com- mand airplane - Interplane communication - The wing - The brigade.	

CONTENTS

	PAGE
CHAPTER VI	
ATTACK AVIATION	148
Characteristics of attack airplane - Fundamental mission - Armament - Moral effect - Attack of column - Other targets - Employment as a reserve - Aids cavalry.	
CHAPTER VII	
BOMBARDMENT AVIATION	178
Post-war progress - Bomb development: demolition, Armor- piercing, chemical, incendiary, smoke and gas - Fuses - Sights - Tactical development - Objectives - Towns and cities - Supply systems - Industrial centers - Lines of communication - Overseas communications - Combat zone - Coast defense - Day and night bombardment.	
CHAPTER VIII	
ANTIAIRCRAFT DEFENSE	209
Importance - Cannon - Accuracy - Difficulties of firing - Advantages and disadvantages - Harassing fire - Location of guns - Missions of machine guns - Defense of columns - Defense of a line and of areas - Listening apparatus - Searchlights - Balloon barrages - Air force - Information serv- ice - Defense of airdromes.	
CHAPTER IX	
NOTES ON AIR LOGISTICS	232
Lessons of the World War - Airdromes - Personnel in move- ments of air units - Supply of units during movements - Regulation of movements - Normal supply methods.	
CHAPTER X	
NAVAL AVIATION	241
Terminology - Points in common with army air forces - naval aviation in World War - Naval aircraft characteristics - Sea airdromes and carriers - Observation - Bombardment - Tests in 1921 - Stationary and moving targets - Bombers and antiaircraft artillery - Protection by pursuit aviation - Plan of defense - Service of information - Ruses - Air battle - Attack on bombers - Inherent weakness of the defensive - Fleets having balanced air forces - Chemical bombs - Night bombing - Torpedo airplanes - Conclusions.	

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1.	Curtiss Navy Racer Airplane (Facing)	38
2.	Pursuit Airplane, PW-8 "	39
3.	Observation Airplane, the XO-2 "	47
4.	Bombardment Airplane, the NBS-I "	48
5.	The Barling Bomber Airplane "	56
6.	Principle of the Wind-Vane Sight	72
7.	Dead Spaces of the Two-Seater	73
8.	Curvilinear Flight	77
9.	Changes in Curvilinear Flight	78
10.	The Tail-Spin	80
11.	The Barrel Roll	81
12.	The Immelman Turn	82
13.	Plan of a Formation	85
14.	Plan of a Nine-Plane Formation	86
15.	Clock-Face System of Spotting Fall of Shots	111
16.	A Five-Plane Formation	130

THIS PAGE INTENTIONALLY LEFT BLANK

AIR WARFARE

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER I

SOME PRINCIPLES OF AIR WARFARE

Future development of war aircraft. To the student of national defense no problem of today presses for solution so urgently as that of determining the part that aircraft is to play in warfare of the future. The question is one of great complexity, since it involves not alone the many arts and sciences that have contributed to the development of aircraft, but also necessitates an evaluation of the numerous other agencies of war. Too many imponderable factors enter into the investigation to permit an exact delimitation of the rôle of the air force. Nevertheless, it is essential that the broad outlines at least be drawn, if a sound doctrine of national defense is to be constructed. It will be the aim of these chapters to describe in a general way the powers and limitations of aircraft, and to indicate what may reasonably be expected of our airmen, when the nation is again confronted with the necessity of waging war.

It has been said that each war begins where the last war ended. Many examples from history can be cited in support of this dictum. Human nature is prone to be affected, sometimes out of all proper proportion, by the experiences nearest in point of time. It is, therefore, entirely natural that the military student of any given period should become expert in the methods of the preceding war. Unfortunately, however, he is sometimes led into the formulation of rules which proved successful in the limited cases under consideration, and are, therefore, assumed to be principles of universal application. Such an error, when disseminated throughout the military forces, has resulted in national disaster. Where, on the other hand, men of superior talent guide the counsels of a nation, it enters on a new war not with a spirit of blind faith in old forms, but rather with a full determination to utilize all new developments to the utmost. History furnishes many examples

where such an increment of force has been enough to achieve victory.

From the above considerations it seems inept to accept the methods in vogue at the end of the World War, unless critical examination has shown that they are probably applicable to future needs. At the beginning of the war the airplane had progressed little beyond the experimental stage. It was incapable of transporting large military loads—it was slow, unarmed, and unreliable. Here and there an enthusiastic airman may have the vision to understand the possibilities of the future. But such men were few in number, and their voices were soon drowned in the din of battle. In spite of some brilliant individual exploits in the air, the part played by the airplane in the huge conflict which centered about the first Battle of the Marne was negligible. As the war continued, mechanical progress became amazingly rapid. The powers of the airplane grew by leaps and bounds. To take a single example, the pursuit airplane of 1917 seemed scarcely to belong to the same genus as its predecessor of pre-war days.

It would, however, be erroneous to conclude from this that the military value of each new development was appreciated and put to full use without delay. Such a thing has rarely occurred in history, and the airplane proved to be no exception. Nor is it difficult to comprehend the reasons which bring about this condition. The decisions of war are too important in their consequences to encourage experimentation. Men in high position, shouldering a vast responsibility, naturally prefer to cling to the known good, and even the boldest spirit turns back from the prospect of hazarding the destiny of a nation on a new and untried agency. Then too, it is rarely practicable in war to evolve a tactical doctrine which is a well rounded whole, harmonious and balanced in its parts. The requirements of the moment take precedence over more distant needs. Expediency necessarily governs. In consequence, the tactical doctrine at any given time usually consists of the many improvisations, which have hitherto proved successful in as many special situations. Such was the case in air warfare. Nevertheless the military value of the airplane, though lagging behind mechanical improvement, steadily increased,

until by the Armistice, the air force had come to exercise a profound influence on the operations of the contending armies. It would be a mistake, however, to conclude that the proper rôle of aircraft had been delimited, and that the relative weight of air power in the scales of war had been determined, even for that short period of time in which tactical methods hold good, before passing into obsolescence.

With the termination of the World War and the withdrawal of its fierce stimulus, the rate of progress in the development of aeronautics has diminished; nevertheless the powers of aircraft have been steadily, if slowly, augmented. Today, so eminent a soldier as Marshal Foch sees in the future of aircraft not alone the power of inclining victory towards either standard, but even the possibility of bringing such pressure to bear on civilian populations as to end war through the action of the air force alone. To an ever-increasing extent military experts throughout the world are realizing that the time has come to subject air power to a critical analysis, and to reapportion the war values of the various fighting forces. It is unfortunate that the subject has occasioned controversy and acrimonious discussion, for when a spirit of partisanship enters by the door, truth is all too apt to fly out by the window. Only the scientific spirit, which seeks truth wherever it may be found, is likely to achieve any degree of success.

The sole practical concern of the military student of today is with the next war. If he refuses to accept the methods of the past as applicable to the present and future, merely because they fulfilled the needs of the past, he must equally avoid the other extreme of discarding the valuable lessons of the past. War has been a human phenomenon as far back as our knowledge can penetrate. Deliberately to jettison the vast stores of information which have accumulated during this time would be an obvious act of folly. Approaching the teachings of history in this spirit, it is seen that two broad categories of facts are universally true, and applicable therefore to present, past, and future, and to all forms of warfare whether waged by land, by sea, or by air. These facts may be roughly described as those which are of the order of mathematical truths, and those which are primarily derived from the nature of man.

The human factor in war. War is essentially a conflict of moral forces. A decision is reached not by the actual physical destruction of an armed force, but by the destruction of its believe in ultimate victory and its will to win. Material things may be, and generally are, of great importance. But in spite of the tendency in modern life to subordinate the man to the machine, it is still true of war that the effectiveness of material things is gauged less by their purely mechanical worth than by the extent to which they raise or lower the morale of the combatants. History contains many examples of the side with the inferior armament gaining the victory, but a demoralized force has invariably gone down in defeat. It is apparent then that what may be called spiritual phenomena are of vast importance in war. On this account, all wars, however remote they may be in point of time, contain material for instructive study. For the nature of man is the same today as of old, and his reactions to physical stimuli remain essentially unchanged.

This statement may well be challenged, and it must be admitted at once that it lacks absolute accuracy. There is abundant evidence that the remote ancestors of man were different creatures from the *homo sapiens* of today, and it appears probable that man may yet evolve into a different animal as the centuries are added together and become an age. But these changes require such vast periods of time to become perceptible, that, for the practical purposes of this discussion, human nature may be regarded as a thing fixed and immutable. Certainly this holds true for the few score centuries of which we have authentic descriptions of war and of soldiers. In the fascinating "Commentaries" of Caesar, there is clearly portrayed the kinship of the legionary with the soldier of today, even to the detail of the rough jest of the camp. It is not surprising, therefore, that the student of the art of war has learned many a valuable lesson from the past. It is notable that when Napoleon recommended to his contemporaries the intensive study of the campaigns of the great captains, he included in his list men who has fought many centuries before the invention of gunpowder.

Numerous other examples might be cited to show the continuing influence of the past, but one more, of peculiar interest to the present generation, must suffice. When von Schlieffen succeeded the elder von Moltke as Chief of the German General Staff, his duties led him to an ever-increasing belief in the value of the maneuver known as envelopment. He considered that the perfect example of this form of attack was found in the defeat of the Romans by Hannibal at Cannae, and he disclosed his views to his contemporaries in a book which bore the name of the battle. It is unquestionable that the lesson of this battle exercised a profound influence on the German plans for the war with France which was then believed to be inevitable. It is even said that on his death bed, von Schlieffen urged that the right of the German hosts, which was destined to attempt the envelopment of the French left be further strengthened. Certain it is that the scheme of maneuver of the invasion of France in 1914 was envelopment. Again we find the same idea predominant in the German mind in the defeat of the Russian invasion of East Prussia in the same year. Ludendorff relates how, after the overwhelming Russian defeat, he gave to the dead von Schlieffen devout thanks for his teaching. It is thus no purely fanciful figure to see the dead hand of Hannibal partly guiding the movements of the German armies of 1914.

It may be assumed from the above discussion that all wars of the past, however much they may have differed from each other, nevertheless possessed certain characteristics in common. These constitute the fundamental principles of war. Since it is essential to the validity of a principle that it be independent of time and of the especial weapons of the contestants, and rest on facts which have hitherto been universally true, it is a justifiable assumption that the principles of war will still hold good for land or sea combat, despite the coming of the new air factor. For whatever the advent of the airplane may have accomplished, it has not altered the soul of man, nor the fact that two men are stronger than one. It is indeed a fair inference that the principles of war are applicable even to purely air combats. The airplane is after all but a weapon, and must needs be directed by man. The forces of the air are at the

mercy of material things to a greater extent perhaps than are land armies. But even more important to the air force than equipment is the nature of the discipline which pervades its ranks. Though it may differ in its forms, this discipline has the same objective as that of land and sea forces: to conquer in the human soul the natural shrinking from danger and death by suitable training in which the fear of punishment and the hope of reward are judiciously mixed. This simple fundamental is often lost to view. Thus a whole philosophy of peace has grown up around the idea that modern ingenuity may make of war a thing so terrible that humanity will find it unendurable, no matter how compelling the inducement to fight. But this belief ignores the many examples from ancient history of panic, demoralization, and utter rout, when the enemy had no weapon more terrifying than the sword. Man's capacity for terror was reached by ancient means quite as effectively as by any of the modern inventions. Man's chief fear is man, not the weapon he carries or the projectile he hurls. He conquers only through discipline.

Distinctive characteristics of air combat. Although the principles of war, as distinguished from derived or secondary rules, apply with equal force to air combat, it is especially important that diligence be exercised to insure that a given statement is in fact a principle. When the attempt is made to ascertain the powers and limitations of the airplane by the process of induction by analogy, there is always a grave danger of confusing principle with rule. This method of reasoning often produces valuable results; comparisons with the older agencies of warfare may result in shedding light on the employment of the new arm. But the method must be used with caution, for where the airplane resembles some other thing in one respect, it frequently differs in all others, and too close an analogy leads to error. The airplane is not, for example, merely a special variety of motor-propelled vehicle, comparable in general to other means of transportation; nor is it simply another form of artillery. It is a thing *sui generis*, and its full significance can be understood only after a thorough study of the intrinsic qualities of the air force itself. No easy comparison with some earlier innovation will suffice.

This caution in regard to the danger of comparison applies also to the conditions surrounding air combat. The airman is precisely the same human as his comrade in the land and sea forces, with the same set of reactions. But the psychical conditions that are commonly met with in air warfare show notable differences from those encountered in other classes of action. Certain of these will be briefly investigated before considering the principles which apply to air fighting.

Shock action. In land warfare, the doctrine of all nations recognizes that the success or failure of the infantry constitutes the final test in battle. This is regarded as a fundamental axiom, based upon unalterable human conditions and therefore applicable even in situations where the support of other arms is essential to victory. In spite of the vastly increased power of modern missile weapons, the psychology of infantry combat still rests on the basis of shock action. The Roman aphorism that the nation which shortens its sword lengthens its boundaries, retains much of its old virtue. Missile weapons are the means; the end is the decision by shock action. Rarely, of course, do bayonets actually cross. Usually the threat is sufficient to destroy the hostile will to fight.

When it is thoroughly appreciated how important shock action is to the basic training of the land fighter, it will be seen how different are the conditions of air combat, where this form of action may almost be eliminated from consideration. In this respect, air fighting resembles more nearly the modern naval action.

Formerly, collision in the air meant almost certain death for both participants. It is evident that we may dismiss from consideration as an important form of action one which demands suicide. This is too great a call on the human spirit, however courageous it may be, to be used for any but rare and highly exceptional circumstances. It is true that instances occurred in the World War which had all the outward appearance of deliberately ramming an opponent. But it appears, on closer investigation, that the act was the result of sheer accident, in the greater number of cases, or at least the result of erroneous belief that the enemy would swerve in time to avoid the onset. In at least two cases, however, ramming was

unquestionably deliberate—the last desperate charge of a pilot, already in flames and himself doomed to certain death, but determined to take a final toll of the enemy. But as a factor in tactical methods in the World War, shock action was negligible.

With the advent of the present parachute, however, which has proved to be practicable and remarkably successful, shock action presents a slightly different aspect. A head-on collision, with its enormous speed of impact, is as certainly fatal in its consequences today as formerly. But it is possible to bring another airplane to earth by ramming from the rear, when the difference of speeds is not great, and allow all personnel to escape uninjured, thanks to the seat parachute. Many such incidents have occurred through accident in peace-time training. In spite of this possibility, however, shock action will probably be of rare occurrence in future warfare. At best, it is an even exchange of airplane for airplane with the enemy, an outcome which each opponent will seek to avoid, even where one of them possesses marked numerical superiority and could perhaps afford the loss. It is obvious, too, that such a method of attack, when made over hostile territory—where an aggressive air force will usually be found—redounds to the enemy's advantage, since the attacker, even though he escapes the collision unharmed, becomes a prisoner of war. Over the sea, also, parachute jumps have not the same hope of a successful issue, as when made over land.

But perhaps the most potent reason against ramming lies in the fact that the same skill and determination which are requisite to successful shock action would generally result in the destruction of the enemy by fire action alone, without the loss of the attacking airplane. With this knowledge in mind, the air fighter will rarely resort to the more desperate method. In general, therefore, we may expect shock action in rare situations only, where other methods have failed and it remains the sole means of retrieving disaster. Thus the modern naval doctrine requires such action by pursuit aviation protecting naval vessels, when the latter are about to be attacked by hostile bombing airplanes and fire action alone has failed to avert

the threatened danger. In general however, fire action is the decisive element in combat.

The rôle of enlisted personnel. A most important difference between the fighting forces of the air and those of the land and sea lies in the functions of officer and of enlisted man, and accordingly in the relationship that must exist between them. In the infantry, for example, the basic fighting unit is the individual enlisted man. The importance of the officer, the leader, cannot be overestimated, for on his effort hinges the fate of battle. But in the final analysis, it is the enlisted man who is the sole wielder of arms. The corps of officers exists only for the purpose of directing and coordinating the blows of many thousands of enlisted men to a common end. They strike no blow themselves. These trite and well known facts are nevertheless worthy of thought and of analysis. The privileged position of the officer, the necessity of instinctive and instant obedience to his commands on the part of the soldier, the necessary restriction of initiative as we go down in the hierarchy of rank until, when the private soldier is reached, it is almost nonexistent—these are facts which enter into the very warp and woof of the fabric of infantry. Long experience of many land battles has demonstrated their necessity. They form the basis of discipline, which is itself only a means to the all-important end: that the soldier, under the tremendous psychological stress of battle, may be induced by the command and example of his officer, to master the urgent call of self-preservation and to perform the very simple but enormously difficult action which constitutes his duty.

When we come to consider the air fighters, these conditions are met with in part only. In the American service, the officer, not the enlisted man, is the wielder of arms in the air. The latter is not a combatant at all. His duties are those of a mechanic, to use that term in a broad sense to include the followers of many trades. He is not called upon, as the infantryman may be, to follow his officer forward in the charge, through the heated atmosphere of danger and death. The duties of the air service enlisted man are complex, but are performed under conditions of comparative security. Of course there must be discipline in an air force, as there must be in

any organization, military or civil, which is to exist for any length of time. But since discipline is not an end in itself but simply a means, it would seem that two somewhat different forms of discipline must exist side by side in the air force. Among the combatants, the officers, there must be a discipline which envisages coordinated effort in battle, one which differs from that of other fighting units only in the notable fact that the commander of an air unit in combat is a leader of leaders. Among the enlisted personnel of the air force, the discipline needed is that of the shop rather than of the battlefield.

Mass psychology. It is a well known fact of psychology that the reaction of a crowd to a given stimulus is by no means a mere composite of what the reactions of the individuals composing the crowd would be, if isolated and subjected to the same influences. There is a definite mass psyche. The wise military leader utilizes this fact in an endeavor to raise the level of his command above the average of the individuals composing it. But the existence of a mass psyche is not without its evils and dangers. Chief among these, to the soldier, is the phenomenon of panic. Its prevention is one of the ends which the strict system of military discipline seeks. Not always, however, is the goal attained. For while raw and untrained troops will almost certainly yield to the first approach of its malign influence, even seasoned veterans are not wholly immune. Such famous organizations in history as Caesar's Tenth Legion and Napoleon's Old Guard were not without such an incident in their records.

It would be an absurd example of unreasoning *esprit de corps* in view of these examples to deny that such a wave of hysteria might be born in the air force, even though its combatant personnel be composed wholly of the officer type. But for the transmission of this wave a certain set of conditions must be present. There is considerable evidence which indicates that these essential conditions for the propagation of panic are absent in the case of fleets of aircraft, although this phase of the subject has not yet been investigated with the thoroughness which alone would warrant a definite conclusion. But experience shows that the successful transmission of this spirit throughout bodies of men necessitates the close

contact, the elbow-to-elbow touch, and the ability to see the expression of a neighbor's face and appreciate the play of emotion in the varied tones of his voice. Only under these conditions will there be a complete submergence of the individual in the mass, and in the definite production of a mass psyche. In the operations of the air force, these essentials are lacking to a very large extent. The airman is physically isolated, and must be ever conscious of his individual responsibility for the maneuvering of his craft. These factors tend to preserve the individual psyche. However strong may be the personally born emotions which are aroused in him, he is incapable of transmitting his panic to another. The infection does not spread.

While the comparative freedom of the airman from the influence of the mass tends to preserve him from the demoralizing effect of panic, it has also its disadvantages. Every infantry soldier is aware of the spiritual comfort which comes in the hour of danger from the close proximity of comrades or from the bearing and example of a leader. This is not totally denied to the airman, but its influence is weakened by the very conditions which render waves of panic so highly improbable. The spiritual exaltation of a leader cannot be readily conveyed to his followers in the air. And although the proximity of his fellow fliers gives the airman an added sense of security, he is nevertheless largely left to his own devices.

The time factor. While the operation of the time factor in warfare serves in general to enhance the value of aircraft, it is intended in this discussion to consider only an important limitation which it sets. In land warfare of the past the contact of the main forces has been followed, in the usual sequence of events, by formal battle, which continued until the fortunes of the field had been definitely decided in favor of one or the other opponent. The drawn battle of the long-continued siege was rather exceptional. The fight, once begun, was carried through to a finish. With the advent of the huge armies of modern times, the period necessary for a decision has been lengthened; our common language, in such phrases as "winning the day," illustrates a feature of ancient warfare only. But even though battles of today may last over many days, they are normally continued to a decision. In this connection, it must be

recalled, the World War, apparently an exception, was a reality in four years' siege of France, interspersed with sorties which were known as battles.

In air warfare, a very definite time limit is placed on each individual combat by the restricted fuel capacity of the airplane. For example, the essentially fighting machine, the pursuit airplane, has a fuel capacity of little more than two hours. Due to this limitation, the necessity for which will be explained in a subsequent chapter, even isolated duels of individual airplanes often result in fruitless maneuvering for advantageous positions, until the diminishing supply of fuel forces the contestants to break off the indecisive action. With larger numbers of airplanes, the difficulty of securing a decision in so short a time is greatly increased. It may be expected, therefore, that the single action in the air will rarely be as decisive in its consequences as the land battle. Whereas the latter is usually a fairly continuous action, though marked by periods of crescendo, air warfare will consist of a succession of actions of great violence, with periods of almost complete calm between.

With this brief indication of certain distinguishing characteristics, which are inherent in the nature of air warfare, it is now proposed to examine the more important principles which govern successful action.

The principle of mass. In the history of the innumerable fights of the past, both on land and on sea, it would seem that the value of sheer numbers would be the principle of all others the most evident, even to the quite casual observer. Nevertheless this fundamental principle of mass has not always been appreciated and given its due weight in the balance of forces. Several facts have conspired to bring about this result. The human mind is naturally impressed by the exceptional, and inclined to make it the rule. The fact that history contains many examples of armies meeting defeat at the hands of a force inferior in numbers, is often allowed to obscure the working of the principle of mass. Of course, there must be cohesion and discipline on each side, before any talk of numbers has either value or meaning; mere armed mobs can be shattered at ease by a true military organization many times inferior in numbers. Then, too, even though two contestants

are approximately equal in armament and in discipline, one may possess a decided advantage in the genius of its leader. But such genius, where it exists, is not expressed in the violation of principles, but in a strict adherence to their true inner meaning.

To illustrate this, it might be profitable to recall the views of some of the great captains of history. Two contemporary geniuses will be chosen, each a master of a different form of warfare. In a speech to the Lords of Admiralty, the great Nelson, a man by no means unconscious of his own genius of inclined to depreciate its worth, nevertheless made the significant statement—one is tempted to call it admission—that only numbers can annihilate. To turn from sea to land, the world is familiar with Napoleon's cynical observation that God is always with the heavy battalions. But another incident in his career brings out even more clearly his views on the subject. It is related that in reply to the question of a colleague, who was seeking to discover the reasons for Napoleon's brilliant successes, he answered that victory is achieved by numbers. This called forth an expression of surprise, as it was common knowledge that Napoleon has almost invariably contended against numerical odds, in spite of which he remained master of the field. In explanation of the seeming paradox, Napoleon then pointed out that, while he may have had an inferior force on the field of battle as a whole, he had so disposed them that at the decisive time and place, he possessed a marked superiority.

In passing to the consideration of air warfare, it is evident by inspection that the principle of mass is applicable in all its fullness. Numbers are of the highest importance. Indeed, in comparing the relative fighting powers of two opposed air forces, when all factors but numerical strength are dismissed from consideration, the ratio of the squares of their respective numbers appears to give the fairest contrast. Of course, any attempt to reduce fighting power to mathematical formulas must be regarded with suspicion. Where so many imponderables enter, the result is never susceptible of proof. Nevertheless, this statement may be accepted as, at least, a very rough approximation.

In spite of the axiomatic character of the principle of mass, it has not always found ready and universal acceptance among those who have been called upon to deal with the strategy and tactics of the air. It is probably true, however, that the many failures to abide by this principle arose not so much from lack of appreciation of the principle as from inability or disinclination to overcome the obstacles to its application. This subject will be dealt with in greater detail in subsequent chapters, but it is purposed to give a brief outline here of the development of the principle during the air combats of the World War.

Air warfare quiet naturally began with the fighting of individuals. This was the period of the Ace. The deeds of derring do of these champions of the air earned them a well deserved fame, and handed down to posterity an invaluable tradition for the guidance of the infant arm. But thinking men realized the value of numbers, and studied to overcome the difficulties which lay in the path of combined action. It was seen to be inevitable that this, the Homeric Age of the air, would pass, just as the duels before the walls of Ilium had long ceased to be a feature of infantry combat. As time went on, this proved to be the case. Fliers began to go forth in small formations of three to five airplanes. As greater facility was acquired with experience, and the value of numbers was brought home in many a thrilling lesson, the size of formations grew, until as large a number as thirty airplanes were led in combat as a fairly well coordinated unit. When this stage of development had been reached, it seemed to many an observer that combinations of aircraft had arrived at the limit prescribed by nature, and that no further progress was possible. That such an opinion should be held ought not, however, to occasion surprise. It requires time for any perceptible forward movement to take place, even when the pathway of progress is seen by all eyes and is free from all obstacles. No such easy conditions were present, however, in this case.

A very real obstacle existed in the lack of suitable inter-plane communication, which was restricted to a few very simple signals.

In these circumstances, combined action of larger units was possible in air fighting in only two ways: a plan might be conceived for a given operation, and thoroughly explained to all concerned before departing from the airdrome; or else air-men might be so thoroughly imbued with the same doctrine that team-work could be hoped for as a result of an almost instinctive understanding of the leader's will.

In handling the small units which were the rule in the World War, these methods gave fairly good results. But they were altogether inadequate to the needs of larger numbers. A plan, to be of any value, must be based upon the situation as it exists at the moment of joining battle. A pre-conceived plan may be based upon sound premises, where the objectives of attack are on the surface of the earth, since there is small likelihood of important changes occurring in the few minutes which elapse between the departure from the airdrome and the launching of the attack. But in air fighting, this is almost never the case. Here the situation may undergo a complete change in a very few seconds, and thus the very basis of the pre-conceived plan will have been destroyed. Nor is a common doctrine sufficient. It is, indeed, a vital necessity for cooperation, and is almost enough in itself to achieve this end, in smaller units like the flight. But it cannot alone bring about the coordinated action of masses. It is necessary in addition that the plan of the leader for the specific situation be conveyed to all through the medium of orders. Even then, history teaches us, men who have imbibed the same doctrine in the same school, sometimes work at cross-purposes, when orders lack clarity.

The status of development of the principle of mass, which was briefly described above, was reached toward the end of the World War. With the coming of the Armistice and the inevitable cessation of military effort, further evolution ceased. Air fighting may be said to have halted at the level of the squadron. It is true that larger numbers of airplanes than this were flying simultaneously on missions which called for mutual aid and support. But their objectives usually lay on the surface of the earth. Judged by the criteria of their ability to carry out a coordinated attack on an objective in the air, in accordance

with a plan conceived in the air and based on the air situation, these airplanes did not constitute a true tactical unit, but were rather an aggregation of semi-independent squadrons.

It is easy to comprehend why the development of the principle of mass halted where it did in the World War. But it is difficult, indeed, to believe that a natural limit was reached in that stupendous conflict, and that air warfare will forever be confined to the puny combats of small formations. It is true that so redoubtable an air warrior as von Richtofen believed that forty airplanes was the largest number capable of being handled as a unit, and this estimate was concurred in by many other able men. But it is unquestionable that these practical fighters were concerned only with the conditions existing at the time, and made no pretense of formulating a rule for other than the present and immediate future, which they were considering. Under these circumstances, the opinion was undoubtedly sound. But it was based on the paucity of existing communications, and these conditions have already changed.

Communication from airplane to airplane by means of the radio-telephone is already an accomplished fact. With this obstacle, the greatest of them all, removed from the path, it is difficult to see any other impediment that time and training cannot readily remove. It is worse than folly to become a victim of that intense form of conservatism, which believes that nothing can ever happen in the future which has not happened in the past. To do so is to fly in the face of nature, which has decreed that change is one of her immutable laws. The principle of mass is clear, and the tendency of the change so obvious, that there is every reason to believe that the nations of the world will move inevitably towards the employment of ever-increasing numbers. The limits of this natural movement will be set only by the resources of the country, and the extent to which it is willing to expend its funds in the construction of aircraft, and in the training of men to fly and maintain them. That nation will be, indeed, unfortunate which opposes to the principle of mass an evil principle of dispersion.

The principle of economy of force. The principle of economy of force is closely interlocked with the principle of mass,

and is, in many respects corollary to it. For true economy must be practiced, if the mass is ever to be available for use. In war there are always thousands of points which seem insistently to demand protection and the consequent expenditure of strength. Many of these demands are difficult to ignore. But the leader who yields to them all soon finds his forces thinly spread out and widely dispersed. The effort to be strong everywhere can only result in being weak everywhere. The continuous drain on the mass which is to deliver the main blow leaves it too weak for its task, and opens the door for disaster to enter. The art of war, if it may be compressed in one sentence, consists in bringing to the decisive time and place an adequate superiority of force. No nation ever brings into the field a strength so vast that it can accomplish this end, without carefully husbanding its resources. Having decided, after a proper estimate of the situation, where the decisive action is to take place, the skillful leader economizes his strength at all other points to the verge of parsimony, in order that he may spend with a prodigal hand at the all-important time and place.

The principle of economy of force has rarely been more clearly illustrated than in the Battle of Chancellorsville. On the afternoon of May 1, 1863, the situation which faced Lee was certainly of an unfavorable character. In the general vicinity of Fredericksburg he had only some 57,000 men, while Hooker was opposing him with a command whose total strength reached the formidable figure of 134,000. Lee, who was thoroughly imbued with the spirit of the offensive was determined to attack, in spite of the huge odds against him, and had already partly succeeded in forcing his opponent to assume a defensive rôle. It is interesting at this time to note the true economy which Lee was practicing. To the east a force consisting of two of Hooker's seven corps, under the command of Sedgwick, presented a serious threat; to the south the cavalry of Stoneman was operating against Lee's communications; while the main Union force, under the command of Hooker himself was strengthening its position to the west, in the thickly wooded terrain about Chancellorsville. In every direction lay danger. But with a clear comprehensive of the essentials of

the matter, Lee permitted himself to make no unnecessary detachments from his main force.

Stoneman he all but ignored. Against Sedgwick, whose force was scarcely inferior in numbers to Lee's entire army, he sent but a small containing detachment, vastly inferior in numbers to the enemy facing them. In this way Lee was enabled to face the army of Hooker with the bulk of his force intact, and so to reduce somewhat the odds against him in the more restricted theatre which he foresaw would witness the decisive fighting.

Reconnaissance on May 1, had convinced Lee that the front and left of the Union position were too strong to attack but his active cavalry soon acquainted him with the fact that the Union right flank was "in the air." This he determined to envelope. Having thus selected the decisive point, he distributed his forces in truly daring fashion, but in strict accord with the principles of economy of force. On the union front where he anticipated no action of moment, he left a bare skeleton line of 16,000 men. To the decisive flank he sent Jackson—a force in himself—with three divisions, having a total strength of 30,000 men. When the blow fell, the Union forces opposing it numbered only some 10,000 men of the Eleventh Corps. Lee, though outnumbered on the whole more than two to one, have nevertheless brought to the decisive time and place three times the number of the force opposing him. While the outstanding feature of this battle is the sublime audacity of Lee, such rare daring that only the eye of genius could distinguish it from foolhardiness, it is no less striking an illustration of the principle of the economy of force.

The principle of economy of force applies to the operations of the air force no less than to land and naval action. This fact, however, has not been universally recognized, and violations of the principle in the employment of air units have been frequent. The explanation lies perhaps in the fact that so few military men, outside of the air force itself, are acquainted by experience with the proper functions of the latter, while nearly all are familiar with the duties of observation aviation. All too frequently, therefore, aviation connotes observation aviation, and the wide field of activity of the air force is ignored. Obser-

vation aviation is a true service, and to scatter it out among the organizations it serves, violates no principle of war. Generally speaking, the principles of mass and of economy of force have no bearing on the performance of its rôle.

But with the Air Force proper, the case is entirely different. Here we have, not a service, but a true combatant arm. To spread it out uniformly over a wide area, under many different commanders, is to commit precisely the same fault that our authorities would have committed in 1898, had they yielded to the importunities of the port towns of the Atlantic coast, and provided them all with some portion of our naval strength. We should have been equally strong everywhere, and too weak to win at the decisive point. In particular, it is fatal to err in respect to this principle with pursuit aviation. In the chapter devoted to that subject, the matter will be gone into in detail. It is sufficient at this point to state that the principle of mass applies in all fullness, and that the true application of this principle is impossible without a proper economy of force. Undue dispersion runs the same risk of being defeated in detail with an Air Force, as with any other combat organization. Its tactical doctrine, and its organization, which should be based on tactics, must alike facilitate the employment of the central mass. Detachments from it must in every case be justified. Rarely can they be satisfactorily explained, unless they prevent a larger force from participating in the decisive action. One exception may be noted. Often, in the World War, both sides alike violated the principles of mass and of economy of force. Where the enemy has dispersed his strength into many small detachments, it may become necessary to follow somewhat the same procedure, in order to run down these many little units. The case then is analogous to guerrilla warfare on land. But where there is no likelihood of encountering more than one enemy airplane at a time, there is obviously no dispersion in habitually operating in flights of three airplanes.

The principle of the offensive. War holds no clearer example of the preponderance of the moral factors over the purely material ones than in the everlasting truth of the principle of the offensive. In land warfare, for example, the development of rapid fire weapons along with other mechanical

improvements has given such power to the defensive that this would almost invariably be the successful form of action, if only physical considerations entered into the situation. But no mechanical development has changed the fundamental truth of the moral nature of the struggle. Because of this fact, the offensive must be taken whenever possible, and held to with the utmost tenacity. Of course, a commander may sometimes be forced to adopt the defensive by the hard facts of war; but in so doing, he renounces, for the time at least, all hope of a decisive victory, and bends his every effort to the mere negative purpose of averting defeat. Unless, somewhere in the future, he can foresee a chance of resuming the offensive, his defeat is merely a question of time and further struggle is largely futile.

The Franco-German War of 1870 furnishes an interesting example of the triumph of the moral over the material. The French were armed with the Chassepot rifle, a rapid fire weapon with nearly double the effective range of the needle gun of the Germans. Realizing to the full the enormous physical power of this weapon on the defensive, and desiring to reap the benefit of their advantage in this respect, the French permitted the gradual development of a cult of the defensive. They began to place their hope of victory in destroying the offensive power of the Germans, while the latter were yet too distant to make reply with their inferior small arms. Such a doctrine, while quite plausible, either ignores or minimizes the lesson of that the essential prerequisite of victory in land warfare is to implant in the heart of every soldier an ardent desire to close with the enemy. This was the fatal defect of the French idea. The débâcle that followed is well known, and while the French defeat cannot be attributed to this cause alone, it was certainly a contributing factor.

All of the moral factors which give strength to the principle of the offensive in land warfare apply with practically the same force in air combat. But the physical factors, which in land warfare are found aligned on the side of the defensive, tend in air warfare rather to favor the offensive; or at least, they do not markedly weaken the value of the latter. The offensive, on account of these factors, is an even stronger form of action in

air fighting. These physical considerations will be briefly discussed.

It will be shown subsequently that considerations of design, due to physical limitations, make it desirable to have the essentially fighting machine, the pursuit airplane, a single-seater, which is capable of firing its machine guns only to the front and in its line of flight. This condition at least holds true at the present time, and seems likely to remain so for an indefinite period into the future. It would, of course, be confusion of cause and effect to assert that design of aircraft necessitates offensive action; rather is it true that the pursuit airplane is so designed because the importance of the principle of the offensive is accurately appreciated. But, in order to insure that pursuit aviation may assume the offensive whenever it desires, it is necessary to strip it of practically all defensive power. In short, limitations of design make it impracticable to have a machine which may be utilized offensively or defensively at will. No reasonable compromise is possible. So a purely offensive weapon has resulted. The single-seater pursuit airplane can inflict absolutely no damage on the enemy, except while the former is actually attacking its objective. Its defensive power, using the term in the sense of its ability to withstand or to repulse attack, is practically nil. It may, of course, escape from an enemy by superior speed or skillful maneuvering. Pursuit aviation is, therefore, an unalloyed offensive agency. As a land force approaches its adversary, it has in general three lines of action open to it: it may endeavor to escape combat altogether; it may attack; or it may defend. But to an air force of pursuit aviation, the last choice is lacking. It may attack; but if this is deemed undesirable, it has left it only the decision to escape.

In the above statements, the terms offensive and defensive were used in a very narrow sense. When used with the broader meaning which will hereafter be understood, there is no real difference in the ultimate methods of fighting between offensive and defensive action. To take an example from land warfare, the infantryman, when on the offensive, uses fire power up to a certain point, and follows it at the crisis with the bayonet. His opponent, on the defensive, meets him with precisely

the same two forms of action. Much the same thing holds true in air fighting. The pursuit pilot who permits the enemy to attack him, merely because the rôle assigned him is of a defensive character, is courting suicide. The essential difference, then, which exists between offensive and defensive combat, lies rather in the fact that the aggressor has the choice of the time of battle, and of the place of delivering his main and subsidiary blows, besides, of course, possessing the moral advantages which have already been discussed. Using the word with this broader meaning, the defensive has certain other weighty inherent disadvantages in air warfare. As an example, when a given area is to be defended against attack by land, skillful dispositions of the defending force will insure that the enemy will be met and his advance contested. If the defending force is strong enough, positive protection is assured. But for the defense of the same area against air attack, even the most skillful dispositions of a markedly superior air force will not guarantee immunity against hostile blows from the air. For this condition, time and space factors are largely responsible.

To consider this phase of air warfare in greater detail, let us ignore for the present the possibilities of anti-aircraft machine guns and artillery, which will be discussed later, and assume that the burden of defense against hostile air attacks must fall on the friendly pursuit force. The difficulties that the latter must face are often insurmountable, even when it has numerical superiority—a condition which, in other forms of warfare, is rarely found associated with the defensive. First of all, it is essential that some system exist for giving adequate warning of the approach of hostile aircraft. The best method yet devised is the establishment of a circle of listening posts on the ground, connected by telephone with the airdrome of the defender. So great, however, is the speed of the airplane, and so high the altitude at which the attackers may fly, that warning will frequently come too late to permit the defending pursuit aviation to launch an attack.

An example perhaps will make the inherent difficulties more evident. Let us assume for simplicity's sake that the area is circular in shape, and is to be defended by a flight of pursuit airplanes, which are located at its center. It is known that

the largest hostile force which may attack the area is a flight of bombardment airplanes. At 12:00 o'clock noon, listening posts, which are on the perimeter of the area, sight the hostile bombers, flying due south towards the center of the area at an altitude of 15,000 feet and at a speed of 100 miles per hour. This information is quickly telephoned to the pursuit airdome, and thanks to a thoroughly trained and alert personnel, at 12:04 the mechanics are starting the engines, while the pilots are assembled at the operations office, where they are receiving this information and the orders to attack the hostile raiders. At present the pursuit airplane is equipped with a stationary water-cooled engine, and time must be allowed for this to be properly warmed; for it is scarcely practicable to keep it warmed and "idling" at all times, and flight with a cold motor often proves quite dangerous. But, being eager to go, the pursuit pilots cut short the usual time of warming, and take-off in a loose "V" shaped formation at 12:15. They begin climbing at very nearly the maximum rate, and at length arrive at an altitude of 16,000 feet at 12:30. Meanwhile the hostile bombers have travelled some 50 miles. If the listening posts have sighted them at a smaller distance than this from their objective, the pursuit flight is obviously too late to prevent the attack. Having superior speed to the bombers, the pursuit flight will attempt to run them down on their homeward journey and exact revenge, but the system of positive defense has obviously proved defective.

Of course, if the pursuit flight has been in the air at the time, much of the time loss in the above example would have been avoided. But since the enemy may select his hour of attack, it is apparent that a positive defense would require that an adequate force be kept in the air at all times. Since the fuel capacity of the airplane is definitely limited, and wear and tear on personnel and material must be repaired from time to time, it is evident that only a portion of the pursuit force can be kept in the air continuously. To do even this involves the risks of dispersion. This will be discussed in greater detail in a subsequent chapter.

In addition to the difficulties of the defensive which are due to the time and space factors, there is still another, which is

not peculiar to the defensive alone, but operates very frequently to defeat its ends. This obstacle comes from the ease with which two airplanes may fail to see each other in the air. To the observer on the ground, who is unacquainted with the limitations of flying, nothing seems easier of detection than an approaching airplane. It fairly shrieks out its presence. But the senses of the man in the airplane are greatly handicapped. Experience shows that the detection of one airplane from another calls for unremitting attention and keen vision on the part of the airman. The man on the ground first becomes aware of the presence of aircraft, in almost every instance, from the noise of the engine and propeller, or from the whistling of the air stream through the rigging of the airplane; the airman, with the roar of his own engine close to his ears, is practically deprived of his sense of hearing. The vision of the man on the ground, too, is often unobstructed; while the airman, seated in the cockpit of his machine, has large sectors of the surrounding space shut off from his view by wings, tail, and fuselage. It is true that he may partly overcome this difficulty by periodic maneuvering of the airplane, so as to bring into his line of vision the hitherto hidden spaces; but in spite of this, many a reasonably alert pilot has first been made aware of the presence of an enemy by tracer bullets. It is probable, however, that the most frequent cause of failure to see another airplane lies in the fact that the eyes are not focused for the correct distance; it is possible in this way to be looking directly at an object, yet have it fail to register its presence on the optic nerve. It is probable that in this respect also the man on the ground, with many objects at varying distances to guide him, is less often led astray.

It is apparent from these facts that, even if the warning comes in adequate time to permit the defense to gain contact with the enemy, it is still entirely possible for the two forces to miss each other in the vast spaces of the air. With the small numbers of airplanes that were usual in the World War, it happened many times. Where large forces are concerned, there is, of course, far less probability of evasion; and where the defense possesses an effective ground anti-aircraft system, to supplement its aircraft, it can be of invaluable assistance to

the latter, and usually can be relied upon to bring about contact with the enemy.

In the above discussion, only the hours of daylight were considered. The difficulties of the defense are multiplied many fold during the hours of darkness. For the greater part of the World War no effort whatsoever was made by aircraft to combat the operations of hostile airplanes at night. Night bombers came and went with impunity, except for artillery fire aided by searchlight; consequently this branch of aviation was generally reputed to be an unusually safe activity. Before the end of the war however, both the British and the Americans undertook to check this night bombing by night pursuit units. Too brief time remained for the full development of methods, which accordingly, by the end of the war, had advanced little beyond the crudities of the experimental stage. Enough was accomplished however, to indicate that some degree of success would eventually be achieved. Since the war, there has been some advance in this direction, and every reason exists for believing that night operation of pursuit aviation will be a regular feature of future wars. Nevertheless, an inspection of the difficulties of the defensive, previously discussed, demonstrates that darkness increases many of them and decreases none. Nothing of human invention will ever entirely take the place of sunlight. Night attacks therefore will always be less liable to encounter opposition than those undertaken by day.

The history of the World War abounds in examples which illustrate the inherent difficulties of any anti-aircraft defense. Conspicuous among these were the defenses of London and Paris. To guard these capitals against hostile air raids, hundreds of guns and airplanes were installed. Notwithstanding all this array of force, the Germans executed raids periodically. Although they were outnumbered by the defending force, often in the ratio of more than ten to one, the German airplanes suffered only insignificant losses. It is true the raids did not inflict enough material damage to produce decisive results. But this was neither intended nor hoped for by the German high command, who were far too well informed to expect important consequences from the desultory attacks of mere handfuls of airplanes. The real purpose of the raids was

achieved with conspicuous success. The Germans had hoped that such clamor for protection would arise from the populations of the capitals that the political rulers would not dare disregard it. They hoped that, as a result of this, guns and airplanes by the scores would be diverted from the decisive theatre of war on the Western front and tied down to the fruitless guard of the capitals. The strategy was not unlike that of Lee in the American Civil War in his many threats against Washington. It met with a full measure of success. A very small force of German airplanes immobilized many times their number of allied aircraft, and reduced by that amount the allied air power in the decisive areas of action. These two examples are perhaps better illustrations of the principle of economy of force than of the difficulties of air defense.

A thorough consideration of the significance of the facts which have been previously stated leads at once to an important question. If aircraft constitute the best defense against aircraft, and yet are inadequate, even when possessing superiority in numbers, to insure against hostile attack, is the rôle of the defenders impossible of execution? In seeking the proper answer to such a question human thoughts will naturally turn to the past and will find comfort in the reflection that the introduction of a new weapon has almost invariably been followed by the development of some adequate protection against it: the sword undoubtedly begat the shield; poisonous gases were countered by the mask. Surely men on the surface of the earth will not have to submit to violent air attack, with no recourse other than to bear the infliction with such fortitude as they may command. Some positive defense will certainly be evolved in the near future.

This line of reasoning is attractive, and not without plausibility. But, in very fact, history shows that a positive defense has not invariably been found for every weapon. The rifle furnishes an instructive parallel. The soldier long ago abandoned all hope of wearing enough armor to provide a positive defense against the bullet. Should he come in the missile's way, he has no alternative but to suffer the ensuing wound. But this does not mean that he is wholly lacking in powers of defense. His best method, as so often is the case, lies in striking at his

opponent, either destroying or neutralizing the latter before suffering damage himself.

It is much the same with aircraft. Despite the many strictly defensive agencies, which will be described subsequently, there is no adequate armor against air attack. Not only is the assumption of a vigorous offensive the best defense—it is almost the only form of action which leads to successful issues in air warfare. Once a hostile air force has gotten within striking distance of its objective, there is little chance of foiling the attack. Nevertheless, the decision to take the unqualified offensive, and thereafter to maintain it, cannot be made without overcoming many obstacles. It is small consolation to the inhabitants of a city, suffering under a rain of bombs from the air, to know that the citizens of the enemy's capital are having to endure the same or worse punishment. Even the soldier may be pardoned, if, in like circumstances, he harbors unfriendly thoughts of the friendly air force, though at that very moment the latter may be inflicting far greater losses on the enemy. Such attacks are heard to bear. It is demanding a great deal of human nature to ask it to ignore local suffering and contemplate only the broad general situation. There will be many of insistent demands for the defensive. Nevertheless ultimate success will be achieved with greater degree of certainty by a vigorous offensive against the enemy's aircraft and his vital centers, than by attempting provide a close and positive defense against similar attacks on his part, a plan which will never produce decisive results, and will often end in stark failure.

The principle of surprise. Hundreds of years ago Xenophon noted the overpowering effect of surprise on the hearts and minds of men, a result which has in no way been lessened with the passage of time. The advent of the airplane has done much, however, to reduce the possibility of surprise, in so far as land and naval action is concerned. It is no longer impossible to see what is happening on "the other side of the hill." It is intended here, however, to consider only the effect of surprise in air warfare, the other phases of the subject being discussed in connection with the service of observation.

Surprise may be either tactical or strategical in nature. The difference between tactics and strategy is difficult to describe, as might well be expected when it is realized that they are merely different phases of the same art. There is rarely a clearly cult line of demarcation, and where a distinction between the two is to be drawn, each writer in turn has been forced to make his own definitions. In this discussion strategy will be considered as the art of so disposing the air force on its airdromes that it may take the air under the most advantageous conditions for success in battle. Tactics, on the other hand, will be considered as the art of so conducting the air force while in the air, as to achieve the same end. The boundary line between the two is the surface of the earth.

Strategical surprise is attained with the air force in much the same manner as with land or sea forces. It consists in general of effecting concentration in decisive areas, and of concealing them from the enemy until it is too late for him to take effective counter measures. It is successfully accomplished by adopting a sound plan, and by carefully working out the details of logistics, just as in a similar operation by the land or sea forces. However, in one important respect it differs from the latter; the factor of time exercises an important modifying influence, as will be shown in a subsequent chapter.

It may seem, on first consideration, as if tactical surprise would rarely occur in air fighting. This, however, is not the case. It is not at all uncommon for a pilot to fail to detect the presence of an enemy, until actually attacked by him. Surprise probably accompanied a majority of the victories in the air duels of the World War. Indeed, many successful air fighters considered it as an almost indispensable pre-requisite for victory, since a skillful enemy, if warned in ample time of the hostile presence, could generally avoid the fatal burst of fire. This belief was carried to such an extent by some pilots, that it was considered futile to continue a duel if the initial dive and burst of fire failed to destroy the enemy.

Surprise is rendered possible not alone by the difficulties of vision described above, but also by the presence in the air of good "cover" for the lurking airplane. Clouds offer excellent concealment. Even more frequently the attacker took advan-

tage of the dazzling effect of the sun on the vision of his victim. So often, in the World War, did the enemy dive in to attack from the direction of the sun, that the British adopted as one of their maxims of air fighting: "Beware of the Hun in the sun."

These methods of securing surprise are obviously well suited to the needs of minor combats. When mass fighting, which seems to be inevitable outcome of the future, is at length realized, since the difficulties of concealment increase with numbers, tactical surprise will grow correspondingly rare. Nevertheless, it must be diligently sought, even if unattainable in all its completeness. If the utmost care and effort should fail to result in a complete surprise, it will nevertheless result in the concealment of some part of the whole. So great is the value of tactical surprise that even the smallest degree of it produces an effect which is well worth the trouble it involves. It is with strategical surprise, however, that we shall have to deal more frequently in future warfare. It is not to be expected, for example, that a group of the enemy will be so completely surprised by a brigade of pursuit aviation that the group never suspected the presence of even a single airplane. But it is well within the bounds of the possible for a well made and skillfully executed plan to lead the enemy to believe he would encounter no larger force than a group, for example. In this way it will often be possible to keep the enemy unaware of the true strength of the force he is to encounter until contact is actually made.

The principle of security. The principle of security is in many respects the obverse of the principle of surprise, since its application lies to a great extent in eliminating surprise by the enemy. We see a typical exemplification of the principle in the advance guard of land warfare. While this detachment has other duties, its primary mission is to insure the main body against surprise. Somewhat similar measures are taken in the air, except that, since the direction of danger differs, the security measures must correspond. The air unit, as we shall see later, is particularly vulnerable from the rear and from above. An attack from the rear is an awkward situation for the land force too; but since the enemy is constrained to move in a single plane at a slow rate of speed, and must give heed to his

own communications, the rear of a land force is usually quite free from danger of attack by another such force. In the air, on the other hand, the habit of three-dimensional movement at high rates of speed, and the total absence of communications, makes every direction one of possible danger. But since the rear promises the greatest results, it will be the usual direction from which attack may be anticipated. Tactical security measures generally, therefore, embrace some form of what may be called a top guard, which remains above and behind the main body, in a position from which it may readily dive down and attack any force endeavoring to interfere with the latter.

It is, however, in the domain of strategical security that future warfare may see many modifications of the past. The World War has left a legacy which has been little disturbed up to the present, but which seems ill fitted to the needs of the future. Formerly the airdromes were nearly always of the nature of permanent or semi-permanent installations, requiring days and even months to complete. Habitually the flying field was flanked on one side by a row of unmistakable hangars, arranged with geometrical precision, and proclaiming their purpose to all who looked. It is true they were almost invariably beyond the range of hostile artillery. Some effort, too, was made at concealment. Hangars were camouflaged and occasionally "dummy" airdromes were constructed. But the meager measures taken were so little effective that each side knew the location of all hostile airdromes with astounding accuracy.

That the airdromes of the World War suffered as little as they did from air bombardment can be attributed only to the fact that bombing methods and bombing equipment were both crude and undeveloped, and that, in general, determined bombing was directed rather against other objectives. It seems reasonable to conclude for the future that the airdrome must have added security, if it is to exist. Aside from this consideration, the necessities of mobile warfare also will rule out the elaborate semi-permanent airdrome. We may rather expect to see as a feature of the service airdrome of the future an almost complete absence of structures of all kinds. The airplanes will

simply have to stand the extra wear and tear imposed by lack of shelter. The possibility of concealing numbers of airplanes in nearby woods will be an important asset in an airdrome. Many alternate landing fields may be located, and organizations frequently shifted from one to another. Personnel will be concealed, of course, and will generally live at a distance from the airdrome. These and numerous other security measures must become the rule, when bombardment aviation of the future begins to attack in the masses that we may confidently anticipate.

The principle of simplicity. Simplicity has been called the soul of art. Whether this be true or not, in the general case, it is certainly the one unvarying essential to the successful practice of the art of war. It is difficult for those who are unfamiliar by experience with the conditions surrounding battle, to appreciate the intense emotional stress which the participants undergo. Under these circumstances, the fine shades and subtle tones of an idea fade altogether from the mind. Only the stark and simple thoughts have any hope of survival. A complex plan is foredoomed to failure. It makes demands beyond the human capacity. For, as Clausewitz has pointed out, in war all things must be simple, and the simplest things are most difficult.

CHAPTER II

THE CHARACTERISTICS OF AIRCRAFT

The Airplane

Early ideas of military uses. When the Wright Brothers, after many years of labor, gave to the world its first successful heavier-than-air flying machine, a few of its military uses were at once perceived; the armies of all nations began to consider its value for purposes of scouting and reconnaissance. A few enthusiasts, of course, saw beyond this to the broad field of activity of today. But these men were in a decided minority. The consensus of military opinion of the day considered those duties its only rôle in war. It was a logical consequence of this limited conception that one airplane was regarded as being much the same as another. The day of specialization had not yet dawned. Air fighting lay far in the future, and was in fact very generally regarded as a wholly impractical thing, a suitable theme perhaps for the poet or novelist, but outside the scope of the serious military student.

On this account speed was not especially sought after beyond a limit which had been almost attained in the very earliest models. On the contrary, high speed was regarded by many as undesirable, both because of the added danger involved, and because of the widespread but erroneous belief that speed would materially interfere with good observation. Since air combat was not visualized, rate of climb too was held to have little practical value, beyond that necessary to get out of restricted airdromes. The same attitude prevailed towards "ceiling"; it was considered necessary to go only to some 1,800 feet in altitude, in order to be beyond effective fire from the ground, and greater altitudes served only to increase the difficulties of observation. It was, of course, recognized that development and improvement must go on, but the only goals generally aimed at were greater safety and reliability. Such was

the general attitude towards aviation in the year 1911. Five years later, we see a changed state of affairs. Air fighting was now commonplace, and demands were being made for ever-increasing speed, rate of climb, and maneuverability. In another direction of development, bombardment aviation was in process of becoming a serious weapon, and was stimulating designers to build craft capable of lifting larger and larger loads. Specialization became the order of the day. This tendency has been accentuated with the passage of time, although today the design of military aircraft has become crystallized into a few fairly well defined types.

Design a compromise. It is the purpose of this volume to deal with the tactical aspects of air warfare, rather than with the technical features of airplane design. Indeed, many volumes would not suffice to cover the vast ramifications of aircraft engineering. It is essential, however, to a correct perception of the tactical methods of any fighting force, that the powers and limitations of the various agencies which are involved, be well understood. We must know, for example, that the horse walks four miles an hour, trots eight, and gallops twelve, if we are to form any estimate of the mobility of cavalry. In the case of the air force, knowledge of the physical properties of the means employed is probably of even greater importance than in the case of any other fighting organization, unless perhaps it be equally true of navies. For the man in the air is peculiarly at the mercy of material things. No matter how great his determination nor how high his courage, he is helpless against an enemy with a machine that can out-run, out-climb, and out-maneuver him. Since the factors that enter into design must be understood before proceeding to a study of tactical methods, this chapter will deal with this subject in a very general way. It is not intended to burden the reader with mathematical formulae. Every effort will be made to avoid involved technicalities. The ensuing descriptions will, therefore be understood to refer to the outstanding features, rather than to express exact mathematical relationships.

It is obviously important that the airman be provided with the machine best suited to the mission he is called upon to execute. Unfortunately for the attainment of any idea, many of the quali-

ties which are especially desirable in the same machine, are conflicting in their demands on the designer. One of them can be attained only at the price of a partial sacrifice of some other. Thus, for a given horsepower of engine, we may have an airplane that will carry a large useful load, or else have one that will fly at a high rate of speed. But it is quite impossible to combine in one machine all these desiderata in the highest degree. Design is of necessity a compromise. On this account, it behooves the tactician to consider all the factors which enter into design with the utmost care. For he must estimate the weight of each of them, in the light of their bearing on tactical success, and thus provide the designer with the broad tactical specifications for his guidance in the development of the machine.

Speed. If we except the fact that the airplane lifts man high above the surface of the earth, and in so doing realizes one of his oldest dreams, the most striking characteristic of the airplane is speed. In respect to this quality no other means of transportation has even approached the airplane. From the tactical point of view, the importance of speed is most evident. Superior speed gives to its possessor nearly entire freedom of choice as to combat. If he chooses to fight, he can run down the enemy and force him to action. If, on the contrary, the situation seems unfavorable to tactical success, he can utilize his greater speed to escape the enemy's clutches. When used, however, in this connection, the word speed has a significance beyond that usually meant in discussions of aerodynamics. It must be remembered that aircraft are three-dimensional voyagers. From the tactical point of view, we must consider not alone their speed in a horizontal plane, but also their speed in the vertical direction. Since the two qualities do not necessarily go hand in hand, it is convenient to designate them by different terms. The word speed is restricted to rate of travel in the horizontal plane, while the term rate of climb is used to designate the same thing in the vertical direction.

Speed in the airplane is not, however, a mere tactical asset. It is also an aerodynamic necessity. Unlike all other means of transportation, the airplane can never come to a halt in its usual medium of travel. A certain minimum of speed is essential to sustentation, for the whole phenomenon of flight

depends on the reaction of air to the fast moving wings of the machine. Let the airplane once drop below this speed, and the machine "stalls," falling to earth with useless controls. Provided this occurs at an altitude great enough to permit the airplane to regain flying speed from the acceleration of gravity, no harm is done. But if it be at too low a height for this, a fatal accident generally results. In fact, inadvertent stalling is the most prolific cause of flying disasters.

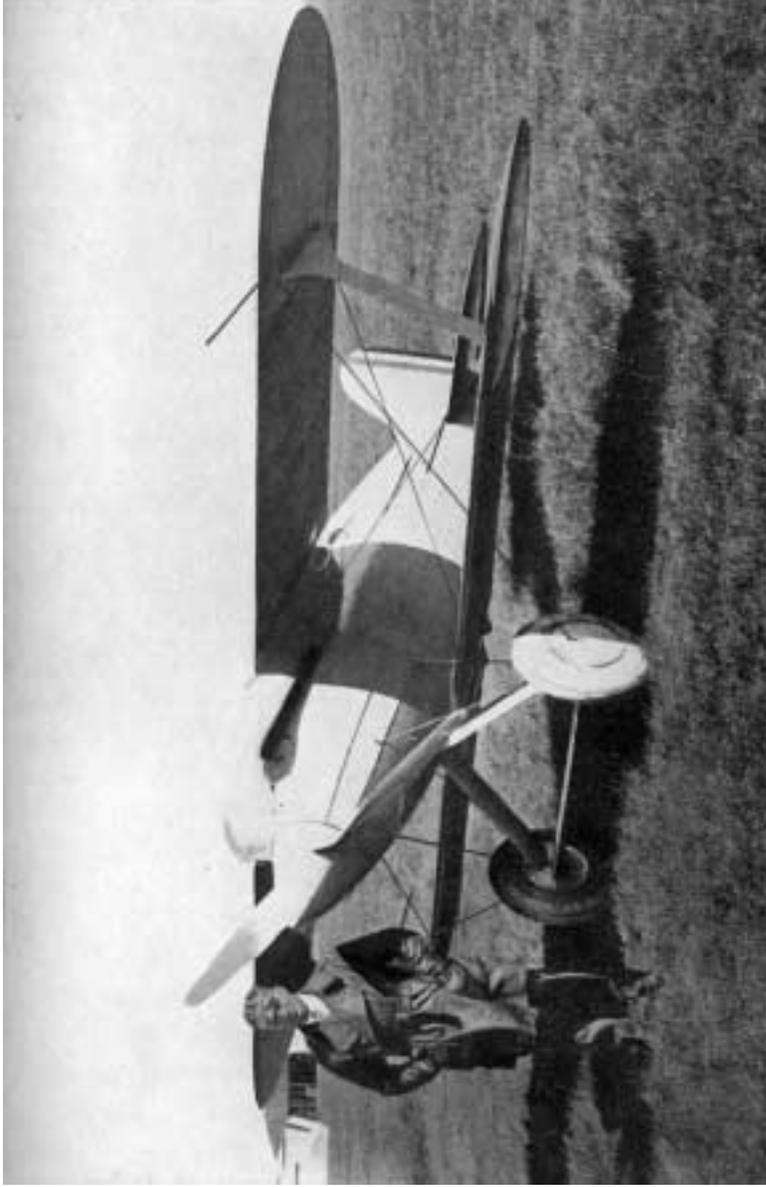
But this minimum speed, which must be had in order to fly at all, does not by any means satisfy the requirements for the military airplane. It is always desirable in war that every mission, no matter what its character, be executed with celerity. Moreover, every military airplane may have to fight, even though its habitual missions may call for the avoidance of combat wherever practicable. It may, therefore, be accepted as an axiom that every military airplane should have the highest possible speed consistent with the possession of the other characteristics that are essential to the proper performance of its special tasks. As suggested previously, these other characteristics almost invariably conflict with the attainment of speed. Some of these will be briefly considered.

Useful load. No matter for what purpose it may be designed, every military airplane must be capable of carrying some useful load. It is this necessity, as will be demonstrated subsequently, which is the greatest enemy of all other desirable characteristics in the completed machine. The addition of weight invariably means a sacrifice of either speed, or of rate of climb, or of maneuverability; often it means that all three must be curtailed. We may, therefore, accept as a second axiom that the useful load of the military airplane should be reduced to the minimum consistent with the performance of the duties for which it is designed. There exists a natural temptation to load the craft down with the every device that might conceivably prove of use. This, however, must be assiduously combated. A suitable compromise in the matter of the load to be carried requires the best judgment of the tactician and of the engineer combined. To consider, for example, the pursuit airplane; its useful load has hitherto been restricted to the weight of one man, his forward guns and ammunition, and a limited amount of fuel. Many reasons can be advanced for

addition to this weight. Thus it would be desirable to increase the fuel capacity, so that pursuit aviation might have a longer cruising radius and be able to undertake more extensive operations. But to do this, as will appear in a subsequent paragraph, might put the pilot at a serious disadvantage in combat. Accordingly, the fuel supply is cut down to the smallest amount that gives a reasonable radius of action in the situations that are likely to arise. It should be mentioned in this connection however, that the installation of extra fuel tanks, which can be carried for long distance operations, and dropped at the will of the pilot, offers a possible solution of this question.

Another most desirable feature in the pursuit airplane is defensive power, primarily in the form of rear guns and an extra man to work them. There have been many advocates of the two-seater fighter. In the World War they were used to some extent, and proved themselves of great value in any special circumstances. There is every reason to believe that they will prove of value under similar circumstances in the future. But the sacrifice of speed that is involved does not seem warranted, and the bulk of pursuit aviation will probably always consist of single-seaters. Yet another desirable addition to the load of the pursuit airplane is the supercharger, which will be described later. This is absolutely essential for flying at the higher altitudes. It is, therefore, apparent that unless some pursuit units are equipped with it, a large reach of the air is given over to the exclusive use of the enemy. But the weight of the supercharger is excessive. A pursuit airplane so equipped is at a disadvantage in combat at low altitudes with an enemy unburdened with this extra load. It seems probable that this dilemma will be solved by further specialization, part of the pursuit force being used only for high altitude operations, where it will meet the enemy on terms of equality.

Much the same problem arises in regard to the installation of radio sets. These are essential to the control of masses of pursuit in the air. But here again weight is an appreciable item. On account of this—as well as for other and perhaps more cogent reasons—it seems likely that only the commanders of the larger units of pursuit aviation will be equipped with the radio, and that they will exercise their functions from com-



(Official Photograph, Air Corps, U. S. Army)

Figure 1. The Curtiss Navy Racer



(Official Photograph, Air Corps, U. S. Army)

Figure 2. Pursuit Airplane, PW-S

mand planes, especially designed for this purpose, and intended for defensive fighting only.

It is evident from the above discussion that, however, desirable, a feature may be, it is often necessary to dispense with it, if the essential attributes of the air fighter are to be retained. When we come to consider the other branches of aviation, however, so rigid a curtailment of weight is not required. At the opposite end of the scale from the pursuit airplane comes the bomber. Here the transportation of heavy loads is its chief reason for existence. This requires so many sacrifices of flying qualities that all hope of retaining offensive combat power must of necessity be abandoned. It must rely for protection upon the operations of friendly pursuit aviation and upon its own rear guns. These constitute no great additional burden where so much as already been assumed. A larger fuel capacity than that of the pursuit airplane is also necessary, if the slow bombing machines are to have an adequate "range." In the same class with bombing planes may be placed seaplanes. The extra weight which is necessary to permit them to alight on the surface of the water, places them under all the disadvantages of the bomber in the land type, with the additional factor that the useful load they can carry is greatly reduced.

Between the bomber and the pursuit airplane come the other service types. Their tactical rôles demand that they carry heavier loads than the pursuit airplane, but lighter than those that must be transported by the bomber. Design full recognizes these tactical needs, and accordingly, the other service types are a mean between the two extremes in flying qualities.

In the preceding discussions enough has been said to show the conflict in design that occurs between the desire for a large useful load and the need for high speed. But there are other desiderata, which must be taken into account and which often require modifications in speed or in useful load.

Structural strength. It is obvious that the airplane must be strong enough to withstand any of the stresses it is likely to undergo in service. Increased strength almost invariably entails additional weight, so that the effect of this factor is similar in many respects to an increase in the useful load. It

exercises its greatest influence in the case of the pursuit airplane; for this is subjected, in the rough and tumble of air fighting, to greater stresses than any other type of service airplane. At the same time, as stated previously, speed is a prime necessity for the pursuit airplane. Here again the necessity for a compromise appears. In the case of other service airplanes, which are not maneuvered so violently and hence are not subjected to the same dynamic loads, strength does not enter to the same important degree. As an illustration of this, it is accepted as entirely practicable to give the wings of the bomber strength to withstand a load of only 5, expressed in multiples of the total weight of the airplane; whereas the pursuit airplane must have wings capable of bearing a dynamic load of the order of 12.

Landing speed. High speed in a horizontal plane is also limited by the necessity for landing the airplane safely. In general, the higher the landing speed of the airplane, the larger must be the airdrome used for the purpose. This offers no serious difficulty in some parts of our country, where spacious airdromes abound. But in the more thickly populated areas suitable landing fields are not commonly found. Yet it is just this character of terrain that is most liable to become the theatre of larger operations. It is obvious then that the landing speed of the service airplane must be kept below a certain maximum, or the success of the air force might be seriously jeopardized by lack of suitable airdrome facilities. Another defect presented by high landing speed lies in the danger of forced landings. For example, an airplane with a landing speed of 100 miles an hour, if forced to land due to engine trouble, would practically never find a suitable landing field. The destruction of the airplane would be almost certain.

Now the landing speed of an airplane and its maximum speed under power are not governed by the same factors, as will be shown subsequently. Nevertheless it may be stated in a general way, that the requirement of a low landing speed usually results in reducing also the maximum speed.

A number of devices have been invented from time to time, to shorten the pace required for landing. The familiar brake of the automobile at once comes to mind. In its usual form this

has proved impracticable, due to the fact that the brake sets up an overturning moment, which usually causes the airplane to "nose over." It appears, however, that this difficulty is not wholly insurmountable, and that some form of brake on the wheel may yet prove of at least some value. Experiments have also been conducted with a parachute, which is released after landing, and acts as an air brake to reduce the velocity of the airplane. While this seems to be an excellent emergency measure, it has also many disadvantages. Designers have long dreamed of a variable wing surface, which would solve this and many other problems. For, as will be shown later, the amount of wing surface plays an important part in determining the characteristics of the airplane. If it were variable, it would be possible to reduce the wing area to its smallest in the air, and so attain a high speed, then to extend the surface prior to landing, so that the machine could be "floated in" at a low and safe speed. Hitherto, however, mechanical difficulties have prevented any realization of this idea.

Another contrivance which is designed among other things to reduce the speed of the airplane on landing, is the reversible propeller. Experiments with this give excellent promise of ultimate success. However, at the present time, none of these devices has reached the stage of development that warrants their inclusion as part of the standard equipment of the airplane. It still has to roll, after landing, until friction and air resistance bring it to a halt, and should some unavoidable obstacle intervene, a crash is the result. So long as this condition exists, the necessity for a reasonably small landing pace will tend to limit the maximum speed of the airplane.

Speed and the human factor. There is more than a suggestion that, even if necessary compromises in design or the strength of materials do not eventually set a limit on speed, the human factor may do so. For example, let us suppose that two of the fastest airplanes in existence today are manned by hostile pursuit pilots and are approaching each other the same line. If the two pilots fail to perceive each other until they are at a distance of 250 yards, less than one second of time will elapse, before they pass each other. Of course, air fighting more frequently occurs where the relative speed of the two

contestants is the difference rather than the sum of their respective speeds. Nevertheless, the conditions in the example will often occur, particularly in a *mêlée*. It indicates, at least, the exorbitant demands that may be made on human reactions, demands which are perhaps beyond human ability to meet. It is interesting, in this connection, to note that pilots who have blown these racing airplanes, complain of the severe physical reaction of the centrifugal force of turning. Of course it is trite to observe that the human body was not evolved to be hurled at terrific velocity through the air. And we have numerous examples in aviation alone, which warrant the belief that the same human ingenuity which accomplishes that result, will also invent mechanical devices, as the need arises, to supplement the deficiencies that appear in the human body. Nevertheless, it is worth considering whether a speed may not be attained—of if, indeed, it has not already been reached—beyond which it is useless to go, since the human faculties are unable to avail themselves of the added advantage.

Rate of climb and ceiling. The tactical significance of rate of climb has already been discussed. Closely connected with it is what is known as the ceiling of the airplane. The word is used with still another meaning, but here will be understood to indicate the maximum altitude which a given airplane may reach. There is an obvious tactical advantage in possessing a high ceiling, since it enables an airplane to reach altitudes where it is secure from molestation by all hostile aircraft with a lower ceiling. Rickenbacker gives an interesting account of just such an incident. On one occasion he attempted to attack a German observation airplane, which had been photographing the American position. The German, however had the higher ceiling, and try as he might, Rickenbacker could never get within range. His vain efforts to climb up the level of his adversary afforded much amusement to the German pilot and observer, who watched his futile attempts in complete safety.

Maneuverability. The world maneuverability in its general meaning is well understood. Formerly no attempt was made to reduce this property of the airplane to a definitely measurable quantity. Maneuverability was considered as entirely compar-

ative, and one machine was held to surpass another in this respect then it could maintain a superior position in curvilinear flight. Of late, however, there has developed a tendency to give a somewhat different definition to the word. Now it is held to be directly proportional not only to the rate of climb, but also to the velocity of the airplane in horizontal flight, and inversely proportional to the minimum radius of the turn which the machine can make in horizontal flight.

Disregarding for the time the speed factor in the last named definition of maneuverability, and considering only the other two, which tend to conflict with speed, the subject is of greatest interest in its application to the pursuit airplane. The relative weights to be assigned the two desirable but conflicting qualities of speed and maneuverability, gave rise in the World War to two schools of thought. These may be called, from the names of two characteristic airplanes, the "Spad" and the "Camel" school. The latter was a slower machine than the "Spad," but excelled it in maneuverability. The typical attack of the "Spad" consisted in running down the enemy, and diving in rapidly for a short burst of fire. Much dependence was placed on surprise. Should this initial attack fail, however, the "Spad" was less effective than the "Camel" would have been under similar circumstances, for there generally resulted in that case a long-drawn-out succession of maneuvers for the advantage of position, a form of action where the "Camel" was peculiarly handy. On the same account the latter was the superior machine when itself surprised and forced to make a defensive fight. On the other hand, the "Spad" could often force an unwilling enemy to fight, where the "Camel" would fail; and could escape from undesired combat, if not surprised, where the "Camel" would be forced to fight. Both ideas had their advocates, and he who attempts to judge between them finds himself heartily regretting that the good qualities of both cannot be combined in the same machine in the highest degree. On the whole, however, it seems wiser to incline towards speed, because of its essentially offensive character.

Factors affecting performance. Many of the desirable qualities in the airplane have now been outlined. It is not the purpose of this volume to discuss in detail the intricate sub-

ject of design. It has been observed, however, that the design of the airplane calls for the balancing of many conflicting tactical demands. Therefore, in order to have some measure of the tactical import of these various characteristics, it is desirable to indicate briefly the factors which affect the performance of the airplane.

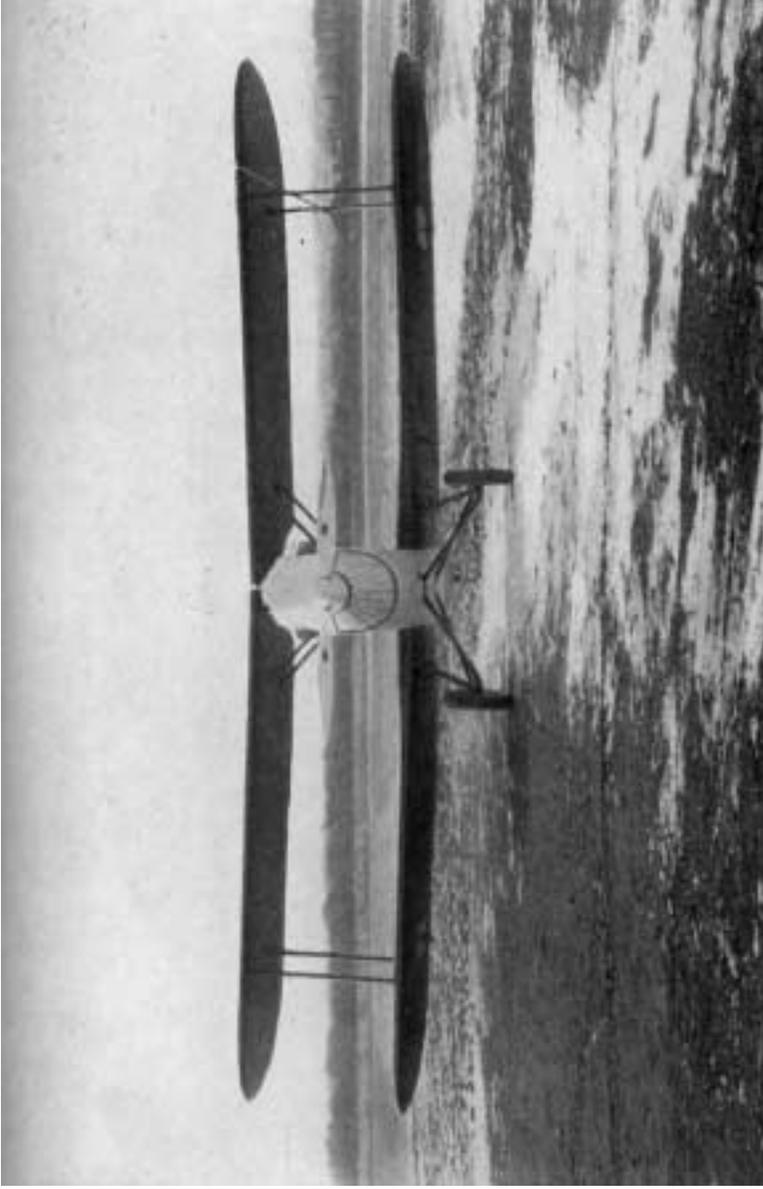
It was stated in an earlier paragraph that the requirement of a large useful load interfered most markedly with the attainment of all other desirable qualities. In this brief illustration of the salient points of design, let us begin, therefore, with a certain useful load, which must be transported through the air. This may vary from a few hundred pounds in the case of the racing airplane, to many thousands in the larger bombers. In addition to the useful load, the wings of the airplane must sustain also the structure of the airplane itself and the power plant, the whole constituting the gross load or weight of the airplane. It is a fundamental law that the total pressure exerted on a wing as it is pulled through the air, is proportional both to the area of the wing and to the square of its velocity. This pressure may be resolved into two components, when the airplane is in normal flight with its wings inclined to the horizontal. The vertical component is known as the "lift"; it overcomes the effect of gravity, and so renders flight possible. The horizontal component is called the "drag" of the wing. Since the former alone may be said to perform useful work, the ratio of lift to drag is taken as a measure of the efficiency of the wing, although the use of the word efficiency in this sense is not in accordance with the usual practice in mechanics.

If we ignore the efficiency of the wing, it is apparent from the fundamental law that the total weight we have assumed, may be supported in the air by an infinite number of combinations of speed and of wing area. Thus a certain wing area may be assumed, traveling at a certain speed, or else the same lift may be obtained by a wing of four times this area, moving at only half the original speed. If this were the only consideration, it would appear that almost any speed may be secured regardless of the size of the load to be carried. But of course, many other factors must be taken into consideration. These will be briefly discussed.

Wing loading. A marked effect is exerted on many features of the performance of the airplane by the wing loading, which is the ratio of the total weight of the airplane to the area of the wings. It would appear from the fundamental law, that the speed could be increased to almost any figure, by indefinitely increasing the wing loading. In practice, we know, of course, that there is a definite limit to the wing loading. Strength of materials long would produce this, even if there were no other restraining factors. For obviously, materials can sustain loads only up to a certain breaking point, and safety dictates that this point must never be reached. But other considerations also sharply define the limits of wing loading. Foremost among these is the landing speed. Provided the wings of the airplane possess the same characteristics, landing speed is proportional only to the square root of wing loading. The necessity for having a reasonably low landing speed for the service airplane has already been shown. This in turn produces an ultimate wing loading, beyond which the designer cannot go.

It is interesting, in this connection, to compare the wing loadings of several different types of airplanes. In Figure 1, is shown the Curtiss Navy Racer. It ignores practically every one of the characteristics which have been considered desirable in the military airplane, except speed and a reasonable factor of safety for the stresses it was intended to undergo. It is quite true that a limited landing speed was prescribed. However, this exceeds the speed which is considered safe for general service use. As might be expected, its wing loading is high, being of the order of 16 pounds per square foot. On the other hand, the service types of airplane show a much lower wing loading. As might be expected from the fact that a safe landing speed is alike desirable in all of them, the wing loading shows very little difference. Thus the pursuit airplane, the PW-8 (Figure 2), the observation airplane, the XO-2 (Figure 3), and the bombing airplane, the NBS-1 (Figure 4), have wing loading factors of 10.97, 10.77, and 10.76, respectively.

It is, therefore, apparent that when a limited landing speed is prescribed, and hence the wing loading cannot exceed a definite figure, if the weight to be carried be now increased, it can be met only by increasing the area of the wing surface. This is,



(Official Photograph, Air Corps, U. S. Army)

Figure 3. An Observation Airplane, the XO-2



(Official Photograph, Air Corps, U. S. Army)

Figure 4. A Bombardment Airplane, the NBS-1

of course, the usual practice. For example, the PW-8, which weights only about 3,000 pounds, has a wing area of 287 square feet, while the bomber with its weight of 12,000 pounds requires some 1,121 square feet for its sustentation. At this point in the discussion however, a question naturally arises. Even though the wing loading be limited, is it not possible to carry the heavier loads in the larger airplanes, without sacrificing the desirable tactical quality of speed? In theory, this is possible, if only the maximum speed at sea level be considered. For while the increase in size of the airplane carries in its train increases in the resistances which are useless in sustaining weight, and these in turn reduce the velocity, nevertheless they can be overcome, and the high speed of the lighter load retained, if only enough power is added. In practice however, there is a definite limit on the power of the engine as well as on the efficiency of the propeller, and the designer is by no means unrestricted in his employment of a power plant.

Power and its effects. The power required for horizontal flight increases directly with the resistances encountered. These are generally divided into two classes, the drag of the wing, which was previously defined, and the resistance offered by the other parts of the airplane, which, since they play no part in sustentation, are known as "parasite" resistances. But the power also is a direct function of speed, and increases not with the first power, but with the cube of the velocity. It is apparent then, that as we increase the wing area, while considering the coefficient of drag to remain constant, we must increase also the power necessary to horizontal flight. As the machine grows in size, there is also an increase in the parasite resistances. It is still assumed, of course, that the wing loading remains practically the same. It is apparent from this that as we increase the weight, it may still be maintained in horizontal flight, provided we decrease the velocity, with the same expenditure of power. But if we attempt to increase the weight and still maintain the same velocity, it can be done only at an exorbitant price in power.

When we come, however, to consider rate of climb, the influence of weight becomes even more marked, in its direct

effect on this factor in performance, as well as in its indirect effect on speed. For the rate of climb is inversely proportional to the weight of the machine, and is directly proportional to the difference between the total available power of the engine and propeller, and the power required to maintain the machine in horizontal flight. From what was said above, it is obvious that if the weight be increased largely, and the speed be maintained high, it will absorb so much power in horizontal flight, that there will be no excess for climbing. If we attempted, for example, to give the bombing machine the same speed as the pursuit airplane, the resulting aircraft would be able to fly just above the earth at high velocity, but would be totally unable to reach an altitude necessary to overcome even slight obstacles in the line of flight. Accordingly, in practical design, as weight increases, speed must decrease; some excess power is left also for climbing, but as weight increases, so much power is required for this purpose, that the heavier machines are also the slowest climbers. It is interesting as an example, to note that while the pursuit airplane previously mentioned can climb to 6,500 feet in 4.2 minutes, the bomber requires more than 22 minutes.

Power and altitude. In so far as the characteristics of the airplane alone are concerned, ceiling and rate of climb go hand in hand. But in practice, the ceiling of the airplane is determined by the fact that there is a marked decrease in the power output of the engine, as altitude increases. This, of course, affects also practically all other performance characteristics, as may be deduced from former statements. For example, the speed of the PW-8 decreases 25 per cent in going from sea level to 20,000 feet. This loss of power in the engine is due to the fact that the density of the air, and consequently the amount of oxygen necessary for combustion of the fuel, decreases with an increase in altitude. Thus the horsepower delivered by the Liberty engine at 20,000 feet is less than 40 per cent of its sea level value. To overcome this defect, an instrument has been developed, known as the supercharger. It consists essentially of a centrifugal air blower, which compresses air and delivers it to the engine at approximately the

density of the air at sea level. In this way, the power of the engine is maintained at almost its value at sea level.¹

The wings. The efficiency of the wing has already been defined. It is impossible, within the scope of this chapter, to enter into the details of the selection of suitable airfoils for the machine being designed. The methods are largely empirical. From wind tunnel tests, and from other experiments, the characteristic of many airfoils have been determined. Usually the designer selects from among these, the wing which seems most suitable, in view of the qualities which are especially desired in the completed airplane. Thus one type of airfoil is especially proficient in attaining a high speed, while still another would be selected for the weight carrying machine.

Visibility. The word visibility is understood here to refer the extent to which vision is uninterrupted by the structure of the airplane itself. Wings, fuselage, and engine all cut off the view of the occupants of the airplane to a greater or less extent. From a tactical point of view, this becomes particularly serious, when it occurs in the hemisphere in rear of the pilot. In airplanes that carry a crew of several men, lack of visibility is rarely a grave defect, since often one may see what is hidden from the view of the others. In single-seaters however, it becomes of great importance. Not only must the pilot be often scanning the sky in rear of him, but he must frequently turn his machine in order to uncover the hitherto hidden sectors. Airplanes that are unusually "blind" are at a marked disadvantage, and particularly so in combat, where every move of the opponent must be closely followed with the eye. Often, in the design of the airplane, the necessity for visibility causes the modification of parts of the structure which interfere, even at a cost of lessened effectiveness from the standpoint of aerodynamics.

Maintenance. Ease of maintenance under service conditions is an important asset in any airplane. This feature of design has not always been given due consideration, so that several otherwise excellent craft have proved to be impracticable instruments of war. Cases have occurred where a squadron

¹Airplane engines and superchargers are described in "Aircraft Power Plants," a volume of the Ronald Aeronautic Library.

with one type of airplane kept 90 per cent of them in commission, while another squadron, under essentially similar conditions, except that it was equipped with a machine more difficult to maintain, could keep only 45 per cent of its strength in commission. It is apparent that the latter squadron was only half as effective tactically as the former. It is particularly necessary that all parts of the engine and airplane, which are most likely to need repair, be easily accessible.

Factors affecting flying. The discussion of the characteristics of aircraft has hitherto been limited largely to the influence exerted by different features of design. These are usually of greater importance, when the criterion is tactical effect. However, there are many factors, outside of the machine itself, which may enter with decisive effect. Foremost among these are the extraneous influences which may be grouped together under the heading of weather.

Wind. In the early days of flying, even a moderate breeze was often enough to daunt the airman, equipped as he was with a slow and dangerously underpowered craft. But this condition has long since passed. The slowest of service airplanes now exceeds the wind in speed, except in storms reaching the intensity of the tornado. The airman of today has little to fear from the wind. Of course, there are storm conditions where the airplane is badly tossed about by the wind, and the pilot is subjected to much discomfort and fatigue. In extreme cases, there is considerable danger. But such conditions are too rarely met with in practice, to be of serious moment.

Of course, the direction and intensity of the wind must be taken into account in every flight. For the velocity of the airplane with respect to the earth, which is the all-important factor in flying, is the resultant of the "air speed" of the machine and the velocity of the wind. As an example, let us assume a bombing airplane whose speed is 100 miles an hour, with a fuel capacity of five hours. This speed, of course, is air speed. Let us assume also that target is 200 miles north of the air-drome. If the wind were blowing from either north or south, with a velocity of 45 miles an hour, the ground speed of the airplane in one direction would be 145 miles an hour, in the other 55 miles an hour. The round trip would take just a trifle

more than five hours, and hence would be impossible. The same result would be encountered with an east or west wind of over 60 miles an hour. Also, it is highly desirable both in landing the airplane, and in taking-off, that the machine be headed directly into the wind; otherwise, a dangerous speed or direction may result, with possibilities of a "crash." It may be said however, that while the wind must always be taken into account in navigation and in maneuvering, it rarely exercises an important influence on a military mission.

Clouds and fog.² In the ordinary practice of air navigation of today, the pilot is largely dependent on landmarks. It is true that he has at his disposal the necessary instruments in dead reckoning, and that he uses these habitually as a check on his flying, and indeed, when unavoidable, as the sole means of navigating his craft. But the methods of dead reckoning leave much to be desired on the score of accuracy, even with the more elaborate instruments used in the navigation of sea going vessels. For these are dependent on landmarks, when their position must be accurately located within a mile or two. The airplane is in much worse case in respect to navigation. The sextant and chronometer are generally impracticable for use in flight. And dead reckoning, when the velocity of the wind cannot be measured with a fair degree of accuracy, which occurs when the surface of the land or sea is completely obscured from view, is apt to be mere guesswork. The pilot of the airplane is, therefore, peculiarly dependent on landmarks in the usual case. Ordinarily the execution of a military mission demands that he arrive over a definite point. In order to do this, while traveling at a high rate of speed, he must be able to see to a distance of a few miles, in order to know his position at all times. He cannot stop for inquiries. It is on this account that clouds and fog are the worst natural enemies with which the airman has to contend. For he must have visibility to fly, and this is almost altogether a question of the amount of water vapor in the air. As clouds lower, visibility decreases until they may render navigation all but

² The volume of the Ronald Aeronautic Library entitled, "Aeronautical Meteorology" treats more completely of weather conditions.

impossible. Under such conditions, attempts at flying are hazardous and almost invariably fruitless.

Aside from the general futility of such efforts, "fog flying" presents an obvious danger. For when the pilot can see but a few feet ahead, the avoidance of collision with trees, chimneys, or other obstacles, is left entirely to chance. Many fatalities are due to this cause. Still another danger arises from the difficulty of preserving equilibrium in the air. To assist him in this respect, man is provided with semi-circular canals in the inner ear; but these are not so highly developed as in the bird, and experience of many fliers indicates that man cannot dispense with vision for any great length of time and still preserve a correct conception of his relative position in space. It is true that instruments have been devised to assist the pilot in maintaining a straight course in fog or clouds, have proven fairly successful. These will probably be of very great value, where the airdrome and the objective are both free from fog, but intermediate spaces are covered. Nevertheless, the fact still holds that fogs and clouds constitute the obstacles to flying which most often interfere with the execution of a military mission.

Rain and hail. Heavy rain may have much the same effect in obscuring vision as clouds, and may, in addition, damage an unprotected propeller. Cases have occurred also when rain interfered with the ignition system of the engine. In general, however, where the rain clouds are not low enough to prohibit navigation, rain proves a discomfort rather than a serious danger.

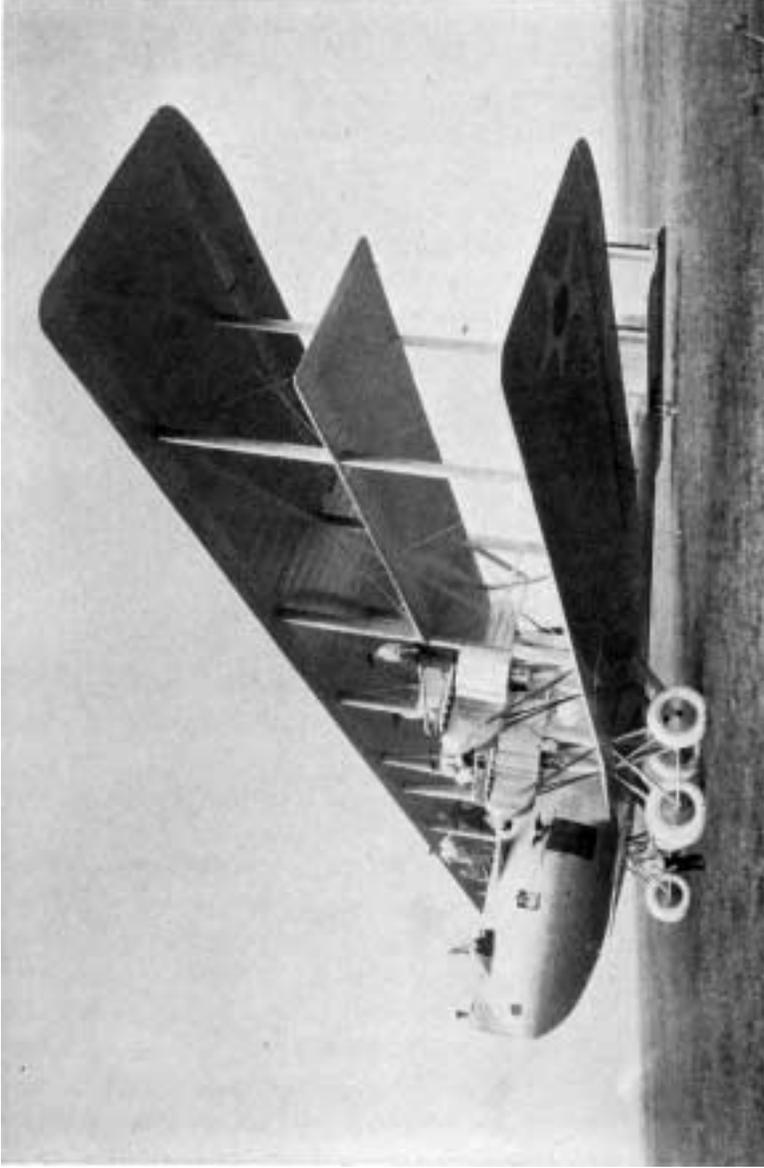
Hail, on the other hand, is a serious menace. The impact of solid particles of ice, at high speed, quickly destroys both fabric and propeller edge. Fortunately hail storms are rare, and in practice have offered no serious difficulties to air operations.

Darkness. It is evident from the discussion of the effect of fog on visibility, that flying would be quite impossible in complete darkness. Absolute darkness, however, never occurs in nature, and often at night moonlight and starlight are enough to make flying entirely practicable. On a bright moonlight night, in fact, many features of the terrain, such as woods and streams, stand out almost as clearly as by day. Under these circumstances, navigation offers very few difficulties. Of course, no matter how clear the night, details of the terrain are never quite as distinctly visi-

ble as in daylight. But night flying airplane is equipped with powerful parachute flares, by means of which terrain features of especial interests may be brightly illuminated. It is provided also with searchlights and wing tip flares, which would be of great assistance, if the airplane were forced to land away from the airdrome. Then too the normal airdrome is now provided with artificial lighting which enables the airplane to land and to take-off as accurately by night as by day.

In general, of course, flying presents far more difficulties by night than by day. A forced landing, for example, has much less chance of a safe outcome at night. Thus, in a recent case, the pilot of an airplane whose engine had failed, preferred to jump and trust his safety to the parachute, rather attempt a landing in an unseen terrain at night. At night, in fact, all observation is more difficult, and the results secured are more apt to prove unsatisfactory. On the other hand, darkness often gives concealment and safety, and many missions are practicable by night which would prove prohibitively dangerous in daylight. So, while darkness is a marked obstacle to flying, nevertheless air operations by night must be reckoned with in every phase of action.

Endurance of personnel and material. There comes a time in war when the utmost exertion and even the ultimate sacrifice must be demanded of men. When this time arrives, the true leader does not hesitate to exact supreme efforts. But the wise general knows the limitations of human endurance, and spends neither the lives nor the reserve energies of his men, unless the end is in view fully warrants it. At all other times, both are carefully husbanded. It is patent, for example, that infantry which has been making forced marches for several days, is too fatigued to fight with anything like its normal effectiveness. Similarly, the amount of flying that may be demanded of a pilot without loss of efficiency, is limited. So small is the amount of muscular exertion required to fly, that those who are unfamiliar with the actual conditions, are apt to underestimate the resulting fatigue. Even in the ordinary flying of peace time the expenditure of nervous energy is great; when there is added to this the strain of meeting hostile air activity, the demands on endurance mount rapidly. Sometimes also, as in flying at great altitudes,



(Official Photograph, Air Corps, U. S. Army)

Figure 5. The Barling Bomber .

there are added physiological effects to be contended with. All of these combine to produce great fatigue. If, for example, a pilot should be sent out on mission after mission, throughout a long day, with barely enough time between to refuel his airplane, the reserve energy which he would thus expend could not be made good during the night's rest. Should such intense activity be continued for several days, his deterioration becomes rapid. After a few days, the average man would be overcome with fatigue, and partially useless for further work. And once a man is strained beyond his limit of endurance, recovery to a normal condition is slow and prolonged.

While the human factor is the more important of the two, the strain on material also must be given serious consideration. Every part of the airplane must be inspected at frequent intervals, and repairs of greater or less importance must be made from time to time. It may be stated as a general index that for every hour the airplane flies, it must spend two in the hangar or machine shop, undergoing overhaul, if it is to remain in the best of condition.

Experience of the World War indicates that the duration of a mission should be limited to two hours, wherever practicable. This is, of course, often impossible; but after two hours of service flying, there is a tendency for both pilot and observer to lose some measure of alertness, which may have undesirable consequences.

The Balloon

Description.³ The observation balloon in general use, consists of a stream-lined envelope, which is composed of a gas-tight rubberized fabric. The balloon is about 95 feet in length, and has a maximum diameter of about 30 feet. The envelope is divided into two compartments by a diaphragm just above the lower surface inside. The upper compartment is filled with hydrogen, which is the lightest known gas, having a specific gravity when compared with air of only .069. It thus furnishes

³ A more complete description of observation balloons may be found in "Free and Captive Balloons," a volume of the Ronald Aeronautical Library.

great ascensional force. The lower compartment, the ballonnet, contains a variable quantity of air, which serves to keep the internal pressure of the envelope constant when the hydrogen contracts or expands, thus preventing the balloon from losing its shape. To provide for the expansion of the gas, the balloon is equipped with an automatic valve, which allows part of the gas to escape. To the rear end of the balloon are attached three air-inflated lobes or stabilizers, which tend to keep its head to the wind as well as to maintain aerodynamic stability. A rigging band, securely attached to the envelope, carries the bridles, which in turn support the basket and the mooring cable. The former is a square wicker basket, large enough to accommodate two observers and their equipment. The mooring cable is strong, light, and flexible, and consists of steel wire strands, laid on a core containing the telephone cable. The lower end of the cable is attached to a winch mounted on a truck chassis. By means of the engine, the balloon can be hauled down. In the air, the balloon has its longitudinal axis inclined, which produced a "kiting" effect in a wind, and so assists in sustaining the weight of the balloon.

Operation of the balloon. As compared with ground observation, the balloon offers two distinct advantages. The altitude to which the latter can attain extends the visible horizon and exposes to view many objects that are hidden from the eyes of the ground observer. Furthermore, even when the latter can see a certain object, the man in the balloon usually has a much better angle of vision. On the other hand, the instability of the platform often makes observation from the balloon quite difficult. As compared with the airplane, the balloon has a great advantage in the face that the observer has direct telephone connection with the unit for which he works. Furthermore it is able to remain up for longer periods of time than the airplane, and can render more nearly continuous service. Weather however, is more apt to halt the operation of the balloon than of the airplane, for conditions of low visibility which prohibit flying, render balloon observation useless also; whereas, high winds may bring about the same result with the balloon, while airplanes are still able to operate. Due to the inflammability of hydrogen, the balloon is quite vulnerable to

attack by hostile airplanes. It may, however, be rapidly hauled down on the approach of the attacker, and is provided with an excellent defensive armament on the ground comprising twelve machine guns, and two 37 millimetre guns, for anti-aircraft use. Should the balloon be set aflame, it is replaced within an hour or two by a spare balloon, which, together with the gas necessary for its inflation, is always kept on hand. The use of helium obviates many of these difficulties, for it is an absolutely inert gas that does not combine with oxygen. The ascensional force of helium is 92 per cent that of hydrogen; also the cost is several times greater although that is not a serious factor during war.⁴

The balloon may be moved over the ground either by man power, or by the use of the winch to which it is attached. In general, it is fairly mobile, and may be depended upon to keep up with any ground troops to which it may be attached.

The Airship

Non-rigid airships.⁵ The division of the airship into classes, is based solely upon differing types of construction, of which there are three: the non-rigid, the semi-rigid, and the rigid. The non-rigid airship is one in which the shape of the envelope is maintained solely by the internal pressure of the contained gas. It is, in effect, little more than a balloon, such as those previously described, with a power plant suspended from it. The envelope contains the gas, and is the supporting agency of the entire ship. Inside the envelope, and attached to it, are one or more small bags, called ballonets, which can be filled with air or emptied at the will of the pilot, in order to maintain the pressure at the proper point, when the gas contracts. Undue pressure caused by expansion of the gas is prevented by safety valves. A car containing the power plant is attached to the envelope by means of steel wire guys. The sta-

⁴ The properties, production methods and cost of helium are given in "Balloon and Airship Gases," a volume of the Ronald Aeronautic Library.

⁵ More complete information about non-rigid and semi-rigid airships is given in "Pressure Airships," a volume of the Ronald Aeronautic Library.

bilizers and control surfaces are attached to the rear portion of the envelope. The non-rigid is the smallest of all airships, varying in size from the "Pony Blimp" of 35,000 cubic feet capacity, to the *TC* type of 210,000 cubic feet.

Semi-rigid airships.⁵ As the size of the airship increases, the fabric of the envelope must become stronger, if it is to withstand the internal pressures necessary to maintain the shape. This adds so much weight in the case of the larger airships, that efficiency is materially reduced. In order to overcome this defect, the semi-rigid airship was designed. It differs from the non-rigid in having a beam along the bottom of the envelope. This supports the car, and permits of such a distribution of the pressures in the envelope that the internal pressures can be kept low. Thus the use of a lighter fabric is allowed, and a greater weight than that of the keel is saved. The larger airships of the semi-rigid class have several compartments for gas, in order to prevent surging of the gas, to localize losses of gas, and to permit the airship the more readily to be trimmed. Ballonets are provided, as a rule, for each compartment. The Army airship *Roma* was of this type. The latest American airship of this type has a gas capacity of 665,000 cubic feet, a useful load of over 8 tons, and a maximum speed of 70 miles an hour.

Rigid airships. There is a definite limit to the size of the semi-rigid airship, if it is to remain efficient. This fact makes the rigid airship of the greatest interest. With it alone, the limit of size has not yet been approached, and to it belongs the future of air transportation. The distinguishing characteristic of the rigid airship lies in the hull framework, which is enclosed by an outer cover, which however has a very small part in the designed structural strength of the airship, but is intended to reduce head resistance to the minimum, and to protect the gas bags from exposure. On this account the fabric is relatively light. The gas bags are merely containers for the gas, and therefore also of a light fabric. The airship *Shenandoah* was of this type. It had a cubic capacity of 2,115,000 feet, and carried a useful load of over 31 tons.

History of the airship.⁶ The airship has a much longer history than the airplane, and once was looked to as the sole

hope of dominating the last element. In this, as in so many other military matters, the Germans led the rest of the world in development, and, by the outbreak of the World War, had reached in the Zeppelin in a high state of efficiency. These airships were employed early in the war in several military operations, the most spectacular of which was the bombing of London. The Zeppelin, at first, had no enemy to meet, who could bring to bear truly effective measures. The airplane, in the first days of war, was unarmed, and even when this condition had been remedied, lacked the ceiling and rate of climb necessary to cope with the airship. Antiaircraft artillery was in much the same case: the weapons in existence were undeveloped, and were too few in number to make their effect felt. Accordingly the airship could operate with comparatively little fear of molestation. This condition of affairs was soon to change. Airplanes were developed that could attain to the altitude of the airship, and had, of course, a markedly superior speed. Antiaircraft artillery too became a powerful menace to the slow and vulnerable Zeppelin. It soon became known that grave doubts were being aroused as to the tactical value of the airship, in the face of these strengthened agencies of attack. Practically all operations of the airship were now restricted to darkness. They continued at intervals however, until the débâcle of November, 1917, which marked the last German sortie. Thereafter tactical operations by airships on the western front were abandoned. It is true that the severe losses sustained by the Germans on this occasion resulted more from natural causes than from hostile attack. Nevertheless it was felt that the results attained were not worth the expenditure of time and of money which was necessitated. The airship all but ceased to be a military factor.

But although these examples of the Zeppelin, and the more recent tragic loss of the *Shenandoah* furnish valuable food for thought, we are not yet warranted in jumping to the conclusion that the tactical usefulness of the airship is altogether at an end. In certain respects, it possesses so marked a superi-

⁶ More complete history of airship development appears in "Airmen and Aircraft," a volume of the Ronald Aeronautic Library.

ority over the airplane, that many air situations will arise where the airship alone will be able to accomplish the desired result.

Airship and airplane compared. In respect to the useful load it may carry, the airship has a decided advantage over the airplane. This advantage too, it probably will always retain: for, while the efficiency of the airship, as measured by the ratio of the useful load to the total load, increases with the size of the ship, this is not true of the airplane. The airship too, is not compelled to fly at a certain speed in order to sustain itself in the air, but may vary its speed from the maximum to zero with entire safety. The full significance of this quality is better appreciated when it is recalled that nearly four-fifths of the accidents to airplanes would have been avoided, had the airplane too, been able to hover over a given spot. On the other hand the airship is unable to attain to anything like the speed of the airplane. This has a vital tactical bearing: for, if the airship ever comes within striking distance of the airplane, it cannot hope to escape combat, except where very unusual weather conditions intervene in its behalf. Nor is the defensive power of the airship adequate to enable it to sustain combat with the airplane on approximately equal terms. An airship having no armament whatsoever on top of the envelope, is, of course, at a hopeless disadvantage. In combat with the airplane, the latter would attack the envelope with bullets and sensitively fused bombs, wholly unmolested by the airship, whose huge bulk would render misses quite improbable. The substitution of helium for hydrogen does reduce one hazard, but does not tend to change the final result, for the fire hazard from gasoline remains in the airship as in the airplane. With the projected airship of 10,000,000 cubic feet capacity, however, there seems to be no reason why it should not be equipped with enough machine and 37 millimeter guns so distributed as to preclude all dead spaces, thus compelling the attacking airplane to overcome a strong defensive fire. Moreover, the launching of airplanes from the airship, and their safe return to it, has already been proved feasible. Thus there seems every reason to believe that the airship of the future may have considerable defensive power, which opens new tac-

tical vistas to it. These however will be considered in detail in later chapters.

One important consideration which cannot be overlooked, is the high cost of the airship. Even though its tactical value seems to be established, its cost raises a doubt that the huge sum involved might not better be expended in other directions. The tactician tied down to a budget may well be called upon to decide between one airship and many airplanes, and cannot escape consideration of the desirability of abandonment of the airship. In particular, the necessity of housing the airship in tremendous and costly hangers militates against its use. This has however been partly overcome by the development of mooring masts, to which the airship may be attached. It dispenses with the necessity of large numbers of hangers.

Of the value of the airship as a means of transportation, where the usual agencies are lacking, there can be no question. This will be considered in greater detail in the chapter devoted to air logistics.

CHAPTER III

INDIVIDUAL COMBATS AND DEFENSIVE FORMATIONS

Individual and mass air fighting. We have seen, in previous chapters, that individual combats were the rule in the earliest days of air fighting; that these in turn were succeeded by combats of small formations of airplanes; and that, in accordance with the principles of mass, there is a tendency towards bringing ever increasing numbers to the fight, so that the student of future warfare is concerned primarily with the larger units of air warriors. Nevertheless, a study of individual combat is not of historical interest alone. In all fighting organizations, the effectiveness of the whole depends in some degree on the proficiency of the individuals composing it. On this account, it is always necessary to study the individual before it is possible to comprehend the mass. Evidently, however, this becomes of decreasing importance in proportion as individual initiative must be submerged in the action of the whole. It seems probable, from these considerations, that individual skill will always be a more important factor in air battles than in the combats of other armed forces.

Moreover, there is yet another factor, peculiar to air warfare, which further accentuates the relative value of individual air proficiency. In the World War many of the old customs of chivalry were retained by the contending air warriors. In spite of this admirable spirit, which was apparently suffered to die in all other forms of warfare, it was nevertheless true that, in air warfare alone, quarter was neither asked nor given. In view of the general amelioration of civilized warfare in this respect, the customary action of the air fighter seems peculiarly ruthless. It is far from the precepts of chivalry to pursue an obviously crippled and helpless opponent, firing into him steadily, until a fatal crash into the earth or the certain action of flames in the air, assures his destruction. Nevertheless the conditions inherent in air fight-

ing render this course unavoidable. Although some instances have occurred of airmen being shepherded to a hostile airdrome as prisoners of war, taken in air combat, these are quite exceptional in their nature. Such a course is impossible in the general case. Normally, the pilot who has definitely established his ascendancy over his opponent, has no middle course open to him between allowing his victim to escape altogether, and destroying him. In such a dilemma, his duty is plain.

The effect that this distinguishing characteristic produces in air warfare can be more easily evaluated by comparison with combat on land. When an army has once been broken into fragments and its cohesion definitely destroyed in the shock of battle, its existence as an army ceases. Only the most culpable negligence on the part of the victor will allow it to reorganize, and operate again as a combat unit. In fact, once that state of affairs is reached, the work of the victor is usually confined to the collection of prisoners, who, in detached groups, surrender freely, often without striking a blow. In air warfare, on the other hand, such a disruption of the hostile forces is by no means the equivalent of victory: it merely offers an opportunity to grasp victory. Unless this is seized and successfully exploited without delay, no appreciable result is obtained, for the enemy can reform his broken units within an hour or two, and be ready to resume fighting. To win an air battle, even where the foundation of tactical success has been well laid, it is necessary to follow up the initial success with the destruction of the hostile airplanes, one by one. No mere threat of shock nor the bare surrounding of a force, can bring about the desired result through surrender, as so often has occurred in the history of land warfare. Nor can the air force at a hopeless disadvantage, strike its colors, as in similar circumstances has often been done in sea fight.

This characteristic of air warfare markedly enhances the value of individual skill. Largely on this account, the study of individual combat is necessary, not alone because it is essential to an understanding of the operation of masses, but also because it is desirable as an end in itself.

The importance of armament and gunnery. The design of the airplane is based upon tactical needs. Nevertheless natural laws put a marked limitation on design. Accordingly, the

study of tactical methods, as a practical matter, may often best be approached from the standpoint of the characteristics and equipment of aircraft, even though such a method is not strictly logical. Since air combat is concerned almost solely with fire action, an understanding of airplane armament and of the fundamentals of air gunnery is essential. In this chapter, only those features of armament will be discussed, which have a direct bearing on air combat, the remainder being reserved for subsequent chapters.

Aircraft machine guns. In the early days of its history armament was exceedingly crude. McCudden tells how the first airplanes of the British Expeditionary Force were loaded with hand grenades, in the hope of being able to drop them on hostile aviators. Sometimes also the steel darts known as "fléchettes" were used for the same purpose. Needless to add, these weapons proved quite ineffective, and were soon abandoned. The value of the machine gun was early understood, but a long time mechanical difficulties stood in the way of its utilization. In particular, the problem of firing to the front was not easy of solution. The pilot had his limbs, as well as his attention, amply occupied with flying his machine. It was recognized that the manipulation of a machine gun in addition was beyond the powers of one man, unless the two operations could in some way be combined. This meant, in practice, that the gun must be rigidly fixed in the axis of the airplane, and fired by aiming the latter.

The first attempts to accomplish this were unsatisfactory. From a structural point of view, as well as from that of righting stoppages in the gun, it was desirable that the latter be near the pilot's hand, which necessitated firing through the plane of revolution of the propeller. The problem was first solved by fastening armor to the blades of the propeller, in order to deflect chance bullets. This functioned after a fashion but in addition to other defects, reduced the propeller efficiency by about one-third. At length a satisfactory device was developed. The synchronizing gear, as it is called, consists of a pump attached to the motor. By means of a column of oil, impulses are transmitted to a similar pump, which in turn actuates the trigger mechanism of the machine gun. In this way fire is so timed that the gun is discharged only when the propeller blades are not in line with the

trajectory. This type of machine gun, with fixed guns, is generally employed for the front guns of all single-motored airplanes.

The second class of machine gun consists of those with flexible mounts. For the reasons given above, it is impracticable to use these, except where some one, in addition to the pilot, may be carried to operate them. They are employed therefore, for the rear guns in two-seater airplanes. They are used also for front guns, but only in multi-motored airplanes, whose design permits the propellers to be removed from the forward line of fire. Commonly, the flexible-mount gun is supported on a turntable, known as a tourelle, with provision for allowing it to be easily moved in altitude also.

Both types of machine gun are habitually used in pairs.

Types and calibres of machine guns. In general, the airplane machine guns are adaptations of those which have been found successful by ground troops. Certain differences however are important enough to merit consideration. Due to differences in the nature of air combat, it is particularly necessary that the aircraft machine gun have a rapid rate of fire. With ground troops, the matter of cooling devices is one of great importance, and frequently is the source of trouble; in air fighting, on the contrary, due to the rapid air stream, the altitude, and the fact that the characteristic action involves short bursts of fire with long intervals between them, more trouble results from low temperatures than from overheating. Another difference in the case of the fixed gun at least, lies in the provision of a synchronizing gear. An important difference too, is in the sights, which will be discussed subsequently. The .30 calibre gun is the standard service equipment of today. However, both the .50 calibre gun and the 37 millimeter cannon have been successfully installed in the airplane. These will undoubtedly be used in future warfare for special purposes for which the .30 calibre gun is inadequate.

In the American army the Lewis and Marlin guns were formerly in extensive use as flexible-mount and fixed-mount guns respectively, but both are now being replaced by the Browning gun.

Airplane ammunition. The ordinary service ammunition, similar to that in use by the infantry, has generally been

employed in the past for aircraft machine guns. But there is an increasing tendency to replace this with ammunition especially adapted to air work. The tracer bullet in particular, though often useful to the ground machine gunner, has proved indispensable to the airman. For the latter can see no spurt of dust to help him correct his aim, and faces a more difficult problem in gunnery than his comrade of the infantry. But by the aid of the tracer bullet, in the base of which is an inflammable mixture that ignites on the explosion of the cartridge and burns with a bright green flame, the airman may follow the flight of the bullet with his eye to a distance of about 600 yards. Usually the tracer bullets are mixed with other varieties of ammunition.

Quite distinct from the tracer bullet, although originally developed from it, is the incendiary bullet. It contains a phosphorus compound, which burns fiercely for many minutes, and is unusually difficult to extinguish. It was originally designed for use against balloons, for which purpose the ordinary ammunition is comparatively ineffective. At the time of its introduction, it was unquestionably prohibited by international agreement (to which however, the United States was not a signatory) for use against personnel. Undoubtedly too, the belligerents intended in general to abide by the agreement. But as the pursuit pilot, although intent on attacking a balloon, sometimes encountered hostile aircraft, and in the circumstances had neither time nor inclination to change ammunition, incendiary ammunition gradually came into use by both sides. It proved too, to be quite effective for use against the gasoline tanks of the airplane, which was another inducement to its retention. The legality of its use was formally recognized in the Hague conference of 1923.

In like case with the incendiary bullet as to its legality, is the explosive bullet. However, it has not been generally adopted, and seems unlikely to come into more widespread use.

The armor piercing bullet also was developed in the World War. It was designed for the destruction of some vital part of the engine of the hostile airplane, as well as for piercing the light armor which was sometimes encountered.

Two other classes of ammunition, which partake of the natures of those described above, are sufficiently explained by

their names: armor piercing tracer and armor piercing incendiary bullets.

Fundamentals of airplane gunnery. Although the airplane machine gun differs very little from its counterpart in use by ground troops, in so far as the factors which determine its ballistic qualities are concerned, nevertheless the problems of air gunnery differ markedly from those normally encountered in musketry. For the rifleman, a correct estimation of windage is essential to accuracy; in air combat, since both gun and target are in the same air stream, and receive the same acceleration from the wind, windage does not enter into the calculation. The other essential calculation for the rifleman is that of range. In theory, range must enter into airplane gunnery also. However, such is the inherent inaccuracy of fire from one airplane on another, due to the tremendous speeds involved, that long range firing is regarded as a mere waste of ammunition, and is accordingly dismissed from consideration. The value of this rule is enhanced by considerations of psychic nature: for, while shock action has no place in normal air combat, nevertheless the inculcation of a desire to close with the enemy has some of the same moral value attached to it by the infantry. For these reasons, in air combat, 100 yards is considered effective range, and 200 yards extreme range, while the airman is urged to withhold his fire until the enemy is within 50 yards. Consequently, in air gunnery, all ranges are point-blank, and the elevation of the piece is neglected. For all practical purposes therefore, the trajectory of the bullet in air gunnery may be regarded as rectilinear rather than parabolic.

The most difficult problem in air gunnery is due to the rapidity of movement of both gun and target. This sometimes results in a correspondingly rapid change of deflection in the target. It is to allow for this factor that special sights have been designed for the airplane gun.

To consider first the simpler case of the fixed-mount gun, the only deflection which must be taken into account is that due to the motion of the target, since the acceleration due to the motion of the airplane on which the gun is mounted, is in the direction in which the gun is aimed. That the deflection due to the motion of the target may make a decided difference

in gunnery, will appear from a simple calculation. Let us assume that the gunner is desirous of firing with the forward guns on a pursuit airplane, whose path is right angles to that of the gunner's airplane. If he should aim at the pilot in the hostile airplane, at a range of 150 yards, and make no allowance for deflection due to the latter's motion, the bullet would pass harmlessly some twenty feet in rear of the tail surfaces of the enemy. It is obvious from this example alone that deflection must be given great consideration. But since an exact solution of the problem demands that both the speed of the target and its angle of approach with reference to the line of flight of the firing airplane be known, it is apparent that a high degree of accuracy in estimating the deflection is thoroughly impracticable in the limited time available. Some assistance may be given the gunner, however.

One type of sight for this purpose consists of a back sight, which is merely a bead, and a front sight of two concentric circles. Obviously, with fixed circles of a given diameter, the circle is an accurate measure of deflection only for one combination of speed and angle of approach. But since the speed of the target can generally be foretold with some degree of accuracy, and its angle of approach estimated from the appearance, the sight is often useful as a guide. Slightly more accurate marksmanship is possible with an optical sight, essentially the same in principle, but not dependent on the eye of the gunner remaining in one place. It has, however, the defect of clouding up at times, and is then useless. The value of this general type of sight has often been called in question. Many pursuit pilots consider it futile to attempt to fire, where any estimation of deflection, not readily made with the simple bar sight, is called for.

With the flexible-mount gun, still another problem in deflection is presented. Not only must the motion of the target be allowed for, but it is necessary to compensate also for the motion of the gunner's airplane, since firing is always at an angle to the axis of flight. This is accomplished by a wind-vane sight, the general principle of which is shown in Figure 6. It is apparent that the actual velocity of the bullet, which we will call V , is the resultant of its velocity due to the action of the explosive, V' , and that due to the motion of the airplane itself,

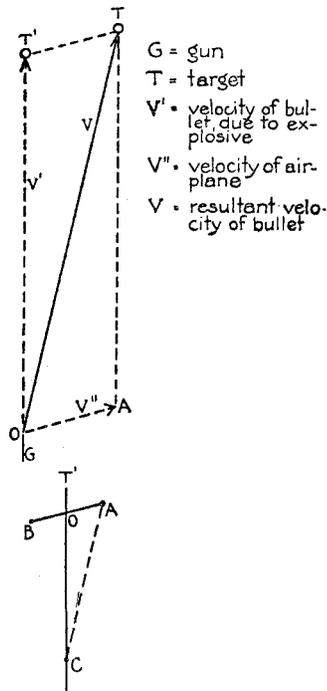


Figure 6. Principle of the Wind-Vane Sight

V'' . In order therefore to hit the target, T , which is assumed as fixed, it is necessary to aim at T' . It is apparent that the angle $T'OT$, through which the gun must be deflected, is known when the speed of the airplane and that of the bullet are known, together with the angle $T'OA$. The first two factors may be considered for all practical purposes as constants, and are determinable by suitable tests of gun and airplane. The angle $T'OA$ is automatically set off by the sight, which consists of an arm, AB , rotating about a pivot, O . On one end of the arm is a wind vane, B , which keeps the arm parallel to the axis of the airplane's flight, and so makes the two angles $T'OA$ the same. If now the distances from the pivot, O , to the bead sight, A , and from the pivot to the rear sight, C , are adjusted so that

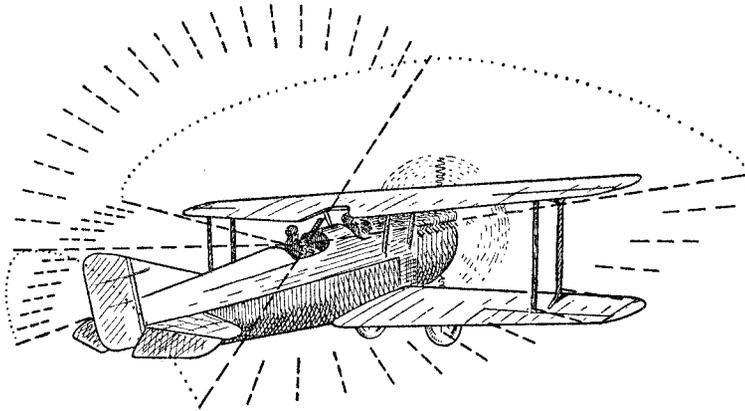


Figure 7. Dead Spaces of the Two-Seater

they are proportional to V'' and V' respectively, the angle OCA will be the desired angle of deflection.

Dead spaces of the airplane. By dead space is meant the space into which the gunner cannot fire, due to the method of mounting the gun, or into which he can fire only at the imminent risk of destroying his own machine. From this definition, it is apparent that to the single-seater, equipped only with fixed-mount guns, all space about it is "dead," except that in prolongation of the immediate axis of flight. In the case of the two-seater, which has rear flexible-mount guns in addition, there is less dead space. Nevertheless, as shown in Figure 7, the rear guns have their fire blanketed in many directions by the structure of the airplane itself.

Vulnerability of the airplane. On first inspection the airplane seems so fragile a structure that one may be pardoned for believing that it can withstand very little punishment. In fact, however, it is not nearly so vulnerable to hostile fire as its appearance indicates. It is practically impossible to bring the airman to earth by hits on the greater portion of the superficial area of the machine. In the World War it was the custom among Allied airmen to paste small patches, marked with the Iron Cross, over holes that had been made by German bullets or shrapnel. It was not at all uncommon to find in many a

front line squadron airplanes which had safely returned home and were in full commission, with forty or fifty such patches. There are records of airplanes which received many more than this number of "wounds" in a single fight, and yet continued their missions to a successful conclusion.

In general, a hit on the airplane has no effect, for the vulnerable portions of the machine constitute only a small proportion of the whole. In fact, the airplane is most often brought down by the prior destruction of its directing personnel. Obviously, if the pilot of a single-seater be put out of action, the airplane itself is doomed. However, many a badly wounded airman has succeeded in making his way to the home airdrome. And where the airplane is provided with means of dual control, the reserve pilot also must be killed or seriously wounded, to cause the destruction of the airplane. In the past, the gasoline tank has often proved to be the source of the destruction of the machine. With the increased use of incendiary bullets, which marked the last two years of the World War, the number of airplanes shot down in flames grew ever larger. But recent inventions of puncture proof tanks promise to neutralize this danger to a large extent. Aside from these two vulnerable features, there are so few others whose destruction would involve also that of the airplane, and these occupy so little space, that only a rare chance shot could accomplish this end.

The various considerations which govern individual combat have now been discussed. Two typical cases of the air duel will now be examined, to illustrate the tactical methods which have been employed in the past, and seem equally applicable to the future.

Combat between two single-seaters. When he joins combat with a hostile airplane, two obvious purposes fill the mind of the pursuit pilot: to secure a position from which he may deliver fire on his opponent with the greatest possible accuracy, and at the same time to avoid, in so far as is consistent with the fulfillment of the first mission, any return fire. From the previous discussion, it is evident that he occupies a position of complete safety so long as he remains outside of the forward prolongation of the axis of his opponent's flight. He may thus accomplish his secondary purpose in thousands of ways. But in order to accom-

plish his main undertaking, the destruction of the enemy, he must secure, as nearly as possible, that position which offers the greatest advantages from point of gunnery.

First of all, it is desirable that changes in deflection be as small as possible; this dictates that the axes of flight of the two airplanes should be in prolongation of each other. Then too, there must be time enough to aim and fire with some degree of deliberation; obviously this condition is best satisfied when the relative speed of the two airplanes is reduced to the minimum. These two conditions are consistent also with considerations of security, and indicate that the ideal position is that in rear of an opponent, flying in the same direction. However, care must be taken not to get into the "back-wash" of the opponent. A further advantage of this position approximately in rear of the enemy, lies in the fact that the truly vulnerable features of the opposing airplane are thus exposed to direct fire, for all of them lie in this same axis. The necessity of short range firing has already been dwelt upon. If the attacker should be able to attain this position with reference to his adversary, and hold it long enough to deliver a good burst of fire, his success is assured. In fact, so well recognized are the merits of this ideal position, that the expression to "be on the tail" of an opponent, has passed into the current language of the airman as synonymous with holding a decisive advantage.

Needless to say, in the duel of airplanes, the position "on the tail" is rarely secured with ease. If the enemy be both vigilant and skillful, it is indeed so difficult of attainment that surprise has always been considered a most desirable feature by all air fighters, and has been judged by some to be an absolute essential. The frequency with which surprise may be secured in the air, and the use made of this fact by the "Spad" school of thought, has been discussed in previous chapter. This method of attack seems to have been first brought to high development by the Germans, under the able leadership of Boelcke and Immelman.

The habitual procedure was to secure the advantage of altitude over the expected opponent, and to await the opportunity for surprise. When the intended victim was seen to be below, and appeared to be unaware of his danger, the Fokker—for such the

attacking German airplane generally was—dived like a hawk on its prey. When but a short distance away, it poured in a rapid burst of fire on the surprised opponent. In case this should prove ineffective, the attacker continued on in the dive, secure in his speed from counter-attack, and either escaped altogether, or else climbed up again for a renewal of the fight. In the hands of these two German airmen, and of their even more famous successor, Richtofen,¹ these tactics proved formidable, and difficult to meet. The essential element in it was surprise. It may seem therefore that the great stress was laid on altitude by these fighters, was somewhat unnecessary. This was indeed carried to such extremes that Richtofen is said to have boasted that whatever came beneath him was doomed. But it must be recalled that superior altitude is in essence, potential speed. Like the weather gauge of the old-time naval battle, it gives its possessor the freedom of choice of accepting or declining battle. With it, one may wait until the enemy is at a disadvantage, and attack with the utmost celerity. Complete surprise is thus often obtained.

If however, the attacker fails to secure surprise, his next recourse, if he is minded to continue the fight, is to endeavour to get on the tail of the opponent by maneuver. This at once necessitates consideration of the probable movements of the enemy. The latter, when apprised of the hostile presence above and in his rear, will first endeavor to escape from this dangerous predicament, and then perhaps to out-maneuver the attacker and secure the advantageous position for himself, thus reversing the positions. Should his sole thought be escape, he may simply dive away. This however, offers little hope of success, unless he has markedly superior speed, or has ample warning of the impending attack. For, so long as rectilinear flight is maintained, a simple movement on the part of the attacker restored the original advantage, and permits accurate fire to be resumed. Much the same remarks apply to any attempt to escape by climbing on a straight-away course. In general therefore, the enemy seeks to escape by resorting to some form of curvilinear flight.

Curvilinear flight. It is evident from the definition of the word, that in any form of curvilinear flight, the airplane is con-

¹A brief account of Richtofen's exploits is given in "Airmen and Aircraft," a volume of the Ronald Aeronautic Library.

stantly changing direction. Necessarily therefore it becomes a more difficult target, as deflection also is constantly changing. There are none of the ideal conditions which occur when the attacking airplane and the target are in the same straight line.

The simplest form of curvilinear flight consists in the pilot "banking" his airplane up at an angle inversely proportional to the radius of the turn he wishes to make, and thus maintaining a circular course in the same horizontal plane. Figure 8 shows the projection on a horizontal plane of two pursuit airplanes, banked up almost to the vertical in a very sharp turn. In this position, since the guns of both airplanes are aimed tangent to the circle, neither can fire effectively on the other. In general, this is the condition that exists while two airplanes are circling each other in the maneuver for position. Each contestant narrowly watches the movements of the other, with a view of taking advantage of the first favorable opportunity for straightening out on the tail of his opponent. Thus if the airplane at A should succeed in assuming some such position as

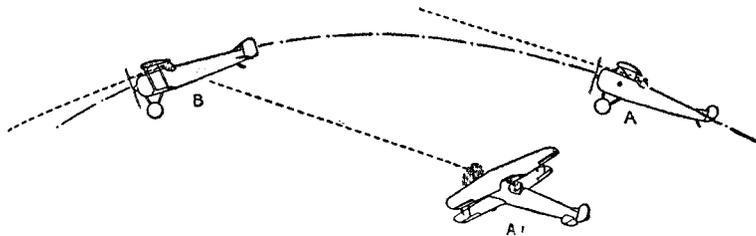


Figure 8. Curvilinear Flight

that of A', fire can be directed momentarily on B. But if B continues in curvilinear flight, he very quickly passes out of the line of sight.

Even though this is the simplest form of curvilinear flight, it is apparent that it permits of an infinite number of different maneuvers by merely changing the radius of the turn. This may even be carried to the extent of reversing the position of the two contestants, as may be seen by examining Figure 9. The two air-

planes are shown at *A* and *B*, as before, except that they are less steeply banked, and are flying on the circumference of the circle, *C'*. It is apparent that in this position, the advantage lies with *A*. If *B*, however, should widen his turn, then abruptly close it by flying on the minimum circle possible, which is assumed to be the circle, *C*, he would arrive at the point *B'*. If *A*, meanwhile, should fail to perceive and meet this maneuver in time, and should continue on the same course, he would be at the position *A'*. The advantage formerly held by *A* would now belong to *B*. Of course, in practice, a maneuver of the simplicity shown in the diagram, would rarely succeed. It is intended merely to illustrate the possibilities of the case.

The importance of altitude has already been mentioned. In actual combat, where curvilinear flight is resorted to as outlined above, the contestants do not remain at the same altitude at which the contest begins. On the contrary, each climbs

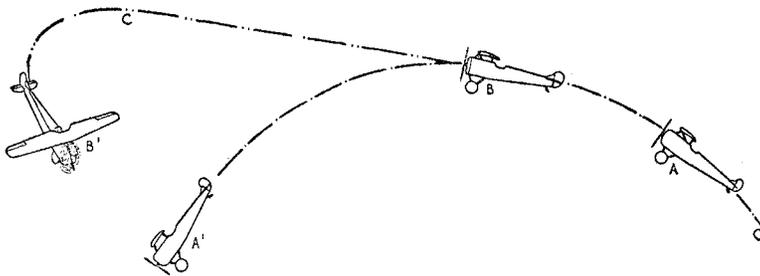


Figure 9. Changes in Curvilinear Flight

at every available chance. If one machine should be decidedly superior to the other in this respect, the former will soon gain the desired height, from which he may either withdraw or renew the fight on advantageous terms. If the two machines however, are equal in flying qualities, the contest necessarily depends in its issue on the relative skill of the two opponents.

In addition to the simpler forms of curvilinear flight described above, there are other acrobatic feats which may be resorted to at times by fighting men. They all, however, consist in some form of curvilinear flight, the objective of which is to get on the tail of the opponent or to prevent similar action on the part of the latter. A few of these maneuvers will be briefly described.

The loop. The loop consists in describing with the airplane a complete circle in a vertical plane. This was sometimes resorted to in the combats of the World War. Rickenbacker describes such a maneuver, in a contest he witnessed between two German pilots in the Albatross type of pursuit airplane, and an American airman in a Nieuport. The Nieuport had succeeded in getting on the tail of one Albatross, which dived rapidly away. The second Albatross had contrived in his turn to fasten himself "on the tail" of the Nieuport. While proceeding at a rapid speed, the leading Albatross suddenly looped, and succeeded in this way in putting himself on the tail of the Nieuport. The effort of the latter to follow the Albatross in its maneuver resulted in tearing the fabric of the Nieuport's wing. Fortunately, however, the intervention of Rickenbacker at this time succeeded in diverting the attention of the two Germans from the crippled American, who finally made his escape.

The loop, however, has not very generally been resorted to as a combat maneuver. It has the disadvantage of leaving the airplane in an undesirable position for further combat in the general case.

The tail-spin. The tail-spin consists of a downward spiral motion of the airplane about a vertical axis. The spin is very often the result of an unintentional "stalling" of the airplane, and occurs when the machine is out of control. It was frequently resorted to in the World War, partly no doubt as a ruse to attempt to convince the enemy that the machine was out of action, partly to offer a poor target in flying a curvilinear course. The diagram in Figure 10 shows the path of the airplane. The spin as a combat maneuver has certain disadvantages: the speed of the drop is comparatively slow, so that as a real effort to escape, it rarely proves successful; judging from many examples of the World War, it was very generally a failure as a ruse; furthermore the

expedient gives no chance for a counter-attack, and leaves the pilot in a vulnerable position when the recovery from the spin is made, in case his adversary has followed him down.

The Roll. The roll (Figure 11) is somewhat similar to the spin, except that the maneuver is executed about a horizontal

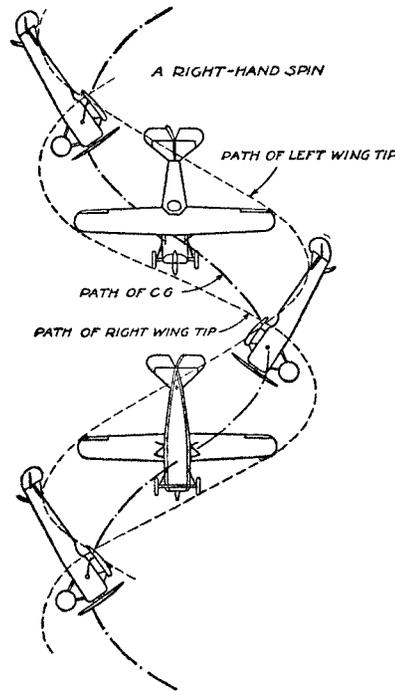


Figure 10. The Tail-Spin
(Reproduced by permission of the U. S. Army Air Corps)

axis. It necessitates high speed for its performance, and has the advantage of losing little or no altitude. It was not however in general use as a maneuver in the fighting of the World War, though sometimes employed.

The Immelman turn. The Immelman turn consists in making a half loop. From the upside down position at the top of the loop, the airplane then executes a half roll, so that, on completion of the maneuver, the course of the airplane has been

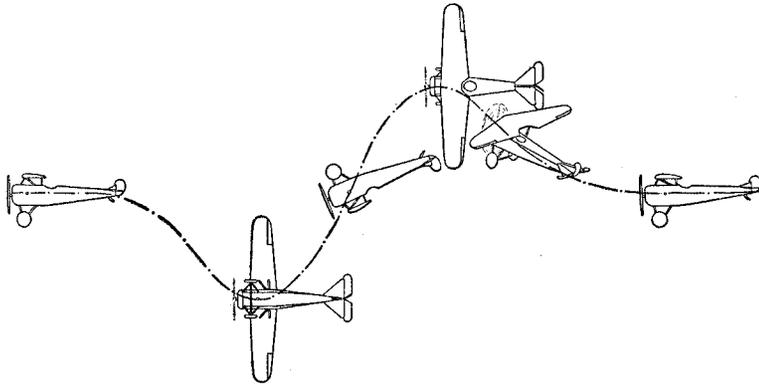


Figure 11. The Barrel Roll
(Reproduced by permission of the U. S. Army Air Corps)

changed 180 degrees, and altitude has been gained. The Immelman turn is shown in Figure 12. This maneuver received its name from its famous exponent, and was very widely used in the combats of the World War. It was resorted to when two opponents met in the air with courses approximately 180 degrees apart. At the end of the turn, if the time and space factors have been correctly estimated, the airplane was in an advantageous position to come in on the tail of the adversary.

Other maneuvers. It is evident from the above brief descriptions of the more common among them, that an infinite number of combinations of maneuvers is possible. Where surprise is lacking, the contest will usually be decided by the relative skill of the two contestants, provided they are equipped with machines of approximately the same characteristics. If the two should be of approximately equal skill, the outcome will often be indecisive. Bursts of fire may be delivered from time to time, but usually from too disadvantageous an angle to secure results. Eventually, one or the other withdraws, either fearing a shortage of fuel, or wearied with a contest in which he can hope to obtain no advantage. The greatest emphasis must therefore be laid on skill in flying and on the power of maneuver. Nevertheless we must not discount too heavily the value of daring. Perhaps the greatest exemplar of

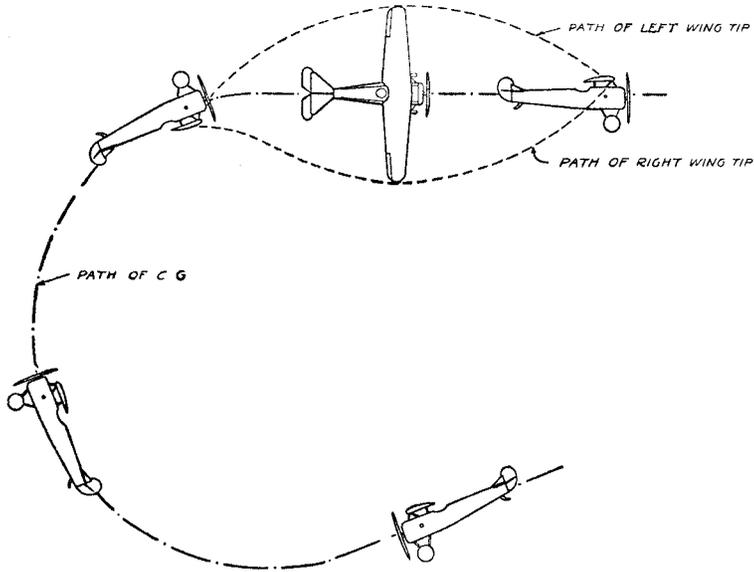


Figure 12. The Immelman Turn
(Reproduced by permission of the U. S. Army Air Corps)

this quality was Guynemer.² Impatient for combat and utterly reckless of all odds, he paid very little heed to the value of maneuver, but attacked with furor, whatever might be the relative advantages of numbers or of position. Audacity became a principle in itself, and the long list of German airmen who fell victims to his guns, bears eloquent witness of the effectiveness of his methods. But seldom did Guynemer return from a fight without his airplane being fairly riddled with bullet holes. His most ardent admirer could scarcely escape the belief that chance played an uncommonly large part in his success, and a wish that his splendid courage had been tempered with greater discretion, so that he might have lived to secure an even greater number of victories and to enjoy his well earned fame.

²A brief account of Guynemer's exploits appears in "Airmen and Aircraft," a volume of the Ronald Aeronautic Library.

From the discussions which have preceded, it must not be assumed that no firing ever takes place except from the position on the tail, nor that air combat is invariably opened from this position. It is merely the ideal position, which is always sought but often not attained. Sometimes, in the air duel, one of the contestants will fire from a much more disadvantageous position, and while the chances of success are thereby reduced, nevertheless many airplanes have been shot down in this manner. This occurs with particular frequency in the *mêlée*, which often results from the combat of formations of airplanes, and which in the World War was given the highly descriptive name of "dog fight." Bishop paints a vivid picture of the methods of gunnery necessary in such a combat. In the story of his career as an air fighter, he says: "Here a flash of the Hun machine, then a flash of silver as my squadron commander would whizz by. All the time I would be the same mix-up myself, every now and then finding a red machine in front of me and getting in a round or two of quick shots. There was no need to hesitate about firing when the right color flitted about your nose. Firing one moment, you would have to concentrate all your mind and muscle the next in doing a quick turn to avoid a collision."

Combat between the singler-seater and the two-seater. In the attack of a two-seater, surprise has essentially the same value as described before in the duel of the two single-seaters, and the factors which depend on gunnery also are practically identical. The dead spaces of the two-seater, however, as previously noted, are by no means so extensive. Accordingly in the attack of the two-seater, the single-seater attempts to keep underneath and directly in rear of it, and to avoid the position behind and above, which is one of safety in the case of the single-seater, but is under fire of the rear guns of the two-seater.

The two-seater, when attacked, does not attempt to extricate itself in exactly the same manner as would a single-seater, in like case. In executing the various maneuvers that were described above, the wings of the airplane are often subjected to dynamic loads which the pursuit airplane can bear with entire safety, but which would closely approach the breaking point of the two-seaters. Even where this is not the case the comparatively inferior speed and maneuverability of the two-seater deprive it of all

chance of counter-attacking with its front guns. However, in compensation, the two-seater requires a smaller range of maneuverability, in order to bring the defensive power of its rear guns to bear. A comparatively slight turn serves to swerve the tail of the machine out of the line of fire, and so enables the rear gunner to counter-attack. To meet this maneuver, the attacker turns also, but in an opposite sense, so that he may keep the protecting tail and fuselage of the two-seater interposed between himself and the rear guns.

While the two-seater is inferior in speed and maneuverability, nevertheless a contest such as that described is by no means a one-sided fight. The rear guns of the two-seater and the smaller degree of maneuverability required, do much to even the odds. In fact, the two-seater has such defensive power that it is rarely attacked by a lone pursuit airplane, until surprise has been secured. But while the two-seater is not at a hopeless disadvantage, once the fight has resolved itself into a maneuver for position, nevertheless the history of air combat shows that duels of this character have more often resulted in a victory for the single-seater. This may be attributed, in large measure, to the fact that the characteristics of the single-seater enable it to accept or decline combat at will. Hence it will often obtain surprise and always have the moral advantage which accrues to the attacker.

The duel between the single-seater and two-seater will probably diminish in importance with time. Rarely in the future will pursuit aviation operation individually. Among two-seaters also the formation will be the rule. Even in the *mêlée*, or in the exploitation of an initial success, the duel of this type probably will be seldom encountered.

Defensive formations. The word "formation" as employed in air tactics, denotes any number of airplanes which are led and maneuvered as a unit. The word has no administrative significance. Often, in fact, the formation is temporary in nature, although this is usually undesirable, since better teamwork is secured when the same men habitually fly and fight together.

The formation may be either offensive or defensive in character. The end sought is the same in either case, but the arrangement and particularly the conduct of the formation depend on

the character of the action, so that it is convenient to discuss the two classes separately. The distinction between them is based entirely on their habitual attitudes in strictly air warfare, from which it follows that the offensive formation is used solely by pursuit aviation. It will therefore be treated in the chapter devoted to that subject. The defensive formation, on the other hand, is never employed by pursuit aviation, but is the almost invariable rule in operations of attack and of bombardment aviation, and is used on occasion by observation aviation also.

The defensive formation is designed to utilize the power of numbers, both by increasing the volume of fire and by so arranging the airplanes in the formation that the strength of one may guard the weakness of the other. In the previous descriptions of the air duel, the existence of a dead space in rear of the tail of every airplane was noted. In proportion as the maneuverability of the machine decreases, the danger of an enemy's being able to remain in the dead space obviously increases. Thus the two-seater, as stated before, may often maneuver so as to keep a lone pursuit airplane from securing this advantageous position.

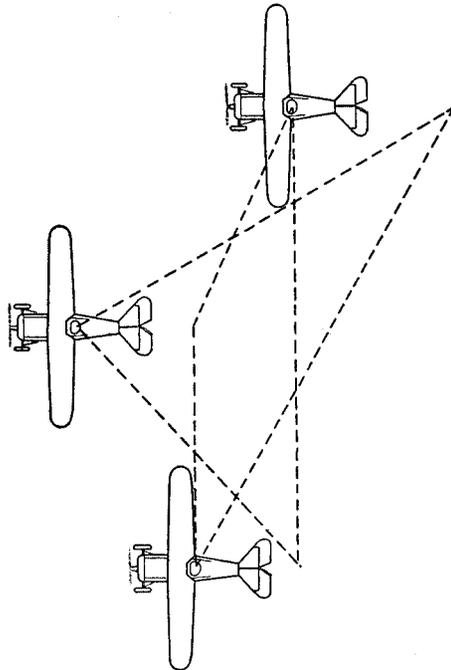


Figure 13. Plan of a Formation

With the heavier and less maneuverable bombardment airplane, however, this is far more difficult of accomplishment; the contest therefore generally results in the awkward bomber falling a prey to the handy pursuit airplane. Even the two-seater is not in much better case when attacked by several pursuit airplanes—which is the almost invariable rule in war; for while it is maneuvering to avoid one of the attackers, the remainder can profit by this action to place themselves in position for a fatal blow. Against such attacks, in fact, the two-seater has no adequate defense. To even the odds which lack of maneuverability places against the heavier airplane, the formation was designed. In it, the airplanes are so arranged that the dead spaces of one are covered by flanking fire from one or more neighbors, and no enemy can attack without running the gauntlet of this fire. The arrangement of the formation is shown in Figure 13. The airplanes are arranged in the form of an inverted “V”, with the leader at the apex. The airplanes are doubly echeloned, both in plan and in altitude, each airplane

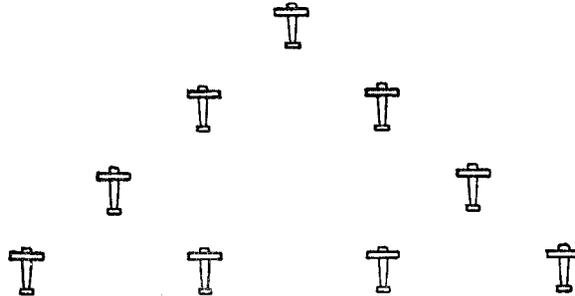


Figure 14. Plan of a Nine-Plane Formation

after the leader being outside of and above the preceding one. While the basic feature of the formation is good cross fire, it also permits ready observation of the leader and allows the others to conform to his movements, an obvious necessity where the leader exercises command in the air entirely by means of his example and a few visual signals.

It is evident that the formation is far less maneuverable than would be the individual airplane. However, the types of airplanes which adopt the defensive formation are already at such a disadvantage in this respect, when compared with the pursuit airplane, that the small additional sacrifice demanded is well worth the additional defensive power acquired through the formation. In fact the tactics of the defensive formation practically resigns all attempt at maneuver, except in avoiding anti-aircraft fire, which will be discussed in a later chapter. When attack in the air is imminent, the airplanes of the defensive formation close in until the space between them is just enough to permit safe flying, and then rely on the concentrated fire of the formation with its mutually supporting guns, for protection.

The single formation usually consists of from three to nine airplanes. A larger number than nine usually proves too difficult to handle. The inverted "V" is generally adopted when the number of airplanes does not exceed five. It is apparent that if the number becomes too large, the rearmost airplanes of the formation are placed beyond mutual supporting distance, so that additional numbers do not add materially to the fire power of the formation. Sometimes one or more airplanes are placed in the base of the "V," to overcome this defect. In Figure 14, there is shown a common arrangement of a nine-plane formation: in fact, it consists of three closely joined formations.

Chains of formations. The phrase "chain of formations" was coined during the World War to describe a command consisting of two or more formations engaged on a common mission. Since the defensive formation is comparatively unmaneuverable, it is apparent that numbers do not offer a proportionately greater degree of safety in combat between defensive formations and hostile pursuit aviation. Two large formations can rarely assist each other. Nevertheless mass attacks will be the rule in the employment of both bombardment and attack aviation; for their missions, which are determined by the demands of the ground situation, will often demand mass action; and while the different formations can do little to render each other aid, nevertheless effective sup-

port by friendly pursuit aviation can best be given, in the general case, when the defensive formations operate in mass.

Before leaving the subject of the defensive formation, it is well to note one physical disadvantage it has, which is quite apart from those inherent in the defensive, in general. This arises from the fact that the airplanes which are attacked, must rely entirely on their comrades for protection, and are practically excluded from making any efforts directly on their own behalf. Even when themselves subjected to intense fire, they must nevertheless concentrate their whole attention on the protection of their comrades.

CHAPTER IV

THE SERVICE OF OBSERVATION

Observation Aviation

History of observation aviation. In the beginning all aviation was observation. For many years no other use was contemplated for it. When, in the course of time, the components of the air force were evolved, it was, therefore, entirely natural that the whole doctrine of air warfare should be unduly influenced by the surroundings of its infancy, and should tend to revolve about the service of observation. This unfortunate tendency was accentuated by the fact that very few military men, outside of the air force itself, came into intimate contact with the work of the latter, while all of them were familiar with the duties performed by observation aviation. Man is prone to be guided by his personal experiences, and to think of the unknown in terms of the known. It is natural, on these accounts, that to many military men, the word aviation connotes observation aviation; the vast field of activity of the Air Force is often disregarded. This has many unfortunate results. For example, according to one school of thought, pursuit aviation existed solely for the purpose of preventing hostile observation and of facilitating our own. Such a view is, of course, entirely too narrow in its scope. Many other examples of a similar kind might be cited, and there can be little doubt that this attitude has done much to retard the progress of the air force. Notwithstanding this obstacle, the Air Force continued to grow, until by the end of the World War, it comprised about three-fourths of all the airplanes on the western front, and undoubtedly would have increased in relative importance with time.

But if observation aviation dwindled in relative numerical strength, it does not by any means follow that either its absolute strength or its importance diminished. Quite the con-

trary condition existed. But the principle of mass, of such vital importance where essentially combatant forces are concerned, is comparatively unimportant to a service, such as observation aviation is, in fact. For example, two pursuit airplanes may be considered to have four times the fighting power of one airplane; but two observation airplanes, operating over a given area, accomplish no more, in so far as essentially observation duties are concerned, than a single airplane.

The general effect of observation aviation on war. A writer who obtained an interview with von Kluck shortly after the war, represents the latter as somewhat heatedly damning the invention of the airplane, for having disclosed the movement of troops, and so rendered abortive some of the strokes of generalship, which might otherwise have resulted in brilliant victories. The complaint is not without cause; for notably on August 22, 1914, and again on September 4, 1914, it was primarily the British airmen whose activities revealed to their commander the movements of the German First Army, and enabled the British to take full advantage of the situation. But although the brilliant work of Henderson and his fellow aviators deserved the encomium bestowed on them by Lord French, it is nevertheless abundantly clear that these early efforts of observation aviation served only to illumine occasional spots, and not to dispel the general "fog of war." Both sides in the contest made many decisions which were obviously based on conjecture rather than on ascertained fact. However, even if the air service of the British Expeditionary Force had possessed in 1914, the perfection of technique they were to attain four years later, the lament of von Kluck over the passing of generalship would still have been pure hyperbole. In fact, the coming of the observation airplane has not so much created a new set of conditions, as it has completed a cycle, and restored a situation which formerly was the rule, and merely seemed to be passing.

In ancient and mediaeval times the general could usually see the field of battle, with friend and foe in their various stations, stretched out like a panorama before his gaze. To do this, he had only to secure the vantage point of some neighboring hill, or perhaps only the superior view obtained from

horseback. Indeed, from the viewpoint of the modern soldier, the thoroughness with which the general of old obtained his information of the enemy seems almost unbelievable. The intelligence officer of an army of today can scarcely repress a smile as he reads of how Marius, in his great battle with the Cimbri, actually agree with the barbarian tribesmen on a time and place for the meeting. Nor was this example at variance with the customs of the time, for it was the rule in the battles of ancient Rome that they took place only when both parties to the contest were willing, and both were thoroughly cognizant of time and place, and generally also fairly well acquainted with the strength of the enemy.

In spite of this seeming plethora of information, surprise was by no means precluded from the principles of war, and then, as now, it was the "thinking bayonet" which won. Even though the enemy's dispositions could be plainly seen, often it was easy to draw erroneous conclusion as to his intentions. Thus we can readily believe that when the consuls Paulus and Varro at Cannae saw Hannibal's center give way before the determined onset of the Romans, they were far from detecting the true significance of the movement. To them it was the beginning of a Carthaginian route; in fact it was a predetermined maneuver by the ingenious Hannibal, which resulted, as he had planned, in the double envelopment of the Romans and their complete overthrow. Many other examples of a similar kind might be taken from the annals of wars of the period anterior to the nineteenth century.

But with the birth of the tremendous industrial development, which has characterized the last century, the conditions of warfare underwent, in this respect, a radical change. Armies of a size formerly undreamed of can now be maintained in the field. Inevitably, therefore, lines of battle grew in length until they could no longer come within the vision of one man. Communications improved also, but the best of communications do not balance the fact that the general could no longer see with his own eyes. He was compelled to rely on hundreds of others, who could rarely see their own small part in its true relationship to the whole; and even where this was not true, it was too often impracticable to transmit information in

time for it to be of value. The "fog of war" increased to a density hitherto unknown, and surprise became relatively easy to secure. This condition reached its maximum of intensity at about the time of the Russo-Japanese war. When the war of 1914 burst on the world, it was already beginning to wane.

Influence of observation aviation on the world war.

That the airplane, in the early days of the World War, served to dispel the "fog of war" for limited periods, has already been stated. However, by the time air observation had reached such a stage that genuinely effective and reliable service could be furnished, fighting on the western front had passed into the period of stabilization, which was destined to last till 1918. On the daily routine of trench warfare, the observation airplane exercised an influence which is not generally appreciated, while at the same time it played an important part in maintaining that monotonous deadlock. In the daily fighting of those long years, which accomplished nothing decisive and yet took such an enormous toll of life, artillery played an extraordinarily important rôle.

It is no exaggerated claim, however, to state that artillery, under those circumstances, would have been far less effective but for the service rendered it by the airplane. The actual observation of fire was a notable assistance; it was resorted to all the more frequently, as time permitted full advantage to be taken of all terrain features, so that targets of interest were generally defiladed from observation by other agencies than the airplane. But even greater in importance was the information furnished by the airplane photograph. From it were compiled the data by means of which maps were corrected and brought up to date. Moreover, a careful study and interpretation of the photograph gave an enormous mass of information of the enemy, from it, there were often located his batteries, command posts, communications, dug-outs, ammunition dumps, strong points, and centers of resistance; it would even show the extent to which paths and roads were frequented; it gave, in short, a fairly complete picture of the daily routine of the enemy's life. Of course, the airplane photograph was not the only source of all this information. But without the accuracy of location, which it made possible, the daily fire of

artillery could never have been so effectively directed, and the nature of the trench warfare of the World War would have been vastly modified.

The maintenance of the deadlock in the west was largely the result of an equilibrium of power. For nearly four years neither side could secure enough superiority to push through a decisive action. This condition was, however, undoubtedly due in part to air observation, which made it so difficult to secure strategical surprise on the grand scale. Both sides endeavoured to guard against the eye in the air. Particularly in the German operations of the spring of 1918, measures were carried out with a thoroughness previously unheard of. All movements were made at night. So much emphasis was laid on air observation that troops were especially trained with a view of securing what was termed "airplane discipline."

In spite of all these measures, the vast operations which were being carried out did not escape the airman's observation. The best regulated movements sometimes went astray; repeatedly the dawn disclosed to the reconnoitering airplane the tail of a column that had been delayed in reaching the cover of its billets. But even more enlightening was the increase in the supply establishments in rear areas, which was the almost invariable forerunner of a great attack. In spite of the sheer impossibility of hiding all the tell-tale evidence of an impending attack, nevertheless both sides, at different times in 1918, secured more or less complete surprise. Either, one of the opponents would be lulled into a false security and allow air observation to be conducted in a perfunctory manner, or else the evidence, although gathered in sufficient abundance, would be given an erroneous interpretation. The number of such instances was small, however, compared with what they undoubtedly would have been but for the observation airplane. It will thus be seen to have played an important part in reducing the World War to an artless struggle of attrition, where only numbers and stamina seemed to count.

Some lessons of the World War. Important as are the services of the airplane in periods of stabilization, they are of even greater value when the trenches are left behind and decisions are sought in the open field. This may seem paradoxical

in view of the tendency of air observation to maintain stabilization. But if we examine into the sources of information of the World War, and above all into the means of communication, and compare the functioning of these in stabilized and in mobile warfare, the reason for the enhanced value of the airplane in open warfare, becomes plain. In the ordinary routine of trench warfare the sources of information were many and varied, and communication was rapid and reliable. If the air service be omitted temporarily from consideration, front line information of the enemy came largely from the reports of ground observers, from prisoners, and from captured documents. Time was rarely an important factor, so that the various echelons of command could thoroughly work these valuable mines of information, and utilize the product at their leisure. For example, if any information of our own troops were needed, a telephone call produced it almost immediately. When the telephone, the most useful of all means of communication, failed for any reason, the radio, the buzzer, or even a runner, proved acceptable substitutes. Such were the conditions of stabilization.

How different is the picture presented in the forward rush of an offensive. Time has now become all important and accordingly affects the value of various sources of information. For example, prisoners can be given only a hasty examination; they have a certain value as a means of identification of the hostile forces opposing, but such knowledge as they may have is almost invariably confined to their immediate surroundings and their own organization, and this information, by the time of their capture, has often ceased to be of any but historical interest. Observation posts can generally be established; but observers find it hard to see through the smoke and dust of battle, and even harder to transmit to the command posts in rear such information as they may acquire. Documents likewise, while often of great general value, rarely assist in the task immediately at hand.

Perhaps the information which is the most vital in the attack, both to the supporting artillery and to the commanders in rear, is the exact location of the friendly assault units. Often this information alone is enough for all immediate nec-

essary decisions. This is particularly the case where artillery support takes the form of the rolling barrage, so familiar in the operations of the World War; but even where successive concentrations are used, it is of great value. It would seem to the casual observer that this information would be quite easy to obtain; but the earlier attacks of the war made painfully evident the difficulty of securing this information from the troops themselves. This fact is easily explicable, when the conditions are understood. The ultimate source of such information is generally the company or platoon commander. His attention is almost always completely engrossed with the fight on hand, and he may be readily pardoned if the importance of reporting his exact location is often lost to view. Even, however, when this is not the case, it is not always as simple as it seems for troops to plot their location accurately on a map in the heat of battle. This is, in fact, one of those simple things which prove so tremendously difficult in war.

Nor is this the greatest obstacle, for it is overcome more often than the lack of rapid and reliable communication. Telephones require time for their installation, and the wires are cut with painful frequency by shell fire or moving vehicles. Radio gives equal information to the enemy, unless a code be used; and coding and decoding are slow processes. Runners too are slow, and all too frequently fail to reach their destination: the casualty rate among this class was appallingly high in the World War.

In view of these considerations, all of the combatants, after many disheartening failures, finally came to rely on the air observer for this important information. In so far as the fighting below him was concerned, the latter was placed in comparative security; with observation as his only task, he could concentrate his entire attention on it. Communication offered no difficulties, for the high speed of the airplane enabled him to cover the few miles necessary in time for his information to be of full value. While, for the obvious reasons, no source of information was ignored, the airplane finally came to be generally regarded as the most reliable means of obtaining timely information in battle.

Future warfare. It is necessary here to repeat the caution that the teachings of the World War cannot be accepted blindly as the unvarying guide for future action; for, although there is no such thing as "normal" warfare, nevertheless the World War maybe called in a figurative sense, highly abnormal. Notwithstanding this fact, we may draw from it more valuable lessons in regard to observation aviation, than in regard to any component of the air force. We may accordingly accept the teachings of the World War with fewer reservations. This results from several causes. Observation aviation has a longer history than the Air Force: it may be said to have reached adulthood, while the latter has scarcely grown to childhood. In consequence of this, observation aviation may be expected to undergo fewer radical changes with the passage of time. Then too, its duties, which are largely those of a service, demand an intimate liaison with the ground troops for whom it works, and have something of the stability of the latter. There are certain unvarying, almost routine labors observation aviation must perform, which seem unlikely to change, except in unimportant details. These conditions permit the student of observation aviation to apply the lessons of the World War, with a feeling of being on reasonably firm ground.

Qualifications of the observer. It is obvious that an untrained observer, ignorant alike of the tactics and of the technique of the troops whom he serves, would know neither what to look for, nor the significance of what he chanced to see. His report not only would be of little value, but might even prove a source of danger, if the justifiable negative inferences should be drawn. Training is, therefore, obviously essential. But the extent to which this should go is not so widely recognized. The area that is usually covered by the observer, is so extensive as to represent the sphere of responsibility of a general officer.

The observer, whose work is to be of great worth, must see, as it were, with the eyes of the general. It is evident therefore that the ideal observer not only should have the qualifications imposed by his flying duties, but should also possess those of the trained general staff officer.

Of course, in a major war, this ideal will never be even closely approached in the American army. Men with such qualifications will be far too few to permit the assignment of thirteen of them to each observation squadron. But the Air Corps, on whom will fall the burden of providing competent observers, must at least bend every effort towards training the older and more experienced pilots with this end in view, so long as existing policies hold. It seems likely however that the day will arrive when general staff officers, and even the general himself, will not be content to delegate this important duty of personal reconnaissance to a subordinate, but will insist on receiving first-hand impressions and information by personal airplane observation. A conspicuous example in the World War was the action of General Chaytor in the Sinai campaign.

There are of course many obstacles in the way of this practice becoming habitual. It is now generally agreed that the observer must also be a pilot: for the old system, under which the observer was unable to pilot the machine, obviously subjected him to a double hazard, for the serious wounding of the pilot meant the loss of the observer also. The general staff officer of the future would also under this assumption find it necessary to become a pilot, and to follow this training with special instruction in observation.

Position of the observer. When the American army entered the World War, it found in the observation service its two chief allies, a marked difference in technique. With the British, the pilot was also the observer, while the occupant of the rear cockpit of the machine acted merely as a look-out and machine gunner. With the French, on the other hand, the observer occupied the rear seat and had no part in piloting the airplane, although he was the commander of the machine. Each system has its advantages and disadvantages. In the French system, the observer is in the unfortunate position of serving two masters: if he concentrates his attention on the ground, he runs the risk of being surprised and shot down by hostile pursuit aviation; if, on the other hand, he keeps a vigilant watch for the approach of hostile airmen, he is all too apt to slight the performance of his main duty. Furthermore communication between the pilot and the observer is never per-

fect: under the most favorable circumstances, it is far easier for a man to put his machine in the exact position he desires, than it is to direct some one else of equal skill. A disadvantage of the British system lies in the fact that the pilot sometimes has his entire attention concentrated on flying the machine: this however, is rarely a serious defect, for after long experience, flying becomes nearly automatic, and the pilot nearly always has one hand free to work the camera or radio, or to write a brief message. And certainly, since the great danger in the air lies towards the rear, the pilot ordinarily can divert his attention from air matters, far more safely than can the observer.

Of course, in the World War, men were numerous and time lacking. Under the French system, pilot and observer, training simultaneously, could be made proficient in less time than could one man, receiving instruction in both subjects. The system accordingly made an important appeal on this ground. It was adopted by the American army, which was influenced to this decision by two other facts: the policy at that time was to detail observers from the other arms of the service, and training of the observer as a pilot was considered as unnecessary. Now that both of these policies have been reversed, it seems desirable that the other system of observation should be given at least an experimental trial.

Tactical objective of observation aviation. All branches of aviation with the exception of pursuit, have two distinctive rôles—one determined by the air situation, the other by the ground situation. The latter is of course the all-important duty of observation aviation, whose reason for existence lies in its ability to furnish desired information to the combatant arms for whom it works. During the World War, the observation units belonging to the various echelons of command, had definite geographical areas assigned to them, in which they were responsible for obtaining all classes of information. Thus the corps squadron would observe to a certain depth in the enemy's lines, where the army squadron would take up the responsibility. This had advantages in the situation peculiar to the World War, but there has been a tendency since to preserve these limitations in all kinds of situations, to many of

which they are wholly inapplicable. Thus, to state as a general rule that the divisional squadron observes to a depth of 5 miles in hostile territory, the corps squadron to a depth of 10 miles, and so on, is a wholly artificial rule. The only good guide in this matter is the area of responsibility of the commander of the unit to which the observation squadron belongs: the latter's zone of observation is exactly conterminous with the former area. Of course where various echelons of command are operating in the same theatre, it is desirable that the limits of responsibility of their respective observation units be well defined, so that there will be neither overlapping nor gaps. This is done for each special situation as it arises, with due regard to an equal distribution of work. The boundary lines of these zones of responsibility should never be artificial ones, but well marked terrain features, such as roads or rivers.

Classes of observation. During the World War there arose a tendency towards specialization, the corps squadrons diverging more and more from the army squadrons, both in their duties and in the manner of their performance. Whatever its merits at the time, there seems no good reason for preserving this distinction. Problems of supply and training obviously dictate that specialization be reduced to a minimum, nor does there seem, in this case to be any weighty tactical reasons to the contrary. There will, of course, be numerous differences in the duties habitually assigned to the various squadrons. Thus the liaison mission (which is described later) will usually be executed by the divisional squadrons; but occasions will arise when the army commander will call upon the army squadrons to perform this duty. The army squadrons will usually be called upon to penetrate more deeply into enemy territory than the divisional squadrons; but a detached division may desire a reconnaissance to a depth of 75 miles, and would unhesitatingly call upon its organic squadron for the duty. For these reasons it seems preferable that all observation squadrons, whether assigned to division, corps, army, or general headquarters, should be entirely alike in training, strength, and equipment; and all should be able to execute any of the missions that may fall to the lot of any squadron.

The air situation. Although the liaison between the observation squadron and the unit it serves must be of the most intimate character, and the demands of the latter form the basis of the duties of the former, nevertheless the work of the observation squadron, in its execution, is influenced to a far greater extent by the air situation than the ground situation. For example, whether the division attacks or defends, pursues or retreats, there is a certain sameness about the work of the observation squadron, unless indeed the situation reaches a character so unusual as to warrant the complete diversion of the squadron from observation duties. But there will be a marked difference in the execution of missions when there is no hostile pursuit aviation to be feared, and when, on the other hand, the enemy's pursuit units are strong, alert, and aggressive. Under the first named conditions, single airplanes can go and come at will, can fly at almost any altitude they desire, and can be guided entirely by the ground situation, unhindered by any fear of molestation.

It is quite another matter when hostile pursuit is active. Other means must then be adopted. Single airplanes may go out as before; but either they must carefully time their sorties so as to avoid the enemy, or else they must take advantage of the protection of friendly pursuit aviation—and this as will be seen in a subsequent chapter, cannot be given on every demand. Generally, in fact, the observation squadron will have to forego the execution of missions by single airplanes, and will have to provide the local security given by the formation. Obviously, when this becomes necessary, the number of missions which may be executed, is reduced to one-third or one-fifth of its former number.

Of course, it may be urged that a single airplane stands a better chance of avoiding discovery than would a formation, and that the latter, too, would be inevitably doomed should it fall in with a large force of hostile pursuit aviation—an argument in favor of continuing the employment of individual airplanes. This is no doubt often the case. But the small formation is not greatly more conspicuous in the air, and it can hold off small forces of attacking airplanes, where the individual would be destroyed. But of even greater importance is the fact

that the observer can concentrate his attention on the ground situation, when he is escorted by other protective airplanes, with the assurance that his comrades in rear of the formation will give ample warning of the approach of hostile aircraft.

Visibility. A question of paramount importance in observation is the distance to which the observer can see. This may be limited by a number of different factors. The first to suggest themselves to mind are the curvature of the earth's surface, and the presence of such intervening obstacles as hills or woods. But while these are the most frequent cause of obstruction of the view of the ground observer, they rarely exercise any great influence in air observation. In so far as the earth's curvature is concerned, a simple approximate formula expresses the relationship; the distance of the visible horizon from the observer in the airplane is equal in miles to one and one-fourth times the square root of the height of the observer in feet. Thus, at an altitude of 10,000 feet, the observer finds his view cut off by the earth's surface at a distance of 125 miles.

It is apparent from this example that this factor will rarely be a serious limitation on observation. Nor are the other obstacles mentioned of greater moment, since the altitude to which the airplane may go, and the velocity of the machine, enable it to transverse any barrier and quickly see the "other side of the hill." In fact, overhead cover is essential in the general case, to protect any spot from the eye of the air observer. However, clouds and fog, for the reasons which have already been discussed, may so limit the view of the observer as entirely to negative his efforts. Also smoke, dust, and partly invisible water vapor—from which the atmosphere is never entirely free—are always inimical to good observation. In regard to these factors, however, the air observer has a decided advantage over the man on the ground. The stratum of dust and smoke rarely extends more than a few hundred feet above the surface of the earth; accordingly, the visual ray to the air observer, being more nearly vertical, has to penetrate a smaller distance through this inhospitable medium than does the horizontal ray striking the eye of the man on the ground. For this reason, objects viewed from the air are usually seen

more clearly and distinctly, than when seen from an equal distance along the surface of the ground.

Effect of altitude on visibility. We are accustomed to measure horizontal distances in miles, and vertical distances in feet; which accounts perhaps for the erroneous belief that air observation is utterly useless once the airplane has ascended to an altitude of more than a few thousand feet. This seems incomparably farther from the objective than a mere half-mile measured along the surface of the earth. Of course, in actual fact, it is the distance alone which counts, whether its longer component be horizontal or vertical, except that the latter condition, for reasons stated in the preceding paragraph, is the more favorable to observation. Many figures have been given from time to time, showing the altitudes from which various objectives on the surface of the earth may be recognized. These however, are apt to be misleading; for too many factors other than altitude enter into the question, and really determine the answer. Thus a recent photograph, taken from 19,000 feet showed such details as automobiles on a street, quite clearly; one could rarely obtain similar results from a visual reconnaissance. In general, it may be accepted as a rule that the observer will descend to the altitude necessary in the actual conditions for good reconnaissance.

Effect of darkness on visibility. The influence of darkness on flying has already been discussed. Visibility at night, as in the daytime, depends on many factors other than the altitude of the observer. As a rough indication of the limitations placed on observation by darkness, the following facts are of interest, but it must be understood that they represent no invariable rule: on bright moonlight nights, movements can readily be detected from 3,000 feet on broad white roads, while even on roads with a darker surface, they can be seen from 1,500 feet; with a half moon, the vague outlines of objects can be detected on white roads from 1,500 feet; with a quarter moon however, it is necessary to descend to a few hundred feet, to secure the same results; almost as good results can be obtained on a clear starlight night.

These figures do not take into account the aid that may be expected from artificial sources. For example, in the parachute

flare the observer has a valuable help to vision: it consists of an inflammable magnesium compound, which is sustained in the air for a time by means of a parachute. It burns for about seven minutes, with an illumination of about half a million candlepower, which is sufficient to illuminate the surface of the earth brightly, during that time, over an area approximately half a mile in radius. Of course, neither this nor any other invention can take the place of sunlight and rob darkness of the cover it affords. But they are successful in increasing the effectiveness of observation aviation, and make it a factor to be reckoned with by night as well as by day.

Reconnaissance. Reconnaissance is defined as the examination of a given terrain by military personnel, while actually in the field, for the purpose of obtaining military information. It is usually divided into distance reconnaissance, on the results of which depend the decisions of the higher commanders, and close reconnaissance, which has a more limited tactical aim.

It has been the misfortune of the air service in the past, to suffer at times from the claims of its too enthusiastic advocates. This has occurred particularly in discussions of reconnaissance, in which it is sometimes alleged that the air service has altogether displaced cavalry, and has rendered that arm, on that account, of greatly lessened importance. It is quite true that the air service has taken over many features of distant reconnaissance, which were formerly functions of cavalry; it has not however relieved the latter of all duties of this nature. The best results will only be obtained when these two agencies supplement the activities of each other; and it might be pointed out, in passing, that although the air service has diminished the importance of cavalry in one respect, it has added greatly to its value in other ways so that the necessity for this arm in modern war has by no means been lessened.

The work of the air service does not relieve any other arm of the necessity for conducting its own reconnaissance. The broad outlines of the picture may be given by the air observer, but many of the details can be filled in only as a result of action by the other arms. There are limitations to air reconnaissance, which either do not apply at all to ground troops,

or else apply in lesser degree. Of these the most important is weather. Under certain conditions, which were previously described, air observation may be altogether forbidden; in such a case reconnaissance necessarily devolves in its entirety on ground troops. On the other hand, there are certain widespread misconceptions of the true limitations of aircraft.

It is altogether erroneous to state that negative information by observation aviation is of no value. This is true in certain circumstances, but is by no means a general rule. For example, an enemy organization may be quartered in a town, and have such a vigilant look-out and such excellent "airplane discipline" that the reconnoitering airman fails to see a single hostile soldier, and reports on his return that the town is unoccupied. A reconnaissance by ground troops would practically never be misled this way. It might be mentioned however, in this connection, that none of the combatants in the World War quite attained to this perfection of "airplane discipline," and that in fact, air reconnaissance almost invariably determined with accuracy which combatant held a given town. It is apparent too, that in open terrain, wherever objects may not be concealed from overhead cover, negative information by the airman may be relied on as implicitly as that derived from the reconnaissance of ground troops. The rule then can only be accepted which states that, under some circumstances, the air service cannot furnish reliable negative information.

Another defect which has been alleged to exist is that air observation is fleeting and discontinuous. This is true in small part only. The airplane travels at a high rate of speed, but it also travels at a high altitude, for the more general purposes of observation, so that its angular velocity with respect to any object on the surface of the earth is not very great. Objects do not apparently dash by, like telegraph poles by the window of an express train. On the contrary, to an observer at high altitude, the surface of the earth seems to stand still; sense of motion is almost lost. A given spot then remains within view for many minutes, even when the airplane is flying a straight course; and should the observer desire to view it for a longer period, he has only to circle, when he can remain in surveillance to the limit of his fuel capacity. It is apparent then, that

airplane observation is not as a rule continuous; but it can be made so whenever the importance of the objective warrants it: it is necessary for this accomplishment only to relieve the first airplane with another, before the former reaches the limit of its fuel capacity.

There is however, one important class of information that air reconnaissance cannot obtain, namely, information leading to identification. Often the real value of this information is not appreciated by troops, whose attitude frequently is that it makes no particular difference to them what regiments or divisions they are facing. But when this information is accurately obtained for the whole theatre of operations, it enables the commander to reconstruct the entire order of battle of the enemy. The usual sources of identification are prisoners, captured documents, or information obtained from inhabitants. Air reconnaissance is obviously unable, as a rule, to secure these.

In summation therefore, it may be stated that although the chief burden of distant reconnaissance falls on the air service, it does not bear it all, but shares it with cavalry; in close reconnaissance, the air service is also of the highest value, but it supplements rather than replaces the work of all the other arms.

Method of reconnaissance. Reconnaissance may be conducted by either visual or photographic means. The airplane photograph furnishes an extremely accurate record in great detail, which is permanent and may be studied carefully at leisure. On this account, it is always preferable to the reports of visual reconnaissance, where the time or light factor does not render its use impracticable. During the World War, it was generally considered that photographic reconnaissance was impracticable during the early morning or late afternoon hours, even in summer time. Since that time, there has been a constant improvement in technical means and methods, so that this prohibition no longer holds with its former force. Recently in fact, photographic reconnaissance on a dark night has resulted in obtaining a wealth of information of military value. Moreover the time factor no longer operates to reduce the value of the photograph to the extent that it formerly did. In the World War, it was usually a matter of hours for the observer to expose the film, return to the airdrome, see to its

development and printing, and place the completed print in the hands of the commander of his staff for study. Recent developments have greatly shortened this time, so that now the observer may commence development immediately on exposure, and can drop the completed photograph, in suitable condition for study, within a few minutes.

The effect of all these improvements will undoubtedly be to render the photographic reconnaissance the rule. It will of course be supplemented by visual reconnaissance in all cases, but the reports based on the latter will always be checked by the photograph, where time permits. The use of the photograph is the invariable rule in the reconnaissance of stationary objectives, such as defensive zones, supply establishments, or the fixtures of lines of communication. But in some cases, visual reconnaissance alone must form the basis of decisions. This will occur the more frequently as mobile warfare becomes the rule. A message by radio will invariably be the more rapid means of transmitting information, and accordingly will be resorted to when time precludes the photograph.

For example, a column of hostile reserves approaching the battlefield may be photographed, and a more accurate estimate formed by this means than by visual methods. But here time is of the essence of the thing. Accordingly the observer sends in at once by radio the location, time, strength, and direction of march of the column, and on his return, may drop either a confirmatory message or a photograph, to insure the receipt of the information in case the radio has failed to function.

Battle reconnaissance. Distance and close reconnaissance tend to merge into each other as the enemy is approached. The spheres of responsibility of the various echelons of command are also changing, and with them, of necessity, the area for which a given observation unit is responsible. As battle becomes imminent, the tactical measures taken by the enemy become of vital importance. There is a marked increase of activity on the part of the divisional observation service. Its work has generally been confined, prior to this time to a certain amount of close reconnaissance, and to distant reconnaissance. Generally however as battle approaches, these duties devolve rather on the corps or some higher echelon of command, while the divisional air serv-

ice devoted itself more specifically to the immediate battlefield. While its duties vary with every situation, there are certain missions which it almost invariably has to perform upon contact. To embrace all these characteristic missions of combat, the term *battle reconnaissance* has been coined. It includes the liaison mission, the contact mission, and such artillery missions as may become necessary.

The liaison mission. The difficulties which were encountered in the World War in locating the advanced waves of friendly troops, have already been described. It was noted also that the airplane finally came to be relied on for the performance of this duty. From this evolved the liaison mission. While executing the mission, the observer is charged with keeping the division commander informed of the position of all his troops, and of their needs.

The airplane is always marked with the distinctive divisional insignia, and habitually flies low enough to permit the troops to recognize it as their own. In the World War, where there was no divisional air service, this mission was habitually executed by the corps; it was the custom to attach one or more streamers to the wings of the airplane, and to fire Very pistol cartridges with a definite number of "stars" in the burst, as a means of identification. This device also may be resorted to in the future where special circumstances render it necessary.

In locating the front line, the method employed in the World War is still adhered to at times. This consists in requiring the front line troops that are most advanced, to display their individual panels (or in some cases, Bengal flares), either at a pre-arranged time or place, or else on call from the observer. This is usually an understood pyrotechnic signal. The observer then plots on a map the line as staked out by the panels or flares, and drops this at the command post of the division. There are objectionable features about this method. The troops themselves are nearly always loath to display their panels. The soldier in battle always feels glaringly conspicuous; perhaps this feeling is unwarranted, but it is none the less real on that account; and accordingly he objects to any further apparent exposure. Often too, in the heat of combat, he becomes oblivious to all but his own immediate desires and needs, and may utterly fail to see the

signal. It is easy also for men to become confused, and to believe that they themselves are the leading elements, when in fact, there are other friendly troops still farther to the front. For these reasons, experience shows, troops will display their panels only when they have been very well trained, and thoroughly understand the importance of it to themselves. Even then, too frequent calls from the observer will almost certainly go unanswered. It is therefore incumbent on the observer to use this method only as a last resort; ordinarily he must fly low enough to be able to distinguish friend from foe by their uniforms. It is usually desirable that reports of the locations of assaulting units be received at frequent intervals. These may be sent by radio with little danger, provided an arbitrary prearranged system of coordinates be used, and changed often enough to avoid its solution by the enemy.

While the most important function of the liaison mission is the location of the advanced elements, it must also report the positions of the friendly supports and reserves. Often these will be in close communication with headquarters, and hence the work of the air observer will be superfluous. But on many occasions, this information will be badly needed and not easily obtained; it should therefore be included in the observer's report as a matter of routine.

It is not sufficient that the observer report merely the location of friendly units: he must also transmit to the proper place their needs, as expressed by means of panels, flares, or rockets.

The contact mission. The contact mission is executed in much the same way as the liaison mission, except that it is concerned with the advanced elements, supports, and local reserves of the enemy. Occasionally, the two missions may be combined, and executed by the same observer.

The zone of responsibility of the contact observer is ordinarily limited in depth to the location of the hostile divisional reserves. If other areas or movements are of primary interest to the division commander, they are usually covered by sending out special missions. Except where the division is acting in a detached capacity, these missions of close and of distance reconnaissance, usually fall to the air service of larger units: they are

generally matters which enter into the decision of corps or army commanders, rather than into that of a division commander.

It is primarily the duty of the contact observer to report to his division commander locations of the enemy within his zone of responsibility, and all hostile activity of importance. But his duties do not end with this, for he must also report to the commander most nearly concerned, all dangers that threaten his men. Often the friendly infantry will have no signal to express a sudden need, or may itself be unconscious of an approaching danger, which is evident to the airman. In such cases, it is incumbent on the latter to take immediate steps to acquaint the persons most nearly concerned with the situation. From his uniquely advantageous position, the airman may often see the birth of matters of grave importance. Much depends on his judgment, and he should accordingly be competent to understand thoroughly the tactical import of all he sees.

Artillery missions. Cooperation between the air service and the artillery in the World War was of an intimate character, and this class of missions reached in consequence a high stage of development. This is, of course, entirely desirable, but it had one disadvantage. In the long routine of siege warfare, where artillery took a predominant rôle, the numbers of artillery missions executed by the air service far exceeded all other missions combined. This eventually led to a partial obscuring of the importance of the other tactical missions, and even to a belief on the part of many officers that skill in the observation and adjustment of artillery fire, when supplemented by some knowledge of photography, were the sole requisites of the good observer. Such, of course, is by no means the case.

The class of duties performed by the air service for the artillery may be grouped into two main divisions. These consist in finding suitable targets for artillery fire, and in assisting the artillery to place accurate fire on the designated objectives.

The importance of the airplane photograph in the World War, in enabling profitable targets to be selected for the artillery, has already been dwelt upon. In spite of the recent advances in the science of photography, it seems unlikely that the airplane photograph will ever again assume quite the same relative importance it held in that contest. In mobile warfare, which is usually

conceived to be the type held in store by the future, time will more frequently preclude the use of the photograph in locating targets, for often each minute counts. But if the air photograph wanes in importance, it nevertheless appears that the work of observation aviation as a whole will grow in value. The time factor in mobile warfare has the general effect of rendering all concealment more difficult, and therefore of enabling all means of observation to function with a greater degree of ease and certainty. But to no other agency of observation, does this bring the same increase in effectiveness as to the airplane. For, when time is lacking, only that concealment can be utilized, which is offered by nature unadorned; and while nature is fairly lavish in providing hills and woods to intercept horizontal vision, she affords remarkably little overhead cover, which must, as a rule, be constructed by man, with much expenditure of time and labor. For example, a hostile battery, coming very rapidly into action, can often find positions which afford flash defilade from the view of ground observers, and in many cases even from balloon observation. It would be rare terrain however, which could give protection from the view of the airplane observer. We may expect therefore to see an increase of the employment of observation aviation in locating suitable targets for artillery fire. It will in fact, become the customary procedure to assign certain battalions of artillery, to answer calls from the airplane for fire on fleeting targets.

The second important class of artillery missions is the adjustment of artillery fire. The airplane, for reasons which will be given later is used for this purpose only when the target cannot be observed from either balloon or ground observation posts. The technique of airplane observation varies in the different services, but the general principle involved will appear from the following description. When the target has been selected, and both the artillery unit and the observer have indicated to each other that they are ready, the artillery fires. The air observer then signals to the artillery by radio the distance and direction of the burst from the target. In doing this, the "clock-face system" has proved satisfactory. The target is regarded as the center of a clock face, with XII o'clock pointing north. Letters designate concentric circles at different

distances from the target, as shown in Figure 15. For example, if the airplane signals D₃, it indicates to the artillery that the shot fell 300 yards east of the target. In this way the airplane can continue its signals until the fire of the artillery is on the target, the latter making the necessary corrections after each report. Another system commonly used, consists in referring the burst to an imaginary line connecting the target and the firing artillery. In this system the deflection and range deviations from the imaginary line are reported by the observer.

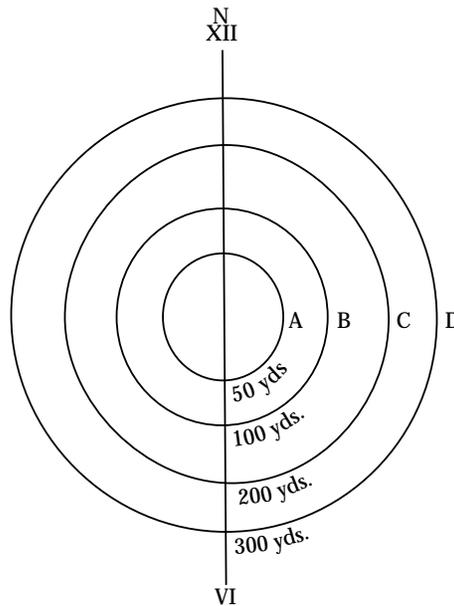


Figure 15. Clock-Face System

Miscellaneous missions. It is apparent that many missions other than the more common ones which have been described, will at times fall to the air service. Thus the carrying of messages, or the transportation of officers on errands of importance, will sometimes be necessary. In the World War, a type of mission was often required, known as the *command* mission. At times, a number of airplanes would be removed temporarily from their squadron commander's jurisdiction and held in reserve, subject to the orders of the corps or army commander only, for the purpose of verifying or supplementing information already gathered

in the usual way. This procedure is ordinarily inadvisable. There are nearly always airplanes on the airdrome available in case of emergency, on account of the reliefs which must be held for many missions. The air service commander, like all other commanders, will have his reserve for just such contingencies. For these reasons, the designation of special airplanes for *command* purposes usually results in interfering with the proper operation of the squadron, and in trespassing on the province of a subordinate, with no corresponding benefit.

Exceptional missions. Long after specialization had become an established order in aviation, there remained many officers in other combatant arms, the pressure of whose wartime duties had not enabled them to keep abreast of the rapid progress in aeronautics. To many of these, an airplane was an airplane, and any one of them might properly be called upon to perform what any other had been known to do. Every commander of an observation unit in the World War was called upon at some time or other, by indignant officers of other arms, to drive away hostile aviators. Explanations usually served to leave the complainant silent but not always satisfied. There is, of course, a certain amount of reason in this attitude. We speak quite properly of a bombing airplane as being slow and unmaneuverable. Such descriptions are however obviously relative in their application: the bombing airplane is much faster than the express train, however slow it may be in combat with a pursuit airplane. In fact, every airplane possesses in some degree the qualities which another may have superlatively; it may accordingly be called upon to perform any duty which normally belongs to another type, when a grave emergency arises. But it may generally be anticipated that the result will vary between slight success and utter failure.

The observation airplane is essentially unsuited to perform the functions of pursuit aviation. It is true that several examples may be cited from the World War where observation pilots destroyed enemy aircraft with their front guns, in true pursuit style. But these must be regarded as exceptional. To assign observation aviation to pursuit missions is badly to misuse the tool, and can only be justified by the demands of a highly abnormal situation.

To assign observation aviation to attack missions is more often justifiable. Nevertheless, this procedure must be generally frowned upon. Both pilots and observers are not trained for this duty, and therefore cannot be expected to perform it with a high degree of effectiveness. If they are continually used for attack duties, their skill will, of course, increase; but such a course will inevitably result in a partial neglect of their own proper functions. Then too, from the previous discussion of the qualifications of the observer, it is apparent that replacements of casualties in this class will be difficult of accomplishment; they should not therefore be subjected to unnecessary losses. But, on the other hand, an observation squadron, equipped only with obsolete airplanes of the World War type, can bring to bear fifty-two machine guns, and can drop 5,200 pounds of bombs on each sortie. This is formidable fire power, and every commander will naturally long to put it to use in battle. Employment of observation in this way must not be habitual; but occasions will undoubtedly arise in combat, when all other needs, including observation for the present and even for the future, become subordinated to the necessity for the rapid and immediate development of the maximum fire power. In these circumstances, there can be but one proper decision: to launch every available airplane into the attack.

Smoke laying missions. Among the French in the World War, there arose a saying that "a battery seen is a battery lost." Like epigrams in general, this must not be taken literally; but it does express in figurative language the overwhelming importance of concealment. Heretofore men have depended for this largely on the accidents of terrain and of weather. However, the recent development of smoke laying devices for the airplane presents the possibility of artificial concealment on so large a scale, that it may have the most far-reaching consequence on tactical methods. The use of smoke has long been an important factor in naval warfare. The airplane now offers the possibility of rendering it equally adaptable to land warfare, where hitherto its use has been quite limited. It may well be a development of the near future for observation airplanes to perform this class of duties for the ground troops, concealing them effectively from all but airplane observation.

Balloon Observation

Balloon and airplane compared. There is enough similarity between airplane and balloon observation to warrant a general description of the latter by comparison with the former. The airplane may proceed to great altitudes, and may observe from a point almost vertically above the target; the balloon, on the other hand, cannot ordinarily ascend to a height exceeding 3,500 feet, while its zone of observation extends from three to fifteen times this distance, which results in such an obliquity of the visual ray as to distort the view. For this reason, the airplane observer can sense the amount of deviation of the shots in artillery fire, both in deflection and in range, and can sense a salvo as a whole and estimate the center of impact, with somewhat greater accuracy. Among other advantages of the airplane, it has a wider range of vision, since some areas are hidden from the view of the balloon observer, while practically all are open to the aviator's gaze. Furthermore the balloon is usually from 3 to 10 miles distance from the objects observed, a handicap which glasses do not altogether overcome.

As against these drawbacks when compared with the airplane, the balloon has many advantages. Due to the fixed position of the balloon in the air, the observer remains at the same point for extended intervals; he thus becomes better "oriented" and more familiar with the zone under observation, and can, therefore, detect the more readily any significant change. The balloon is more vulnerable to attack than the airplane, but to balance this, has a far more powerful defensive armament, so that the pursuit pilot looks on balloon destruction as a particularly hazardous undertaking. Then too, the balloon observer can devote his entire attention to the work in hand, without feeling under the necessity of keeping a look-out for hostile aircraft: for not only is he protected by armament, but also sentinels on the ground give him warning of the approach of hostile airplanes, and tell him when the times arrives to jump with the parachute. But the most important advantage of the balloon is its facilities for rapid communication, for it has direct telephone connection with the unit it serves. The future perfection of the radio telephone may diminish the

importance of this advantage, but is unlikely to overcome it for many years. For the reasons given above, balloon observation is always preferred over that from the airplane, whenever it is feasible. It is obvious that many duties of reconnaissance cannot be performed by the balloon; but it finds a wide field of usefulness in artillery observation.

Balloon missions. Although, as stated above, the balloon cannot replace the airplane as an instrument of reconnaissance, nevertheless it may supplement the work of the latter in the execution of the liaison and contact missions under favorable conditions. It is seldom that the balloon observer is able to follow the progress of the infantry, but is often possible for him to see signals from the front line, and transmit this information to the proper places. Often however, the balloon observer can follow artillery activity, and so form an accurate estimate of this important element of the situation. The balloon is well fitted for general and continuous observation of a sector over a long period of time, and this, along with artillery missions, continues to be its chief use.

Airship Observation

Balloon and airship. From time to time a plan has been proposed for substituting for the kite balloon a small airship of approximately the same lifting capacity. This would permit more rapid movement from place to place, and in this respect would prove of some advantage. However the kite balloon can be moved under existing circumstances as rapidly as the troops it serves, and any mobility in excess of this is so rarely needed that it seems scarcely worth the expenditure of much labor to secure it. It is contemplated that the small airship, while actually observing, should be in all respects similar to the kite balloon; but it is obvious that it would than have the added vulnerability presented by the gasoline tanks—no mean addition, if helium had been substituted for hydrogen. Furthermore, while moving from place to place, since it would be deprived of its ground protection, it would fall an easy prey to the hostile airplane. An obvious disadvantage, from the standpoint of supply and equipment, lies in the added power plant. In short, it seem that this substitution

would surrender many advantages of the balloon, and offer almost nothing in exchange.

Airship and airplane. If we disregard the effect of hostile air activity, there is scarcely an observation mission previously described which may not be executed by the airship almost as well as by the airplane, while many of them, such as very distant reconnaissance, may be done even better. In final analysis, if we except all such considerations as initial cost and maintenance, the one great tactical advantage of the airplane is its comparative invulnerability, due to its speed, small size, and maneuverability. But this one advantage is decisive, wherever the enemy has an active air force or a strong anti-aircraft armament. We may therefore expect to see the airship used for observation purposes only in rather exceptional circumstances: where, for instance, the enemy is a small state, unequipped with anti-aircraft means; or when weather conditions permit the rapid escape of the airship into friendly cloud banks of great extent.

CHAPTER V

PURSUIT AVIATION

Introduction. In previous chapters the fundamental principles of combat were discussed and their application to individual fighting. It is the purpose of this chapter to continue the same investigation, and to study the methods that are feasible in applying these principles to the larger air units. Up to a certain point we stand on fairly firm ground. Individual fighting attained to a high degree of development in the World War; and although there will inevitably be some modification due to changed equipment even in the individual combat, it seems probable that no innovations will occur except in minor details. Much the same may be said of the combat of so-called formations, that is, of the smallest band, composed of from three to nine airplanes, which is led and maneuvered as a unit.

However, as we go forward in the direction of larger numbers, the foundation of historical fact becomes and more insecure. We shall see later that even some of the men who were advancing in the path prescribed by the principle of mass, nevertheless took these footsteps falteringly, and were frankly doubtful of their wisdom. Such is indeed the general history of progress. Nevertheless there was advance; and it seems a logical deduction from the facts we know, that we shall continue to advance in the employment of mass, until at least the largest pursuit organization now envisaged—the brigade—will not be alone an administrative unit, but will be brought to the battle and directed while in it, by a single commander. In this way only may its full power be concentrated on the destruction of the enemy.

It is apparent that any attempt to describe in detail how this is to be accomplished for the larger units, may well take us out of the realm of the disciplined imagination into that of the unfettered fancy. But at least the broad general outlines of

the solution seem capable of being deduced from the facts now at hand. Certainly the attempt to do so is well worth while. The doctrine thus evolved may prove in future warfare, to fall far short of perfection. It would be exceptional, were it to turn out otherwise. But if it adheres closely to those fundamentals of warfare which were discussed in a previous chapter, it cannot be essentially unsound, however much it may fail of attaining the ideal. If the history of war shows one thing with certainty, it is that any reasonably sound plan may well result in success, if executed vigorously and whole heartedly. Only the adoption of a plan fundamentally unsound, or, worse yet, the failure to adopt any plan—with its inevitable consequence of indecision and inaction—is almost certain to entail defeat.

The basic mission of pursuit aviation. With the exception of pursuit, all other branches of aviation have a dual rôle. Their missions may be of the nature of a service, as is habitual with observation aviation; or they may consist in offensive action against hostile elements on the surface of the earth, which is the proper rôle of bombardment and of attack aviation. In any case, they have a certain duty to perform, which arises from other than air considerations. In so far as the latter are concerned, their missions are mostly invariably of a defensive character. Whenever consistent with the playing of the first part of their roles, they studiously avoid combat. With the pursuit aviation, on the other hand, air combat is the sole reason for its existence. It is true that it may be called upon at times for the execution of some other mission; but in such cases, it ceases in fact to be pursuit aviation, and must be regarded as temporarily converted into attack or observation aviation. It is apparent then, that all air combat generally involves pursuit aviation, since there must be an attacker. The study of air warfare, in its most limited sense, is the study of pursuit strategy and tactics.

In the days of its beginning, pursuit aviation had as its basic mission the destruction of hostile observation aviation, and the protection of its own. This rôle has now been greatly widened, and today the basic mission of pursuit aviation is the destruction of all hostile aircraft, and the protection of friendly aircraft. The latter part of its rôle might almost be eliminated,

since the destruction of hostile pursuit aviation provides automatically for the protection of friendly aircraft.

In a certain sense, pursuit aviation may be called an auxiliary to the other branches of aviation: for the criterion of its value is the effect it has on the air situation; and this, in turn, is of importance only to the extent it affects the operation of attack, bombardment, and observation aviation. If we imagine a situation where the enemy has no aviation, our own aviation, with the exception of pursuit, is greatly enhanced in value, whereas our pursuit aviation would be useless as such. Nevertheless, no mistake could be more destructive in its consequence than to underrate the value of pursuit aviation to air operations as a whole, under any conditions of serious warfare. It is, in fact, the very backbone of the air force. Unless all other branches of the air forces are tied closely to it, their worth will be greatly reduced. Without a pursuit force, the whole scheme of air operations would fall apart, against an enemy strong in this essential part. Just in proportion as pursuit aviation grows in effectiveness, so also will the remaining branches of aviation have their value enhanced.

Control of the air. The normal rôle of pursuit aviation is to assist its comrades in the other branches of aviation, by gaining and maintaining control of the air for the necessary period over the zones of operations. It is, however, necessary to a correct understanding of this statement that the term *control of the air* be explained, for it is easily susceptible of being misunderstood. All readers are familiar with the corresponding expression of naval warfare, *control of the sea*, and those who are less familiar with aircraft may easily be led astray by relying on too close an analogy between the two.

The meaning of the word *control* is essentially the same in both phrases; but the extent to which it may be attained differs in the two classes of warfare. As an example, the British Navy had almost unquestioned control of the sea, in so far at least as surface vessels are concerned, during the entire duration of the World War. The British merchant marine came and went at will, for the most part, while the badly needed cargo vessels of the German Empire were tied up uselessly either in their own or in neutral harbors. However, in spite of this

unquestioned superiority of the British Navy, isolated units of the German Navy, such as the *Emden* and the squadron of von Spee, succeeded for a time in eluding their superior foe in the vast spaces of the sea, and in working more or less destruction. Similar examples might be cited from every war in which one belligerent has dominated in sea power.

If the immensity of the sea permits such evasions, how much more likely they are to occur, where the air is the medium to be guarded—the air which covers land and sea alike, and does not restrict its voyagers to a single plane. Such a result might well be expected, and such is in fact the case. Control of the air is not an absolute but a relative condition. It is generally restricted in scope and fleeting in duration. No matter how overwhelming a force of pursuit aviation a belligerent may have, it cannot wholly prevent hostile air activity. Just as, to consider another comparison, the most overwhelming superiority in artillery never in practice results in counter-battery fire so effective that not a single hostile gun can fire, so also superiority in aircraft never insures that the enemy's air activity will be reduced to zero.

Too often, in the World War, this fact was not appreciated, and the sight of a few hostile aircraft proceeding on their way unmolested led ground troops to conclude either that their own air force was outnumbered and neutralized, or else that it was neglecting its obvious duty. Of course, such a conclusion was entirely unwarranted, and came from a widespread ignorance of the capabilities, and particularly of the limitations of the new arm. With the more general diffusion of knowledge, which will come with time, all arms of the national defense will understand that even the largest air force cannot entirely prohibit the passage of hostile aircraft. Once this condition is reached, ground troops will undertake to advance under fire from aircraft, just as formerly they were not invariably halted by artillery fire, meeting the new menace in much the same way they met the old: by concealment, by deploying, by counter-attack with fire, and by summoning the necessary fortitude to withstand the unavoidable losses. Then they will judge the friendly air force, not on the negative basis of moderate hostile air activity, but by the number of hostile aircraft the friendly

pursuit forces destroy or neutralize, and by the damage inflicted on the other elements of the hostile army. Then also, they will understand that just in proportion as the air force is aggressive and carries the war into hostile territory, to that extent will its activity be unobserved by friendly ground troops. With this knowledge in mind, ground troops would be the last to insist that the friendly air force remain above their heads in costly defensive inaction, for they would realize that these unseen battles over the enemy's lines determine in the end the extent to which ground troops will suffer from hostile air attack.

But because control of the air is temporary and limited, it does not follow that it is unimportant. It is, in fact, the principal element of the air situation, and may be said to exist when friendly aircraft can carry out their assigned missions with only rare interruptions by hostile pursuit aviation, while hostile airplanes, on the other hand, generally have to fight to perform their allotted tasks.

Indecisive nature of the single battle. It was noted in a previous chapter that single fights are rarely decisive in the air, when compared with the results which usually flow from land battles. But this must not be understood to minimize the importance of each separate fight to an undue extent. It must be remembered that each victory does so much to raise the morale of the winner and lower that of the defeated, that on this account alone, each successful fight paves the way for succeeding triumphs. Moreover the actual numerical relationship will generally be changed. So much is air warfare determined by the actual physical destruction of the opponent, that the relative losses form an accurate estimate of the outcome. In this respect it often differs from land battles, where sometimes the losses of the victor equal those of the vanquished. In the air there will be few Pyrrhic victories.

As an illustration of the protracted nature of air fighting, the example of the American pursuit units attached to the British Expeditionary Force may be cited. There were in all 216 American pilots with the British. Fighting in which some of these pilots were involved, was of almost daily occurrence, now one side and now the other entering combat under the

more favorable circumstances. Slowly the American fighters as a whole began to get the upper hand, but at the end of many sing combats, it was still impossible to say that they had definitely and decisively defeated the enemy. Nevertheless, the comparative moral and numerical ascendancy of the Americans was eventually asserted. By the end of the war, according to the British official figures, they had accounted for 225 hostile aircraft, with a total loss to themselves of only 71. It is instructive to note that on the last day of these operations, an American squadron entrapped a German squadron which had been reduced to seven pilots, and destroyed the entire unit, without the loss to themselves of a single man. While such complete results were due in part to good fortune, they were primarily a consequence of superior numbers, skill, and morale—all attributable, to some extent at least, to preceding successful fights.

Cooperation. In a previous chapter, the principle of mass, in its application to pursuit aviation, was briefly discussed. As a corollary to it, stands the principle of cooperation. Its importance to the pursuit force as a whole is apparent. Each squadron must play its part in the group team, working with a single eye to the welfare of the whole, or it is obvious that the full strength of the entire force can never be brought to bear. Too much emphasis cannot be laid on this phase of the principle of cooperation.

But it is apparent also that there is a practical limit beyond which cooperation need not extend. To attempt to go beyond this, in pedantic compliance with the principle, usually results in cramping initiative and in introducing unnecessary complications, which military towards defeat rather than victory. In its exterior relationships, pursuit aviation rarely needs to cooperate with any force other than air units and antiaircraft troops. With the latter, its liaison must be close, for both have essentially the same mission. But with infantry, for example, the liaison need be only the most tenuous kind. It is quite true that the needs of the infantry ultimately determine the missions of observation, attack, and bombardment aviation, and that these in turn may govern the action of pursuit aviation. It may therefore be argued that cooperation of a close kind is

essential with infantry. But such reasoning is mere sophistry. Practical experience, backed by common sense, shows that pursuit aviation can accomplish its own essential tasks with little or no reference to infantry dispositions, except in the most general manner. Its interest lies in the air.

The cooperation of pursuit aviation however must be fairly close with the other branches of aviation: the greatest air victories come from skillful combinations of all parts of the air force. But in this case also, it is dangerous to go to extremes. The principles of war do not always lie side by side in complete harmony: he who makes a fetish of the principle of security, for example, almost certainly resigns all chance of success in war. So it is also with other principles. Thus to divide up the various pursuit organizations, and parcel them out among many attack and bombardment units, in the name of cooperation, is to commit the vital error of dispersion, to negative the principle of mass, and to violate an important phase of cooperation itself—that which should exist throughout the pursuit force as a whole. Cooperation then, must be given its due weight, but must not be used as a screen for the violation of other principles. It is a means, and must be employed with the end in view, not sought for its own sake, to the exclusion of all else.

Close protection. Still another error which has been committed in the name of cooperation, is what is known as “close” protection. It is, of course, one of the primary duties of pursuit aviation to protect friendly aircraft. Yet if the principles of war and the characteristics of pursuit aviation are not made the basis of the method of protection, but a system found useful in other forms of warfare is blindly adopted, the purpose of the operation is all too apt to be defeated. This is the fundamental error in close protection of other branches by pursuit aviation. It was exemplified in World War most frequently in the escort of observation airplanes by flights of pursuit aviation. An infantry escort, for example, will usually be so conducted that it may interpose itself between the convoy it is protecting and any threatened danger. In the case of pursuit escorting observation aviation, almost the same method was adopted. The escorting flight would remain just above the observation air-

plane, with a view of attacking any hostile airman who attempted to interfere. The objections to such a procedure are manifold. To attempt to keep two different types of airplane, with different cruising speeds, in fairly close contact, is undesirable, although this difficulty is not of a serious nature. The chief objection lies in the fact that pursuit aviation is a purely offensive force; its defensive strength is negligible; to compel it to await attack is almost to devote it to destruction. Under these circumstances, the enemy, secure himself from attack, has simply to wait until all the conditions are in his favor, and fall upon the escort. With all these advantages, he will not often fail to secure the victory. With the protectors thus disposed of, the fate of the protected is merely a question of time. Undoubtedly, the presence of friendly pursuit just above him, may give the observer a comfortable feeling of false security. If he be far-sighted however, he will vastly prefer that his pursuit escort be employed in its true offensive rôle, well knowing that in the long run, he will thus obtain far better protection. One after another, the various belligerents of the World War tried out the system of close protection, and one after another abandoned it, as its true nature came to be realized.

Of course, there are occasions when close protection, or some form of escort, is essential. The importance of many missions thoroughly justifies it. But it is best accomplished not by tying down pursuit aviation to a hopeless task (and here it must be recalled that pursuit aviation is assumed to be composed entirely of single-seaters), but by utilizing the peculiarly offensive power of pursuit aviation on its more distant missions, and supplementing this for closer protection with the defensive power of formations of two-seaters. In general, observation aviation times its flights so as to take advantage of the offensive sweeps which pursuit aviation makes, in the execution of other missions. Such sorties of pursuit aviation may indeed be made for this very purpose, where the situation warrants it, but this may be regarded as exceptional.

Air barrages. In much the same category with close protection is the attempt which was made from time to time in the World War to establish so-called air "barrages." As the name indicates, it was an effort to put up a defensive dam along

some line on the surface of the earth, which would positively deny the passage of hostile aircraft. It is difficult to say whether the idea originated from the older conception of the cavalry screen, or whether it was adopted in the blind hope of overcoming the apparently insurmountable difficulties which had been encountered in the usual defensive schemes against aircraft. But that such a plan is ill adapted to air tactics becomes manifest on consideration of a single example.

Let us assume that an army is being concentrated in an area approximately forty miles square. Orders are received to prevent hostile observation of the area by establishing an air barrage about the perimeter. If the barrage is to be truly effective merely against single hostile airplanes, it is necessary to have a patrol of friendly pursuit airplanes approximately every 5 miles of the entire perimeter of 160 miles. Moreover, the third dimension cannot be overlooked, so that the cordon must be established vertically, consisting of patrols about every 2,000 feet of altitude from the ground to the ceiling, which may be assumed as some 24,000 feet. Furthermore, if the barrage is to be continuously maintained throughout the day, three reliefs of patrols are required. A simple calculation shows that the number of airplanes needed for this operation reaches the formidable total of 6,760, a number far exceeding that which may be allotted a single army, even in the dreams of the most ardent air advocate. If we imagine, however, that such a vast number of airplanes is available, and that they are being employed to form a barrage, the futility of the thing becomes apparent when the probable action of the enemy is considered. After numerous attempts by his observation airplanes to penetrate the screen—all of which, we may assume, met with disaster—the nature of the defense becomes manifest. The appropriate action of the enemy in such a situation is easy of deduction: he would have to concentrate a force of pursuit aviation of only a small fraction of the size of the total defending force, to be able to have decided local superiority, and so to be able to break through the barrage at any time and place he may choose. The air barrage thus fails in its purpose against an aggressive enemy. By violating the principle of the

offensive, and adding to this the error of dispersion, it invites disaster.

The objectives of pursuit attack. In principle, the objective of pursuit aviation is that part of the enemy's aviation which offers at the time the greatest menace to the friendly forces as a whole. It will therefore generally have a specific mission. But so fleeting are the opportunities in air combat, that it is the usual rule to allow great initiative to the pursuit commander, and to permit him to diverge from the original plan whenever, in his opinion, the circumstances warrant it. Thus on a sortie, made primarily for the purpose of destroying hostile pursuit aviation, the pursuit commander may fail to encounter the latter, but fall in with enemy bombardment aviation under circumstances favorable for attack. Under the altered circumstances of the case, his decision to change his mission, and to attack, would be thoroughly justified. On the other hand, the mission assigned to pursuit aviation may be of such vital importance to the plan of operations as a whole, that no divergence from the original orders is permissible. For example, pursuit aviation engaged in protecting surface vessels from attack by hostile bombardment airplanes must ignore all other objectives, no matter how tempting, and concentrate its strength the bombers alone. As a rule however, the objectives assigned a pursuit commander are stated in broad general terms, and the specific objective of each attack is left to his discretion.

Pursuit formations. The word *formation*, which in general military usage, has a meaning different from that employed here, has already been defined. As numbers became the rule in air combat, there arose a need for new words, for the new tactical units often failed to coincide with the previously existing administrative subdivisions. Accordingly a new word was coined, and the smallest tactical grouping became known as a *formation*, while two or more of the latter were called a *chain of formations*. Now however, there is no longer the same need for these words. It is obvious that, since tactical success is the reason of existence for all combat units, they should be administered also to that end. Accordingly the formation should be designated as the flight, the smallest chain of for-

mations as the squadron, and so on to include the group, the wing, and the brigade. Should it become necessary for tactical reasons to alter the size of the formation, it is equally desirable to change also the composition of the flight, except perhaps in observation aviation. To have separate subdivisions for administrative and for tactical purposes is to introduce an entirely unnecessary complication. The word formation, in the meaning used here, having served its purpose in a period of transition, may now well be abandoned, to revert to its more general meaning.

There are many points of similarity between the offensive and the defensive formation, or flight. In both, the leader must be in plain view of the remainder of the flight, so that they may readily follow his example, or obey his signal. In both, due attention must be paid to security measures. The arrangement of the airplanes in the two classes of flight is therefore much the same: it consists of an inverted "V," with airplanes doubly echeloned, both in plan and in height. There are however notable differences. In the offensive formation, security is attained not by the flanking fire of the rear guns, as in the defensive flight, but by so arranging the airplanes in flight, that they may maneuver to bring their front guns to bear. For example, if the leader is attacked, the pilots in rear of him, having superior altitude, can dive and place themselves on the tail of the attacker. Even the rear airplanes are not wholly unprotected by their fellows, for they too, if attacked, can dive under the forward airplanes, and so put the latter in an advantageous position to counter-attack. The foremost consideration in the offensive flight however, is not security, but is the ability to bring the concentrated fire of many front guns on the given objective. This is achieved primarily by maneuverability, which is of the highest importance in the pursuit flight. On this account, the offensive flight is much less compact than the defensive formation, for there must be space enough to permit maneuver.

Number of airplanes in the flight. The demands of increased fire power and of maneuverability are conflicting; in consequence, there is a natural difference of opinion among airmen as to the best number of airplanes in the flight. Those

who set the higher value on fire power naturally desire to increase the number of airplanes in the flight; those who set a greater advantage in maneuverability prefer to reduce the flight to the smallest number, that really gives the advantage of the principle of the mass. It seems, on the whole, that this one of the many tactical details, which must necessarily be left to the future to determine: for the present, only the broader outlines can be drawn.

There is substantial agreement among pursuit fighters that nine airplanes arranged in the usual inverted "V" constitute a hopelessly unwieldy flight, so that opinions favor either three, five, or seven airplanes as the proper number. To consider the first number, it has the advantage of a high degree of maneuverability. Furthermore it is especially suited to certain phases of air combat. As we shall see later, the pursuit battle consists in general of two parts, which may be called, for lack of better names, the break-up and the exploitation. In the former, the aim is to break up the cohesion of hostile groupings, so that formed bodies of friendly pursuit aviation may exploit the initial success by destroying the isolated units of the enemy. In its final application, the latter phase consists in the destruction of single airplanes. For this purpose the flight of three seems ideally adapted. On the other hand, the loss of one airplane from the formation of three, destroys the integrity of the flight and weakens it disproportionately. Furthermore, considerations of organization tend to favor a higher number. It was pointed out previously that tactical and administrative units should be the same. There will generally be a certain number of airplanes out of commission, for one reason or another. The logical paper strength of the flight should therefore be that which tactical reasons show to be the desirable number in the air, plus the number that experience shows will normally be out of commission. A flight of a paper strength of three would obviously be of no value when any of the airplanes are out of commission, unless combined with others in similar case. If organized with a paper strength of four, it envisages too low a percentage of airplanes normally in commission. Of course this defect may be readily overcome by utilizing temporary flights, whenever circumstances render it necessary. But this

is an undesirable procedure from the point of view of good team-work. It is probable therefore, on the whole, that the disadvantages of the flight of three outweigh the advantages. However, among certain authorities, there is a distinct tendency to favor a flight of nine airplanes, which really consists of three formations of three airplanes each, the formation being echeloned with respect to each other in the same way as the individual airplanes in the formation.

Many famous air fighters, among whom may be included von Richtofen, preferred the flight of seven. When the factor of space is considered, in view of the probable masses of the future, this number may well become necessary. On the whole however, the present tendency seems to rely on the flight of five airplanes (Figure 16) as the best compromise among the conflicting demands. This number will be understood in future references to the flight, unless otherwise stated.

Attack of a single airplane by a flight. In the attack of a single hostile airplane by a flight, there are two general methods that may be employed by the latter in order to utilize to the full its superior numbers. In both of these schemes of maneuver the same general configuration govern as in the air duel, which was discussed previously: every effort should be made to get on the tail of the enemy. But it is apparent that when we come to study the action of the flight, space factors enter to complicate the situation. It is almost impossible for five airplanes to crowd into the dead space of a two-seater, unless the flight remains at long range. It is evident that in converging their fire on the hostile airplane, the attackers also converge in their courses, and if they attempt to close in to truly effective range, there is imminent risk of collision. This has been a frequent cause of disaster in air combat: the redoubtable Boelcke, for example, met his death in collision with a friendly airplane. Of course, it is possible for the pursuit flight to remain far enough away from the enemy to avoid this risk, and still remain in the dead space of the airplane attacked. It can then continue its fire with at least some hope of success, due to superior volume. But long range fire in the air is all too often wasted, and this method gives no assurance of ultimately

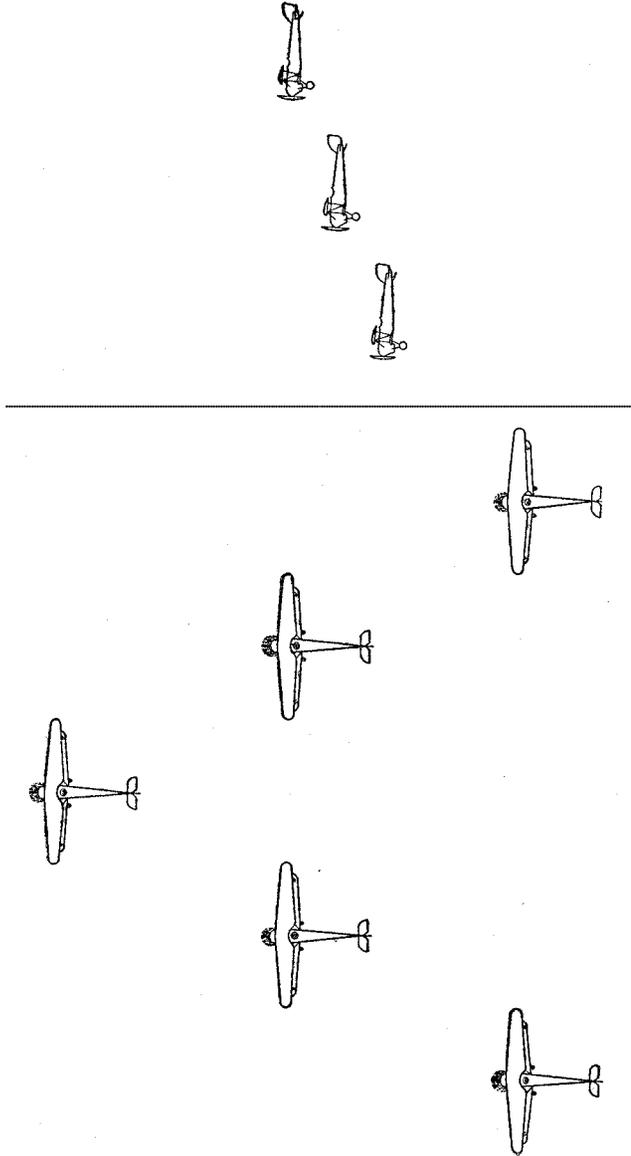


Figure 16. The Five-Plane Formation

accomplishing the mission of destroying the hostile plane. It is usually necessary to close with the enemy.

For these reasons, the tactics of the flight usually consist in attempting to give the death blow with only a part of the flight, the remainder assisting their comrades in this task. Of course, surprise is always sought, and where achieved it permits the leader alone to deliver the coup. If we assume such an attack in a two-seater, where complete surprise is not obtained, the two-seater may be counted upon, as a rule, to maneuver to bring the rear guns to bear on the first attacker. It is apparent however, that such a maneuver places two at least of the attackers in such a position that they may readily dive in from sectors of comparative safety. The airplanes of the flight which are left in the zone of fire may then pull off to avoid it, while their comrades dive in to the attack. Some such procedure is the ordinary rule in such a fight as that described. It is apparent that, with so limited a maneuver space, the flight of three airplanes can accomplish almost as much as the flight of five, in the attack of a lone enemy. However the flight of five has one important advantage: where there is danger of hostile interference, one or more airplanes of the flight should remain above it as a top guard, taking no part in the fight, unless hostile reinforcements arrive, or some emergency arises.

The attack of a single airplane by a flight was common enough in the World War. Observation airplanes habitually flew alone, and often pursuit followed the same custom. Occasionally, as might be expected, such lone fliers were used as decoys, to allure hostile pursuit flights into an attack: when the attention of the attacker was occupied in this way and his flight perhaps partially disorganized, lurking pursuit, awaiting just this favorable opportunity, would attack in its turn. However in future warfare, it seems likely that single airplanes will rarely venture forth. This type of attack will therefore seldom occur except in the exploitation of an initial success, after the disruption of hostile formation.

Combat between two pursuit flights. In the World War, the combat between two pursuit flights usually took a very definite course. The aggressor, having superior altitude, would

first maneuver to get "into the sun," and then dive to the attack. The leader would single out an opponent, and give him a burst of fire, then either continue his attack or else pull out above the fight to act as top guard. The remaining pilots of the flight would in turn single out their opponents and attack, attempting to keep up their fire until the enemy had been destroyed. Often the attacking airplane thus followed an enemy down for thousands of feet. It is apparent that the aggressor had a decided advantage in an initial attack under such circumstances. But once this stage was passed without decisive results, the combat all too often degenerated into a "dog fight", where the value of numbers was scarcely utilized at all, and individual skill alone decided the issue of the day. Bishop's description of such a *mêlée*, has been quoted previously. Still another incident, which commonly occurred, may serve to illustrate the nature of the fighting: in the confusion of the *mêlée*, a pilot would see a friendly airplane dive by with an enemy "on his tail"; rushing to his comrade's rescue, he would fasten in his turn onto the enemy's tail, firing furiously as they dived, only to be compelled to desist by the flashing of tracer bullets about himself, which apprised him that he, in turn, had an opponent on his tail. The end of a "dog fight" almost invariably found the contestants scattered over a wide expanse of sky: their existence as a tactical unit was lost, until such time as they could be assembled at some rendezvous point.

It is apparent that, in such a combat as that described above, there is little art to be discovered, except perhaps in the launching of the initial attack. It would however be quite presumptuous to condemn, on that account, the action of the many air fighters, who deliberately brought on a "dog fight" at every available opportunity. Though art may be a very admirable thing, it can only assist courage, and guide the eager desire for combat; it cannot replace either of these requisite of the air fighter. On the other hand, art may be, at times successfully dispensed with: a stout heart has pulled many a fighting man out of difficulties, in which he found himself through poor tactical judgment. Moreover, it is plain that, when units as small as the flight encounter each other, there

is little play for art. However, though courage may be the one indispensable, the greatest results in warfare are not accomplished by either art or courage acting alone, but by their happy union.

Sometimes, the tactics of the flight were varied by the original division of the flight into two parts. It is said that Richtofen habitually operated in this way. With one or two of the most skillful of his followers he would remain above the combat, sending the rest of his flight in to the attack. When the initial onset had developed—as it so often did—into a “dog fight,” he and the other veterans with him rarely failed to find opportunities to shoot down some of their opponents, easily caught at a disadvantage in the whirl of the *mêlée*. He was credited by the Germans with the destruction of eighty allied aircraft, and met death himself, not at the hands of an air adversary but at those of ground machine gunners, whom Richtofen had ignored in the too eager pursuit of a British airman.

In general, it seems to be the best tactical practice for a flight to retain its essential cohesion, regardless of the temptations to throw it away in too eager attack. It should, in general, be content with the result of its initial attack, and such further success as it may be able to attain, on being reformed immediately after the first dive. To allow the combat to develop into a “dog fight” is to permit the enemy to fight on equal terms, which should obviously be allowed him only when unavoidable. Of course, when the leader feels confident of the individual superiority of his followers, there is more justification for his discarding the power of his flight as a whole. In his anxiety to fight, he may feel reasonably confident of the outcome, even without the advantage of the cooperation of numbers. It will rarely prove the way to victory however, when the flight is acting alone. Of course, when the flight is acting as part of a larger unit—and this will be the rule of the future—the loss of its cohesion is not so serious a thing, and may indeed be necessitated by its mission. This will be discussed in subsequent paragraphs.

Combat between a pursuit flight and a defensive formation. In an attack on defensive air organizations, the conditions differ somewhat from those described above in the combat of two

pursuit flights. The difference becomes more marked, as larger units are considered, but will be briefly discussed here, in its general aspect. Defensive units are so restricted in their power of maneuver that attacking pursuit has nothing to fear from an offensive counter-attack from them. There are therefore fewer unknown elements in the situation, and the pursuit leader can estimate it as a whole with a higher degree of accuracy. He knows that the enemy will "close up," and meet his onset with a definite number of guns for each air space, which can be easily foreseen. He knows that, if his own unit should become disorganized in the attack, there is no danger of the defensive formations running down his stragglers, and destroying them in detail. He knows that, at any given moment, he can break off the combat, and withdraw without further losses. And, he further knows that cooperation in defensive organizations is limited to the short effective range of mutually supporting guns, so that, beyond the flight, there is little additional strength in numbers. This enables him, in the attack of larger defensive units, to select the portion of the enemy's force he wishes to concentrate upon, secure from interference by the remainder. Thus a pursuit force can attack a bombardment group with almost as great impunity as though it were a flight. In general therefore, pursuit aviation will select as its objective, the smallest unit of the enemy which it can attack without suffering embarrassment due to lack of maneuver space. It will press home its attack until successful in destroying the integrity of the unit, and exploiting this by shooting down the isolated units. If this is successfully done, other parts in turn may then be similarly attacked.

While the above considerations are general in their application, they do not, as stated, attain to marked importance in so small a unit as the flight. Nevertheless, there is some choice in the target, even in the flight. The pursuit fight is not constrained merely to shooting it out on equal terms, but may take advantage of its maneuverability to secure more favorable positions from the point of view of gunnery. Thus, if we assume a bombardment of five airplanes being attacked by a pursuit fight, the latter, by concentrating on the outside bomber could so place itself that the fire of three of the bombers would have to be directed at ranges exceeding 100

yards, whereas the pursuit flight could close in to an average range not exceeding 70 yards. The odds in such a contest would favor the pursuit unit. But there is no great disparity in power, an pursuit will find in a bombing flight of equal numbers, no mean antagonist. However if it should succeed in destroying the integrity of the formation of bombers, the individual airplanes would fall an easy prey.

The pursuit squadron in attack. The squadron is composed of three or more flights, the former being the more common in the various air forces. Communication between the airplanes of the squadron is confined, as in the flight, to visual signals; on this account it is necessary that all the flight leaders be able to see the squadron leader. To accomplish this, the flights are echeloned in height. They may also be echeloned in plan, in much the same manner as the individual airplanes in the flight.

When acting alone, the squadron in attack is usually divided into three parts, which are designated as the assaulting flight, the support flight and the reserve flight. The assaulting flight attacks as described previously. Due to the fact that supporting units are nearby, it is a far less serious error for the assaulting flight to lose its cohesion, than would be the case if it were acting alone. Its primary duty is to destroy the integrity of the formation it is attacking, and this should be accomplished even at a sacrifice of its own cohesion. After this is accomplished, the assaulting flight attempts to reform as soon as possible, meanwhile leaving the exploitation of the initial success to the remaining flights. The function of the supporting flight is to take advantage of any confusion that may be wrought by the assaulting flight, and to destroy any hostile airplanes which may become isolated. In case the assaulting flight fails to break up the hostile formation, the support is used either to repeat the attack, or, in case the enemy consists of pursuit aviation, it may be necessary for it to protect the assaulting flight while re-forming. The reserve ordinarily will be held out of the fight as a top guard, so long as there is immediate danger of interference by hostile pursuit aviation. However, these security duties are secondary in importance, and the mere possibility of attack—which is

always present—should not prevent its use in the critical stages of the fight to decide the outcome, nor should it interfere with the complete exploitation of an initial success.

The squadron commander normally flies at the head of the leading (and lowest) flight, which is almost invariably the assaulting flight. He does not however on this account, resign the command of his squadron as a whole, and content himself with the leadership of one flight. His usual procedure is to accompany the assaulting flight. He does not, however, on this account, resign the command of his squadron as a whole, and content himself with the leadership of one flight. His usual procedure is to accompany the assaulting flight on the first attack—which he leads—and then to climb above the fight, allowing the deputy flight leader to conduct the further operations of the flight. He will then signal, in turn, to the remaining flights to attack, joining them when he considers it advisable.

Size of assaulting units, support, and reserve. Because the squadron acting alone is habitually employed in three equal parts, it must not be supposed that this is a universal rule, applicable to higher organizations. In principle, there should be no fixed rule for the relative sizes of assaulting, supporting, and reserve units: these should be governed in every case by the needs of the particular situation encountered. In the case of the squadron, due to its small size, and the paucity of communications, its conduct, when acting alone, has of necessity to be somewhat stereotyped in nature, and to conform to a pre-arranged method. The ideal is sacrificed in the interests of simplicity and cooperation. But in the case of larger units, this is unnecessary, and the fixed rule should therefore be avoided, and a more elastic system adopted.

The size of the assaulting units depends on the size and type of the enemy force, that it intends attacking. The type—that is, whether it be offensive or defensive aviation—exercises a great influence on the decision. When the enemy consists of pursuit aviation, it is necessary that the attention of all of its elements be occupied, in order that none of them may be free to counter-attack. It is instructive to compare this to the normal procedure in infantry attack. In the latter, pressure must be brought to bear not alone on the part of the hostile line

selected as the decisive point, where the main blow is to be delivered, but also on the entire line to a great enough extent to "pin down" these forces and thus prevent their jeopardizing the success of the principal attack. The same idea underlies the size of the assaulting unit in combat with hostile pursuit: it must be large enough to engage the entire force. On the other hand, this is unnecessary when the enemy consists of other than pursuit aviation. For reasons pointed out above, only the units selected for a sustained attack, which it is intended carrying through to completion, need be engaged. Accordingly a wider range of choice in the size of the assaulting unit is permitted. The space factor now enters to a great extent, for it is desirable that the assaulting unit be as large as possible, consistent with having sufficient maneuver space. To illustrate with a simple example, if the objective of attack were a three-plane observation flight, it would be undesirable to have more than a flight in the assaulting unit, since a larger force would scarcely have sufficient space to maneuver.

The size of the reserve is governed by the extent of knowledge of the enemy's strength and dispositions. In proportion as unknown factors may enter into the situation, the reserve must be increased. It must, in general, be large enough to attack any hostile pursuit units which are likely to intervene in the fight. It can usually be made fairly large at the beginning of a fight, as its mobility permits it to be thrown in almost instantly, when needed. However, one consideration must always be kept in mind: great success can be achieved only by the output of one's entire strength. To hold out a reserve beyond the proper time for launching it in attack, merely as "an anchor to windward," is a half-hearted measure, which, venturing little, is certain to be repaid in like degree.

The duty of the support partakes somewhat of the nature of that of the reserve in that it provides security for the units already engaged. The support is however essentially a reinforcement for the assaulting units. While it may exploit such local success as the assaulting units achieve, it may also repeat the attack of the assaulting unit where the latter has failed to secure the desired result—a rôle which would rarely fall to the reserve.

In a sense, the support may be regarded as a local reserve. It will rarely be held out by units larger than a group.

It is by the suitable employment of supports and reserves that the various commanders retain control of the fight and guide it to the desired end. This is a general truth applicable to nearly all classes of warfare. But the time and space factors make a difference in practice, which seems in air warfare, almost to be a principle, although in fact it is not. Thus, in infantry combat, the main blow of an attack must usually be prearranged, and supports and reserve planned in such a way as to forward the general scheme. It is generally impracticable to alter this plan, once the attack is launched, except in minor details. The pursuit commander, on the other hand, is to a much greater degree, an opportunist. He will rarely determine his scheme of maneuver before ascertaining the outcome of the assault. Such a course is generally precluded for infantry through its comparative immobility, which leaves it little latitude for taking advantages of sudden opportunities. But this is the very essence of air combat. The pursuit commander watches over the fight for signs of greatest enemy demoralization, then hurls in his remaining units where there seems the greatest chance of destroying hostile craft.

The group. An historical example. In attempting to forecast the tactics of group, wing, and brigade, operating as combat units, we must rest for authority on reason rather than on experience. When the Armistice terminated the World War, the evolution of air fighting had proceeded little beyond the squadron, although the trend of it seems quite evident. In attempting to go beyond this point, it is interesting, first of all, to examine a series of air operations, which took place in the latter days of the World War. The size of tactical units was steadily, albeit slowly, increasing. Nevertheless there was no general appreciation of the necessity of mass operations. The same organization would make its routine sorties first by squadrons, and then by flights; and even the aspirant for the honors of the "ace," hunting alone, was not yet a thing of the past. On this account, it is all the more interesting to study the inception of group operations, since comparisons lie so readily to hand. By examining this subject of air fighting in its

various stages of growth, we may perhaps envisage the ultimate to which it will attain, and throw light on the problems of the future.

The example selected for study is taken from the "Official History of Australia in the War 1914-1919," in which is described a series of operations of a "circus," composed of British and Australian pursuit squadrons. This word "circus," was first applied by British airmen to the German unit commanded by Richtofen, either from its habit of moving from sector to sector of the front—always to the point where active operations were under way—or else to the fact that these selected German fighters habitually painted their airplanes in highly fantastic fashion. Eventually, the word came to be applied unofficially to all pursuit aggregations of two or more squadrons, and may be considered as signifying approximately a group.

It is noteworthy that the first circus appeared on the German side. The British soon followed. While the account does not so state, it is certainly a fair inference that the formation of British circuses was not done in admiration of German methods. Nor was it brought about through any general demand on the part of individual fighting pilots. The evidence is abundantly clear that, to these, the unavoidable suppression of individuality was rather distasteful. It was, in fact, brought about through the sheer force of necessity, since numbers can be met successfully only by numbers. It is the operation of a natural law. And although at some future time, there may be an attempt to impose an unnatural restriction on growth, it can be done only so long as the enemy consents to a like limitation. It is indeed obvious that the side which first succeeds in handling the larger air units will possess a marked superiority, until its opponents, in turn, succeed in adopting the same practices. Such had been the German move in this example, and a similar development was the British answer.

During April, 1918, there was formed a circus composed of an Australian squadron, No. 2, and of two British squadrons, Nos. 43 and 80. The group at that time habitually patrolled the region of the Somme, in search of the enemy. The usual formation that it adopted consisted of an echelonment in altitude; the two British squadrons, which were equipped with

the highly maneuverable "Camel," previously referred to, would fly at altitudes of 12,000 and 14,000 feet, while the Australians, who were equipped with S.E.5's, a machine better suited for diving, flew at 16,000 feet. For some time after the formation of the group the Germans were not in force on that part of the front, and control of the air by the British was almost undisputed. On the approach of the group, all enemy aircraft who could dived east at their highest speed and so avoided combat. This was all the more easily accomplished as the size of the group made it difficult for it to escape observation. There were accordingly very few air combats. This was profoundly disappointing to the members of the circus. To No. 2 Squadron in particular it was vexatious, for a strong rivalry existed between it and another Australian squadron, and the pilots of No. 2 Squadron felt that flying with a circus put them under a decided handicap. In an official report, the squadron commander complained that while circus might "have the desired effect of restricting the work of his (the German) air force, it does not do very much towards the primary objective of a scout (pursuit) squadron, that is, the destruction of all enemy machines." He then goes on to state that "better results would most probably have been obtained, both as regards the squadron personnel and as regards the number of enemy aircraft destroyed, by the use of smaller formations."

Of course, in many respects, the complaint of this officer—who had an enviable record for gallantry—was well founded. Where the enemy does not operate in force, but relies on evasion, as the Germans did temporarily during this period, his small units can be hunted down more effectively by squadrons or flights, than by groups or wings. This method of warfare is the invariable refuge of the weak in all classes of combat. In its ultimate form it becomes guerrilla warfare—the despair of all great military forces. But it shows the inherent weakness of its character: it can postpone the day of defeat, but cannot hope to secure a positive victory. Only combat can accomplish this. But when the nature of major warfare is considered, it would appear that its commander underrated the work of the squadron, and its parent organization. When pursuit aviation denies the air to the enemy, and gives full freedom of action to

friendly aviation, it has accomplished its full mission, even though it does not destroy a single hostile airplane. The latter accomplishment is but a means.

The situation as described above, continued on this part of the British front for more than a month, when it suddenly changed, and the employment of the air force in larger units more than justified itself. On the morning of June 1st, signs of markedly increased German activity became evident. Soon the Germans began to appear in the sky in force, and there was no mistaking their offensive attitude. Accordingly there was no lack of air fighting, for the British adhered to their rule of diligently seeking combat. A few examples of the methods which were employed are of tactical interest. On the morning of June 1st, while the Allied circus was flying in its usual formation, a single daring German, apparently unaware of the presence of the Australians in the upper flight, dived on one of the British "Camel" squadrons. The Australians promptly seized the opportunity, and easily destroyed the daring attacker. This, of course, was simple enough in itself, and reflected no particular credit on the squadrons concerned. But it was a precursor of much that was to follow. That same evening, a flight of eight Germans was caught in almost the same fashion between the "Camels" and the S.E.5's above, and was badly defeated; all but three of the flight were destroyed with a loss of only one Australian pilot. On the next day, similar fighting occurred, where the tactical advantage lay again with the British, and the results were eloquent of the work of the circus. On these two days alone, No. 2 Squadron destroyed fifteen enemy aircraft—more than its own average fighting strength. Again on June 12th, somewhat similar fights occurred. On two occasions, German pursuit attempted to attack the lower squadrons, only to be overwhelmed by the S.E.5's in the upper echelon. It was a striking proof of the eternal truth of the principle of mass.

To follow the career of this Australian squadron still further offers many valuable tactical lessons. In September, the squadron was again operating as part of a circus, the other squadrons at this time being No. 88 (British) and No. 4 (Australian). While these units habitually operated as a group,

from time to time this practice was varied by flight or squadron patrols. Such a patrol of five airplanes, from No. 4 Squadron, was surprised on September 5th, by a group of three German squadrons. The flight leader signalled to avoid action, and himself dived away. He apparently was unobserved by the Germans, and so escaped. But the remaining pilots of the flight were shot down to a man. On the following day, the British circus was successful in avenging this defeat. "This time," says the official account, "in good cohesion," they flew in three echelons, Bristol Fighters from No. 88 at the top, S.E.5's of No. 2 below them, and "Camels" from No. 4 in the lowest tier. At 14,000 feet, seven Fokkers were sighted. Though aware of their presence, the "Camels" flew on below them, hoping to decoy them into an attack. The ruse again succeeded. The Fokkers failed to see the upper squadrons, and maneuvered to attack the expectant "Camels." At a well-timed instant, when the attention of the Fokkers was wholly absorbed in their own plan, the S.E.5's dived in to the attack. In the initial onset, one Fokker was immediately destroyed, and another was driven down, apparently out of control. In an endeavor to escape, the remaining Germans went into "spins." In doing so, they dropped past the level of the "Camels," who hastened to attack in their turn, and accounted for three more of the enemy. Only two of the Germans escaped.

Such examples as the above might be multiplied indefinitely. They show, first of all, the absolute necessity of mass operations, unless the enemy makes similar mistakes; they demonstrate the desirability of mass operations, even where the enemy employs a system least harmful to his opponents. But primarily they show the practicability of mass operations, even where the means of coordination were limited and far from effective. There can be little doubt that the operations of these circuses would have been decidedly more damaging to the enemy, had the squadron commanders been able to communicate with each other. As it was, all cooperation depended for its real power, on the diffusion of a common doctrine. There was no other means of effecting true subordination to one will. Nevertheless the group operations were highly successful, and

easily suggest the means whereby the mass operations of larger units may become feasible.

Assumptions in regard to future operations. In order that mass operations may take place, certain developments beyond the stage reached in the World War, are necessary. In the remainder of this volume, it will be assumed that these improvements are already *faits accomplis*. Their nature has been foreshadowed in previous chapters, but they will be described in somewhat greater detail below. Without exception, these assumptions are based on actually successful experiments, or else on accomplishments which are easily within our present powers to attain. The objection might well be raised at this point, that no nation of today is attempting mass operations of pursuit aviation in their peace time training programs. The objection is admittedly true. But the explanation lies, not in the impracticable nature of such operations, but in the fact that the general demobilization which occurred at the end of the World War, left no country with both the will and the money to conduct extensive tests and maneuvers under service conditions.

The command airplane. The commanders of groups and of higher units will habitually exercise their authority by directing rather than by leading the units they command. They themselves will avoid combat wherever practicable, and will fight only when attacked. The commander will habitually fly as the leader in a formation of five airplanes, taken from the headquarters flight or squadron of the unit. This serves the twofold purpose of providing a protective escort for the commander, and of enabling him to have nearby the members of his staff. The details of the command airplane must necessarily be determined by future experiment. Preferably it should be able to seat three men, for the commander should be able to concentrate his attention on the tactical situation, and not be distracted by the necessity either of piloting his machine, or of manning the rear guns, in case of attack. The commander will probably have to be his own radio operator: not only would a fourth man add undesirable weight to the machine, but so rapid is the action of air warfare, that even the time lost in repeating messages to and from the operator cannot be

spared. The command airplane should carry no extra equipment which can possibly be dispensed with. Its fuel capacity should be the same as that of the pursuit airplane proper. It need not be so sturdy as the latter. In sacrificing strength, it would have also to forego maneuverability, but this would be no very serious loss, since its attitude is entirely defensive.

It might be expected that the enemy would make especial efforts to attack and destroy the command plane flights, which would be easily distinguishable from the single-seaters. As however, the former not only will have the defensive power of the formation, but also will habitually fly within supporting distance of single-seater units, there will be no unusually grave danger that sudden attacks will disorganize the agencies of command.

Interplane communication. Within the squadron, communication will be by the means hitherto used: signals made by the airplane itself and by pyrotechnics. All commanders of squadron and higher units will be equipped with sets for sending and receiving radio messages, both by telephone and by telegraph. In order to reduce interference to a minimum, there will be definite ranges of kilocycles assigned to communication between squadron and group, between group and wing, and so on.

Normally, in the transmission of orders, the radio-telephone will be used. This is of course open to the objection that the enemy may also receive the message. However, this objection will usually not be a weighty one: for the range of these sets is quite limited, and often the space considerations will make it altogether safe to employ this means; moreover such is the rapidity of action, that, in many cases, it will matter little if the enemy does hear the orders, since the execution follows so fast on the heels of the command. But experience has indicated that often the conditions are such that the telephone does not function satisfactorily, while the telegraph, on the other hand, is entirely audible. In such circumstances, the latter will, of course, be employed. But where every second counts—as it indubitably does in air combat—this is a slow means, and must be supplemented by the use of some form of abbreviation. Some form of code will be necessary: this must be very simple, and easily decoded. It must be, in fact, so easily

remembered that a few letters will transmit the general idea of the commander, and be quickly intelligible to his subordinates.

There is, of course, always the possibility that radio transmission may be interfered with, either by the enemy's action, or by some natural agency. It is therefore essential that some alternate means of communication be provided. Several methods suggest themselves. Pyrotechnic signals may be carried along, with definite emergency meanings. Nor has the air force, as yet, exploited the possibilities of flag signaling in the manner which navies have found so convenient. There seems to be no good reason why a short folding mast may not be provided for each airplane of the command formation. A simple code is arranged. When the commander breaks out his flag signal, the command formation is temporarily broken up, and the liaison airplanes, which have been previously assigned, fly to their designated units and coming close alongside each leader, show him the code signal which tells him the part he is to play in the coming action.

The group. The group is composed of two or more squadrons, four being the more usual number. It is obvious that the formation adopted in both the flight and the squadron cannot be indefinitely continued, without resulting in a hopelessly unwieldy unit, which could change direction only with the greatest difficulty. Accordingly the double echelonment, both in height and in plan, with the leader at the head of the inverted "V," is not carried out in units larger than the squadron. The group habitually flies with squadrons echeloned in altitude only, each squadron, in so far as plan is concerned following in trace of its predecessor. This has the advantage of enabling the group to change direction very readily, or to assume any other formation quickly. The group will thus have the same frontage as the squadron. Each squadron leader flies in trace of the leader of the first squadron, and at an altitude about 100 feet above the last airplanes of the preceding squadron. An interval of about 150 feet is preserved in depth between these two airplanes.

The wing. The wing is composed of two or more groups, three being the more common organization. The wing habitually flies in column of groups. In exceptional circumstances a

formation on a wider front may be adopted, but this is rarely justified unless the exact location of the objective of attack is known. The column, with an interval of about 300 feet between groups, is the only formation which permits of an easy change of directions.

The brigade. The brigade also habitually flies in column of wings, for the same reasons as were given in the case of the wing itself. Intervals of about 500 feet are preserved between the wings. In this formation, the radio of the brigade commander easily reaches to the airplane of the most distant wing commander. This formation also may be said to be a habitual route formation, rather than an attack formation, in which, of course, the column will generally have been broken up.

Development of the column. In general military usage, the word "development" means the splitting up of a column into two or more parts. In infantry combat, this is the preliminary to deployment, which is the final step in assuming battle order. No such importance attaches to the development in air combat as in infantry combat, for obvious reasons. The habitual formation of infantry combat is the line, of naval combat the column. There is no such habitual battle formation for the larger units of pursuit aviation, although it will more nearly resemble naval than land warfare. Moreover, air forces do not meet with the many limitations which other combat units encounter. Thus, the development of an infantry division often depends on the road net: the crossing of two columns would result in inextricable confusion. This may however, be easily done in air movements by merely assigning different altitudes: thus two wings may readily cross each other's horizontal paths, by the simple expedient of remaining in a previously assigned bracket of altitudes, which need embrace only some 1,800 feet. This advantage possessed by the airplane does much to simplify maneuvering masses. On the other hand, the high speed of the airplane renders all complicated movements difficult if not dangerous. It is simple to calculate that units as large as the brigade can change direction or even counter-march without destroying their cohesion. But the detailed movements that are necessary in such a maneuver must be left to the future to determine. So all-important is the time element in such movements that any miscalculation may

result in dire consequences. Maneuvers which appear practicable on paper may prove too complicated for war purposes. This, like many other details of pursuit action, can only be determined by future training and experiment, and this of course, can never occur until the nation possesses the number of airplanes necessary. For the present therefore, we must content ourselves with a very general outline of the mechanism of development.

Let us assume, for example, that the brigade commander, after an estimate of the situation, has decided to attack a hostile bombardment wing. In the orders that transmit his will to subordinates, he divides the command into assaulting and reserve echelons, and assigns to each its objective of attack. Let us further assume that he decides to concentrate for the initial attack on the last two groups of the hostile wing, leaving the first two temporarily unmolested. The attack is to be made by the two leading pursuit wings, the third remaining in reserve. No support is held out. The assaulting wings of pursuit at once proceed by the shortest air route towards their objectives, while the reserve wing begins to climb above the scene of the expected flight. The development thus begins.

It is progressively continued in the same manner. Let us follow the action of the commander of one of the assaulting wings, whose objective is the last hostile bombardment group. He also decides to hold out one of his groups as wing reserve, and orders his other two groups to attack the last and next to last bombing squadrons. The group, in like manner, keeps a squadron in support, and due to lack of maneuver space, the squadron assaults with only two flights, keeping the third in support. In the final analysis therefore the attack is the simultaneous assault of flights. But in support or in reserve in each higher organization are units which can quickly take advantage of any initial success, or meet any threatened interference by hostile pursuit.

Attack of lighter-than-air craft. Formerly the attack of balloons and airships was one of the functions of pursuit aviation. With the introduction of a third branch of the air force—attack aviation—it seems that this duty should properly devolve on it. Accordingly the subject will be discussed in the chapter devoted to attack aviation.

CHAPTER VI

ATTACK AVIATION

Inaccurate terminology. It is to be regretted that the new science of aviation has been, at times, singularly unfortunate in its choice of words and phrases. Many misnomers occur, and many of the terms adopted from common usage are entirely too comprehensive to be accurately descriptive. An obviously outstanding example is the airplane itself; its wings, from which the machine derived its name, are not planes, but curved surfaces; the Air Service, as it was called in the American army, is not a service at all, in the usual military meaning of that word, but is a combatant arm; etymologically, the word aviator itself is not above suspicion. Among these unhappy examples from the nomenclature of the air may be listed *attack aviation*. The word scarcely serves to distinguish the branch of aviation to which it is applied, since the attack of objectives, either in the air or on the ground, is a rôle of all branches of the air force. However, as the term has now been in use some years, and has come to be widely understood, it must of necessity be retained throughout this discussion.

Origin of attack aviation. The attack of ground troops was one of the earliest uses to which the airplane was put, coming in this respect second only to observation. But for a long time, it was generally believed that this duty could be performed by the various branches of aviation in addition to their primary functions, and that no specialization was necessary. Only one of the major combatants in the World War considered it advisable to assign a branch of his air force to this duty alone. At the present time, the air authorities of the larger powers by no means agree as to the merits of this specialization. We shall find therefore, in the study of historical examples, that "ground strafing," as attack missions were called, was usually performed by pursuit aviation, although bombardment and even observation aviation were sometimes called upon to exe-

cute similar mission. It was considered practicable for these units to carry out attacks of ground objectives, without unduly interfering with the duties for which they were primarily intended. The Germans however, towards the end of the war, arrived at a different conclusion. They were influenced to this view by two considerations: first, it was believed that the type of airplane suited to this work differed radically from any previous designs; and second, it was thought that the tactics as well as the technique of executing ground attacks differed so much from other air operations that a separate organization and separate tactical training were necessary. Accordingly, in 1918, the first attack units, which were called by the Germans "battle flights," appeared on the Western Front. When the United States army was reorganized, following the termination of the World War, it was decided to retain attack aviation as a separate branch of the air force, and it so remains today.

Characteristics of the attack airplane. Many flyers in the World War considered "ground strafing" the most dangerous of all missions. While the statistics of airplane losses do not seem to bear out this view, nevertheless from a purely physical point of view, the anti-aircraft machine gun seems to be at no disadvantage as compared with the same weapon on the airplane. Both have essentially the same problems in gunnery to solve. There is however, undoubtedly a great moral advantage with the airman, which will be discussed in greater detail in a subsequent paragraph. But whatever may be the comparative advantages and disadvantages, it is certain that ground machine gun and rifle fire are formidable foes for the airman to cope with. It was chiefly the effort to solve this problem which led to the birth of attack aviation as a separate branch. The first solution, as might have been expected, lay in the direction of armor.

The first distinctively attack airplane to appear on the front had the vital parts of the airplane protected by an armor belt against the .30 calibre bullet and shell fragments. When the American army came to design an attack airplane, shortly after the World War, this characteristic was retained. When however, these airplanes were subjected to service tests, the result was decidedly disappointing. Although the machine

provided protection against .30 calibre fire, it proved to be slow, clumsy, and quite difficult to maneuver. It was, in fact, altogether unsatisfactory from the standpoint of airworthiness, although it was almost impossible to bring it down by .30 calibre rifle fire. Its defects as a flying machine were sufficient in themselves to cause this type to be condemned for service purposes, even against an enemy armed only with the .30 calibre weapons. But the advent of the .50 calibre machine gun and the 37 millimeter gun as anti-aircraft weapons, destroyed the one advantage this type of airplane had, for its thin armor belt could not withstand the greater penetrating power of the larger projectiles. It seemed then that if protection against the lighter weapon so overloaded the airplane as to render it unsuitable for air work, it was altogether futile to make any further efforts in this direction. In so far as aircraft were concerned, the age-old race between armament and armor was definitely conceded to the former. The plan for the construction of an airplane with both a powerful armament and an adequate armor, a veritable "flying tank," appeared to be completely discredited.

A large weight of opinion then swung to the other extreme. The history of the World War gives abundant proof that a reasonable degree of security against fire from the ground can be attained by speed, by maneuverability, and by the effect of fire from the airplane itself, when coupled with the moral effect of surprise and of overhead attack. If this view be adopted, to the exclusion of all other considerations, it is apparent from a brief comparison of their characteristics, that the attack airplane will be in effect, merely a pursuit machine. The few minor differences, which in theory are desirable, would be eliminated in the interests of production and maintenance.

But this view cannot be adopted in its entirety without a dangerous disregard of the principle of security. The effectiveness of attack aviation will always be greatly influenced by the relative aggressiveness of hostile pursuit aviation. Since "close" protection by friendly pursuit is usually inadvisable, it is essential that attack aviation have at its own disposal suitable means of defense against air attacks. If left at the mercy of these, it would soon be destroyed. Of course, it will at once

be contended that attack aviation is not deprived of all means of defense, merely because it uses a pursuit plane, since it obviously can protect itself in the same manner as does pursuit aviation. This is quite true, but it ignores the normal attitudes of these two branches of the air force towards air objectives. As pointed out in a previous chapter, the rôle of pursuit aviation is distinctively and almost invariably offensive in character; its purely defensive power is negligible. Attack aviation, on the other hand, preserves a defensive rôle in air warfare. It is apparent, then, that if attack aviation is equipped with the pursuit airplane, and expected to furnish its own protection, it is, in effect, pursuit aviation, but pursuit aviation with two fundamental missions, which will often be conflicting.

The possibilities of evil in such a conflict, may perhaps best be illustrated by an example. Let us assume that an attack unit, equipped with the pursuit airplane, is sent on the important mission of destroying a threatened counter-attack by reserves of hostile infantry. On approaching its target, the attack unit encounters hostile pursuit aviation. What, now, is its proper action? To carry out the original plan in its entirety, as though no enemy were in the air, is to invite disaster, and practically to insure the failure of the original mission. On the other hand, to turn its attention entirely to the hostile pursuit, is a complete abandonment of its mission: for its first action would probably be to get rid of its bombs, so that it would not have to meet the enemy at a disadvantage. If we may take the custom of the World War as a proper precedent, the attack unit probably would adopt the latter plan, lighten up its machines for the approaching combat—and in so doing, largely divest itself of its attack character—and turn to its pursuit work of assaulting the hostile airmen. Such a course is both reasonable and justifiable; but one can easily imagine that the high commander who ordered the attack mission, would be little pleased at its outcome. Of course, the attack unit might seek a solution of the dilemma in compromise, part engaging the hostile pursuit aviation, while the remainder proceeded with the original mission. But the very necessity of such half measures shows the inherent weakness of having

two fundamental missions, two masters to serve. Of course, the possession of a type of airplane other than the pursuit, does not, in itself, provide a guarantee that the enemy will not interfere with the attack unit, even to the extent of completely neutralizing it. But at least, the attack unit has a chance of success. War being what it is, defeat at the hands of the enemy may excuse a failure to execute an ordered mission: few other reasons can be accepted in extenuation.

The essential difference in the fundamental missions of pursuit and of attack aviation, brings other distinctions in its train, besides the characteristic design of the airplane. The tactical training of the leaders of attack aviation must include a thorough knowledge of ground troops and their methods; the pursuit commander, on the other hand, can perform his essential duties with little or no training in infantry tactics. In the air, the attack commander, provided his command be equipped with defensive air power, has a rôle to perform which is simple and stereotyped in purpose and in theory, however difficult it may prove in the execution; the pursuit commander, on the other hand, never meets two situations which are alike in all particulars and can be solved in exactly the same way—he must be essentially an air tactician. This fact alone is a weighty reason on the side of specialization.

From the above discussion, it appears that attack aviation operates to the best advantage, when equipped with an airplane that has true defensive power in the form of rear guns. This gives also the advantage of additional fire power. Once this point has been conceded and the extra weight allowed, some further sacrifices may be made without seriously impairing its flying qualities. The load of bombs may well be raised from the 100 pounds, which the pursuit airplane may carry, to 400 or even 600 pounds. The addition of a third pair of machine guns, so located as to fire beneath the airplane, would make it a far more effective weapon for use against ground troops. Furthermore, it is doubtful if the question of armor should be dismissed at this time with no further trial, in spite of the unfortunate results of the first efforts. Of course, it is quite beyond the bounds of the practical to enclose engine, crew, and gasoline tanks, in armor which can

resist the normal impact of a .50 calibre armor piercing bullet. But light armor, capable of turning aside glancing blows, for portions of the bodies of pilot and observer, may prove, like the steel helmets of the World War, to be well worth the sacrifice of weight. It is apparent from these rough specifications that the attack airplane will more closely approximate the observation than the pursuit type, and indeed, in the interests of production, it may prove desirable to combine the two in one design. From the point of view of flying qualities, the requirements are much the same, except that, in the case of the attack airplane, ceiling is of negligible importance, although the same cannot be said of its concomitant, rate of climb.

The fundamental mission of attack aviation. Two branches of the air force, attack aviation and bombardment aviation, have so many characteristics in common, that much that is said here in regard to one, is almost equally applicable to the other. It is often difficult to draw a definite boundary line between the functions of the two forces. The distinction between them is usually based on the differences in the characters of their objectives: it is generally considered that attack aviation exists for the destruction of personnel, bombardment aviation for that of material. Though perhaps this is the most acceptable definition, which may be compressed into one sentence, it does not express a hard and fast rule. Attack aviation may sometimes be employed to destroy railroad tracks, to set fire to dumps, and to strike at structures of lighter build. Bombardment aviation may be employed for the destruction of personnel; usually however, this is done, only where some physical protection, such as a vessel at sea, or overhead cover on land, must be disposed of as a necessary part of the operation.

In view of the origin of attack aviation, it is of peculiar interest to ascertain authoritative German conceptions of the mission for which the new branch of aviation was designed. In his "Own Story," Ludendorff states this in the following words: "In order to provide aircraft support for the infantry, special battle aeroplane flights were formed. As had hitherto been done by individual airmen, they dived down from great heights and

flew along at a low level, attacking with machine guns and light bombs the infantry lines, the artillery, and, as the practice extended, the enemy's reserves and transport columns, as well as columns of troops coming up from farther in rear. Originally intended to be an 'auxiliary' arm to the infantry, these battle-flights were finally given important tactical tasks. Thus the air force gained a new field of activity of the greatest importance."

With some modifications, which time and experience have shown to be desirable, this quotation may be accepted today as a statement of the fundamental mission of attack aviation. But some readjustment of values is necessary, for, as will subsequently be shown, the attack of infantry lines is to be regarded as rather an exceptional practice. Moreover, many other duties have since been added. The primary duty of attack aviation is still determined by the demands of the infantry, for the most dangerous foe of the latter is always the logical objective of attack from the air. But this is no longer the sole element in the situation. Attack aviation may now be called upon to support combined operations of the air force by counter-battery action against antiaircraft artillery, either in land or in naval warfare; it is one of the principal weapons for attacking hostile airdromes; it is the logical instrument for the destruction of lighter-than-air craft; and its employment in conjunction with cavalry opens new vistas of usefulness to that arm. All of these duties will be discussed in greater detail subsequently.

Armament of attack aviation. The bomb usually employed by attack aviation is the fragmentation bomb, which is designed for use against personnel, either in the open or where the protection afforded them is very light. The bomb ordinarily is provided with a very sensitive fuse, which detonates the bomb immediately on coming into contact with any surface, without penetration. There are two sizes of bombs in general use, weighing 17 and 25 pounds, respectively. Both have an average radius of effective dispersion of about 100 yards from the point of impact. The bomb sight employed is quite crude; but so low is the altitude from which the bombs are dropped that, after a little experience, airmen become very proficient,

and sights are really unnecessary. Occasionally attack aviation uses demolition bombs weighing as high as 300 pounds. In this case, of course, the bomb must be dropped from higher altitudes. However bombing of this character is exceptional for attack units.

The attack airplane is normally armed with the .30 calibre machine gun, but a few units for especial purposes are equipped with the .50 calibre or 37 millimeter gun. It is instructive to compare the effect on ground troops of machine gun fire from the air, and the same fire when directed from an emplacement on the ground, disregarding the moral factor and considering only the physical surroundings. The methods of gunnery employed by attack aviation contain no differences in principle from those described in a previous chapter. As the target on the ground is stationary, for all practical purposes at the ranges employed, deflection on this account does not have to be considered as it does in air combat. Difficulties due to the motion of the airplane however, are equally great. It results from this that fire from the air is decidedly inferior in accuracy to fire directed from an immobile emplacement, all other things being equal; and this disparity increases as the range grows longer. But, of course, in practice, all other things are never equal, and this tends somewhat to redress the balance in favor of the airman. The target of the aircraft machine gunner is nearly always more plainly visible to the airman, than is the case with the ground gunner. The latter too, is comparatively immobile; he can do little to remedy an unfavorable location. The airman, on the other hand, can move his piece with great rapidity to that location which gives the most favorable conditions for firing.

In attacking from the air, the method generally used consists in the airplane diving in on the target, usually in the direction of its greatest dimension, during which fire is delivered with the front fixed guns. At the lowest point in the dive, which is ordinarily well under 500 feet, one or more bombs are dropped. The pilot then pulls up, when a slight turn of the machine enables the observer-gunner to bring the rear flexible guns into action. When the airplane is equipped with a third

pair of tunnel guns, these are fired during the dive and the immediate recovery from it.

The nature of attack aviation. It must always be borne in mind, if we are to obtain a correct perception of the nature of attack aviation, that its primary objectives are determined by the direct or indirect needs of ground troops. Nevertheless, it is a serious, if not a fatal, error, to ignore the peculiar characteristics of attack aviation, and to employ it in blind conformity with the detailed operations of ground troops. Such a procedure may not result in disaster, but it will certainly fail to utilize the full value of this arm. Nevertheless it is fairly common to find a belief that the employment of attack aviation should be made to dove-tail in with the minor tactics of infantry. It appears probable that such misconceptions as this are due to the natural error of attempting to understand the nature of attack aviation, by reasoning from analogy with other combatant arms. To one man, for example, attack aviation is merely a special form of artillery; to another, it is neither more nor less than a machine gun organization of rather unusual mobility. And each of these men, when faced with a situation in which he must determine for himself the proper employment of attack aviation, harks back to his knowledge of these other and better known arms, and adopts the methods which they have found advisable in similar cases. Naturally, he often finds himself in error. It is not meant by this to state that reasoning by analogy is necessarily faulty. It is, on the contrary, a most valuable method. But, in using it, care must be exercised not to be carried away by the resemblances, which may be greatly outweighed by the differences.

To proceed with such an analogy, the outstanding characteristic of attack aviation, as compared with other arms, is its mobility. In the small span of one hour, attack aviation can cover a distance which requires for infantry nine days of marching. Where the time factor is expressed for ground troops in hours or days, the unit for airman is the minute. On first examination, this may not seem to be a fundamental difference; strictly speaking, it is only one of degree; but, in its tactical and strategical effect, it is not a mere difference in degree, but one in kind. From a centrally located airdrome,

units of attack aviation may be thrown into the fight at any point of an extensive army front, in less than an hour. This characteristic enables the commander to correct many errors in foresight, and stamps attack aviation as the arm, par excellence, of opportunity. This then should be the guiding spirit in its employment. Of course, situations may sometimes arise where the bombs and machine guns of the airman can be most profitably employed in mere reinforcement of the fire of artillery or of infantry weapons. Such instances are rare: to adopt this emergency measure as a general rule, will result in the loss of many brilliant opportunities for effective surprise strokes, in which the full value of the air arm can be realized.

A second peculiar property of attack aviation, when compared with the other participants in the ground battle, lies in its vantage point for observation. It is largely on this account that too close an analogy with artillery proves fallacious and may lead to a failure to employ the air arm to best advantage. In discussions of modern warfare, we hear much of the difficulties of infantry-artillery liaison, and of the necessity for intimate cooperation if the essential team-work of these two arms is to be secured. This is entirely proper and desirable. But when these difficulties are transferred bodily to the support of infantry by attack aviation, and conclusions are drawn on this basis, they are likely to be wholly fanciful and to have nothing in common with reality. The majority of failures in infantry-artillery liaison are attributable to faulty communications. The man who lays the gun cannot as a rule see, with his own eyes, either the friendly infantry whom he supports, or the enemy on whom he fires. He must see through the eyes of a forward observer; and the latter, even when he has an unobstructed field of vision, is often unable to communicate his observations to the battery. In the case of attack aviation, these difficulties do not exist. When its commander arrives over the field of battle, he can usually see the dispositions of both friend and foe, spread out beneath him like a panorama. There is no danger, as in the case of artillery, that defective communications may cause his fire to run too far ahead of the infantry advance, or even fall short on the friendly forces. To cite other examples, the attack commander needs no message

from the infantry to inform him that they are being held up by a galling fire from hostile artillery, and would like immediate counter-battery fire; or, that hostile reserves in overwhelming strength are forming for counter-attack in a nearby wood. All these things he can quickly see for himself; often indeed, he will perceive sources of danger to the infantry before the latter are themselves aware of it, and can proceed at once to the assault.

Another reason which is sometimes advanced, in demonstration of the close similarity between attack aviation and artillery, is based upon the fancied necessity for coordinating the action of the former with the plan of artillery fire. This idea, at times, has even been carried to the extent of insisting that all artillery fire must cease on a given area, before it can be attacked from the air. This, in general, is entirely unnecessary. In pursuance of its customary objectives, attack aviation operates either above or beyond the trajectories of friendly artillery fire. Even in the exceptional cases where it must fly through them, the danger is not as great as appears at first blush: for it takes a direct hit to do any damage; compared to the danger infantry would run in such a case, the results are the same as if the artillery projectiles were all "duds." Of course, exceptional situations may require attack aviation either to reinforce artillery, or even altogether to replace it. But even in these exceptional cases, no intimate liaison with artillery is essential.

The danger of regarding attack aviation as being merely a special class of artillery has been dwelt on in some detail, because this has been at the source of much confusion of thought. As an example, there is a widespread tendency to parcel out attack aviation among the infantry units, down to include the division and even the brigade. An analysis of this error, and many others of the same general kind, usually shows that precisely the same plan has been followed for attack aviation as for artillery. Often the reasons for such a plan of employment, when expressed, include the old artillery *bête noire*, liaison. It is believed that enough has been said above to demonstrate the fact that this fear is groundless. Of course, it is not meant to contend that infantry and attack avi-

ation can operate effectively in complete ignorance of each other's plans and characteristics. Such a statement would be an obvious absurdity. It is necessary, first of all, that attack aviation have a thorough knowledge of infantry tactics; without this, it is quite incompetent to render good service. But, when we come to consider special situations, the only information that is really necessary for the commander to have, beyond his general knowledge, is the time and place where the action is to occur, and the general scheme of maneuver of the infantry. Thus equipped, the attack commander is in a position to strike blows just as effective, as if he were assigned to the smallest infantry unit he happens to support.

Before closing this set of comparisons, it is desirable to point out a marked difference between the action of attack aviation and of infantry. The blows delivered by infantry may be sustained for hours, and even days, and may be maintained at a high pitch of intensity for considerable portions of this time. Attack aviation, by contrast, strikes by a succession of intensive, but short lived, impulses, each of which rarely lasts for more than half an hour. On the other hand, this limitation of attack aviation is offset by a characteristic which has an important influence on its employment. When a higher commander once launches an infantry unit into a fight, he practically relinquishes all further control of it, for the duration of the action. It is therefore apparent that the influence of a higher commander in battle is exercised almost solely by means of his reserves, and is confined to their combat strength. He may therefore be pardoned if he hesitate long before throwing in an infantry reserve. It is easy to understand his natural qualms before the irrevocable nature of the step. But if he have a powerful reserve of attack aviation, he is spared much of the anxiety of this decision. When he launches it into the battle, he resigns further control of its power for only an hour or two at most. Upon the completion of that mission, the attack unit returns to its airdrome, and in a short time after landing—twenty minutes to an hour—may be given another task, its organization intact and its power undiminished, except for the airplanes actually destroyed in the first sortie.

The moral effect of attack from the air. When it is remembered that war is essentially a conflict of morale, it becomes evident that a study of the moral effect of any weapon is certainly not secondary in practical importance to an investigation of its physical powers. Of course, moral effect is always dependent in some degree on destructive power. But experience has shown that two weapons of equal might often produce decidedly different effects on the minds of men.

Testimony on the moral effect of attacks from the air is so voluminous that no attempt can be made, in the limits of this work, to embrace more than a very small part of it. However there is a sameness about it all, amounting almost to unanimity; so that a very few examples and opinions suffice to illustrate the whole.

The following quotations are taken from the records of the Fourth (Australian) Squadron, mentioned in a previous chapter. They consist in effect, of brief notes made on the operations report of each pilot, explaining the results of his mission. They were chosen at random, and the substance of them might be repeated in hundreds of similar reports:

“Fired 600 rounds at troops and transport on road Bihucourt-Sapignies from 800 feet. Saw many fall apparently hit and remainder scatter in all directions.”

“Fired 350 rounds at troops and transport at Achiet-le-Grand from 1,000 feet. Caused troops to scatter and seek cover.”

“Fired 100 rounds into cavalry from 900 feet on Ervillers-Bapaume road. Observed number of horses and men lying on road and remainder scatter for cover.”

The above examples are particularly interesting in that they illustrate the almost invariable reaction by ground troops to air attack during the World War: a complete surrender to the desire to escape. Apparently counter-attack was unthought of, until too late for effective action. Thus, the above squadron, during five days of the most intense activity in the spring of 1918, in the course of which hundreds of sorties similar to those described were made, lost only one pilot killed and one shot down and made prisoner. This fact alone proves the existence of a strong moral factor, for a column armed with rifles

and machine guns could never be attacked with such impunity if it vigorously defended itself: from the standpoint of purely scientific gunnery, the airplane certainly has no such decided advantage as these results would indicate. It must be remembered too, that these ground troops were by no means raw recruits; they were, on the contrary, seasoned veterans of German "storm" divisions, in the full flush of a seemingly great victory. Of course, the Germans, in common with nearly all other nations, had not rightly estimated the effect of air attack. But that they had at least a partial appreciation of its value, even as early as 1916, is shown by the reports of Sixt von Arnim, who stresses the moral effect on the Germans of British air ascendancy during the battles of the Somme. At the present time, at any rate, they have ample respect for air attacks: in the German Field Service Regulations, issued since the World War, the following conclusion is expressed, in regard to attack aviation: "The appearance of airplanes, flying in close formation at low altitudes over marching, fighting, or resting troops, produces a great moral and material effect on friend and foe."

The examples given above are entirely typical. In subsequent paragraphs other historical incidents will be related, all of which bear out the view of the overwhelming moral effect of air attacks. These examples are all, of course, taken from the World War. They cannot, therefore, be accepted as an invariable index of future results, without complete analyzation; and this is fraught with many difficulties. Psychology is far from being an exact science. Nevertheless, we must make an effort to determine, at least approximately, what portion of the moral effect of air attacks was due to transient causes, and what to permanent ones, if we are to obtain any conception of the future rôle of attack aviation.

Undoubtedly some of the moral effect was due to the very novelty of this method of attack. There is an inevitable period of lag which intervenes between the discovery of a new means of offense and the development of suitable methods of defense, even when the latter is destined to become fully effective. The World War was just such a period. In its beginning the thought of training troops to resist air activity was scarcely enter-

tained. Even by its end, although concealment from air observation had come to be thoroughly appreciated, little or no attention was paid to training infantry to meet attacks from the air with its own weapons. It was therefore, entirely natural and to be expected that the infantryman, on meeting a danger, which was unforeseen and which he had never been taught to combat, should seek safety in flight. The experienced soldier knows that such a reaction was inevitable. But it may be safely predicted that this condition will not last indefinitely.

Whatever the beginning of the next war may witness, its end will assuredly see all ground troops well trained to withstand this new form of attack. The details of this training necessarily must be left for future determination, but the general outline of a suitable tactical scheme of defense can be foreseen with reasonable accuracy, and will be further discussed in connection with the subject of antiaircraft tactics. When ground troops are once trained to fight airplanes as a matter of routine, some of the moral effect of air attacks will unquestionably disappear. But it may be confidently asserted that much of the effect—perhaps the greater part of it—will still remain: for the element of surprise will frequently enter into the situation. Training, of course, does much to diminish the frequency of surprise; its greatest value perhaps lies in this. Training, too, enables troops to recover more quickly from the effects of surprise. But it is doubtful if even the best of training can rob surprise of its full demoralizing effect during the actual time of its duration. When completely surprised, trained and untrained men show much the same reaction. Despite every precaution, the very rapidity of the airplane will tend to achieve surprise, more or less complete. There will rarely be more than a few minutes between the appearance of the airplane to ground troops, and the launching of the attack. The airman will, of course, do all in his power to increase the value of this natural asset, by utilizing all the accidents of terrain and of weather to conceal his approach. Moreover, the attack is usually of such short duration, that counter measures, unless taken from the very beginning, are almost certain to be too late. It would seem then, from the foregoing considerations, that the airman in future wars will still retain a cer-

tain advantage in the actual give and take of blows, although his superiority in this respect will not be as great as it was in the World War.

Attack aviation also possesses the manifold advantages of the offensive, which have been previously discussed. Surprise, of course, is one of the most important of these. But quite apart from its value, there still remains the superiority conferred by the initiative. For example, a column may not be surprised, but may nevertheless be compelled to fight under heavy disabilities. The example of the Turkish column, given in a subsequent paragraph, will further illustrate this.

In addition to these considerations, there is more than a suggestion in the history of the human race, that superiority in altitude carries with it a definite psychical advantage. One does not need to be a disciple of the "new psychology" to perceive in such common phrases as the "upper hand" and the "under dog," the imprint on the unconscious mind of a long series of combats, in which superiority in altitude was both the cause and the criterion of victory. Such racial memories are difficult to obliterate, no matter how inconsistent they may be with reason or proved facts. We see them working in the tenacity with which men sometimes cling to high ground or elevated locations, when no physical advantage is thereby gained. There is indeed an abundance of evidence in support of the believe that man has an inherent feeling of inadequacy in the face of an enemy whose physical location is the higher. The practical consequences of such a believe are manifest: any old soldier knows, although he may never have heard of the "inferiority complex," that the man who enters a fight convinced of the superiority of his opponent, is already half defeated. But in spite of the evidence in favor of the existence of this almost instinctive feeling of inferiority, it must still be regarded as no more than an unproved hypothesis. To what extent it explains the moral effect of air attack, cannot be determined at the present time.

Attack aviation and the column. From the foregoing paragraphs, it is evident that a column of troops on the march, whether infantry, cavalry, or artillery, is the natural objective of air attack. While of course, every special situation must be

considered as a separate thing, and handled on its own merits, it will nevertheless usually be found that assaults on columns offer the most far reaching results to attack aviation, with the same expenditure of effort. This is due primarily to the importance of the time element in every operation, and to the fact that attack aviation can count almost with certainty on influencing this factor, even though its assaults are negligible in destructive effect.

In marches by day, the column of the future will provide an anti-aircraft guard, with the same regularity with which it puts out an advance guard when approaching the enemy. On account of this, it is highly probable that attacks on columns will not result in complete demoralization—which was the rule of the World War. On the other hand, it is certain that strong attacks by aircraft will not be met by the troops of a column with entire equanimity. It shows marked inexperience in war to fancy that men will march along a road, under a hail of bombs and bullets, with the regularity and precision of a parade. No matter how nearly perfect their discipline, they could scarcely be expected to attain to such an ideal, under the usual psychical environment of a route march. Nor will any system of defense, based on practical experience, demand such a course. On the contrary, anti-aircraft training visualizes a totally different reaction. Under the threat or the reality of attacks from the air, the column either halts and returns the fire, or temporarily takes cover off the road, or else abandons the road altogether, effecting a partial deployment and moving across country. Whatever may be the plan it adopts, it is certain that the column cannot march at the rate which is customary when not in face of the enemy. Always, time will be lost.

The fact that the time is of the essence of the matter is strategic, and even in tactical combinations, is sometimes overlooked. Few historians have concerned themselves with speculating as to what might have been; it is too often regarded as an example of futility, scarcely worthy of the attention of the serious student. Nevertheless, if we examine the important battles of the world's history, we find that in a remarkably large proportion of them the decision of the day

would almost certainly have been reversed if the march of this column had been accelerated, or the march of that one retarded.

It is in this connection that the experience of the World War can so easily lead us astray. Stabilized warfare has many characteristics peculiar to itself. Among them is the ability to regulate the movements of troops with a high degree of exactitude. Everything can be foreseen, and all necessary marches conducted at night. The presence of a strong defensive zone gives assurance that no sudden thrust of the enemy can disconcert the movement, except through the medium of the air; and darkness reduces this to its lowest effectiveness.

But all this prevision, extending to the minutiae, is utterly impracticable once open warfare becomes the order of the day. Even in the World War (which never was completely divorced from stabilization on the Western Front), as soon as the elaborate trench systems of defensive zones were left behind, the time factor could no longer be foreseen, and bent to the commander's desire. Just in proportion as mobility ruled, schedules of movements could not be pre-arranged, and marches in daylight became necessary. If we assume that warfare of the future will be characterized by a far higher order of mobility than the protracted siege of France in 1914-1918, it is a logical corollary that time and space factors will enter into every situation in decisive fashion. The delay of hostile columns will often mark the difference between victory and defeat; and such delaying actions are the peculiar rôle of attack aviation.

Attack of a column. An historical example. It is not however, in delaying action alone that attack aviation may exert its power. Whenever a situation demands movements of troops in daylight, attack aviation may enter as the decisive force. A delay to advancing troops may turn aside defeat; a delay to retreating troops may easily change an orderly retreat into a rout. A weakened morale seems peculiarly unable to withstand attacks from the air.

A striking example of the value of air power, and particularly of the effectiveness of attack aviation, is furnished by the final phases of Allenby's brilliant campaign in Palestine. On September 19, 1918, the British armies began the offensive which

was destined to end in the annihilation of three Turkish armies, and the elimination of the Turk from further consideration as a serious factor in the World War. Allenby's scheme of maneuver was a penetration of the Turkish right, which rested on the coast, and an exploitation of the initial success by means of his numerous cavalry, which was to be poured through the breach. The plan succeeded beyond all reasonable expectation. But a critical analysis of the battle shows beyond all doubt that the nearly perfect consummation of his hopes was rendered possible only through many brilliant feats of air leadership.

In the initial attack, the main blow fell with crushing effect on the Turkish Eighth Army. Within a few hours, two British cavalry divisions were advancing up the coast, intent on the encircling maneuver which was to cut off the Turkish retreat. An unusual situation now developed: for while the Turkish right was crumbling under the weight of the British attack, the Turkish left and left center lay inert, in complete ignorance for two whole days of the fate of their comrades. The fact that such a condition could exist is directly attributable to the effectiveness of the British airmen: British observation squadrons gave the high command ample information of every Turkish move; British bombers completely destroyed the main telephone centrals at the commencement of the action, and paralyzed the Turkish communications; but, more important than even the latter operations, was the action of British pursuit aviation: it established a supremacy so complete that not a single hostile reconnaissance was successfully carried out. The Turkish high command was effectively blinded.

It now remained for attack aviation to complete the air operations, so brilliantly begun. By September 21st, the Turkish Seventh Army was apprised of the danger in which it lay, and had begun its retreat. As British cavalry had closed all routes to the northwest, the Turkish retreat began towards Beisan, in a general northeasterly direction from the original position of the Turkish Seventh Army. There was one principal road, running from the original front towards the northeast. Dawn of the 21st of September disclosed this road filled with Turkish columns, first with transport, and then with cavalry and

infantry, in full but orderly retreat. The critical part of the road lies between Balata and the Jordan river, where the route is winding, with mountains on one side and a sheer precipice on the other. This stretch of road was selected as the objective of air attacks.

They began shortly after sunrise, and continued throughout the day. The effect was indescribable. Men on motor vehicles deserted them in a mad scramble for safety. Frightened animals dashed in every direction, many of them over the precipice. All semblance of control vanished. It was a veritable *saue qui peut*. The day following, the attack continued. One column of Turks at length displayed a white flag, and countermarched, desirous only of surrendering. The Turkish Seventh Army ceased to exist. Scattered bands here and there escaped, only to be picked up by British cavalry or Arab tribesmen. When British cavalry passed along this melancholy road, two days later, they counted more than a thousand abandoned vehicles, among them eighty-seven guns. The results of these air operations appear all the more remarkable when the size of the British air force is considered. There were only two pursuit squadrons, and one bombing squadron. A fourth squadron, equipped with Bristol two-seater fighters, executed distant reconnaissance missions, and conducted the greater part of the attack missions also. A mere handful of men accomplished this result, a thing truly remarkable, when the disproportion between cause and effect is appreciated.

Methods of attack of a column. In the attack of a column, the airman endeavors, first of all, to secure surprise. This would appear to be difficult, in as much as the sound of the motor can usually be heard from a great distance. But troops will rarely be able to distinguish friend from foe by the characteristic sounds of a motor, and will never be able to open effective fire until the airplane becomes visible. On this account, troops in a defile, with obstacles to view on either side, are almost at the mercy of attack aviation. Mountain passes and bridges will therefore often be chosen as the objectives of attack.

Usually in the attack of a column, better moral effect is secured by attacking from rear to front. This will be the nor-

mal procedure against infantry and cavalry. But where wheeled transport predominates, it is desirable to reverse this procedure, in the hope of blocking the roads by hits near the head of the column. If the transport be animal drawn, it is particularly easy to produce panic and confusion.

At night, the effectiveness of attack aviation is much diminished, although it is by no means destroyed. It may therefore be accepted as a rule, that columns will invariably move by night, when within range of hostile aircraft, unless the exigencies of the tactical situation absolutely demand daylight movements.

Other targets of attack aviation. Next in importance to marching columns, as a suitable target for attack aviation, come the assembly areas of troops. This may be a bivouac area, or an area in which the troops are assembled prior to deployment on the line of battle. The massing of troops should always be vigorously attacked by the air force. On the other hand, troops deployed in thin lines form a poor target for attack aviation; and when a position has been well organized, and troops are protected by trenches, firing on them is rarely effective, even though the more nearly vertical fire of the airplane has an advantage over the flat trajectory fire of the greater portion of the weapons used by ground troops.

Similarly, artillery, when in the well protected emplacements of stabilized warfare, is not highly vulnerable to attacks from the air. But in mobile situations, artillery will rarely find time for the construction of suitable protection, and will accordingly be open to the assaults of attack aviation. It is true that the light armament of the latter does not enable it to inflict any serious damage on artillery material. But, in practice, batteries are rarely silenced by the actual destruction of the pieces: it is the personnel which is neutralized. When artillery is animal drawn, every effort will be made by attack aviation to locate the horse lines, and destroy or stampede the animals.

Against hostile cavalry, attack will be directed as a rule against mounted men and led horses. Dismounted cavalry presents a poor target for attack aviation. But mounted men are far more vulnerable, both because they experience added

difficulty in returning the fire, and because of the comparative ease with which horses may be stampeded. On this account also, led horses may be successfully attacked: it may well result in immobilizing the cavalry unit, and so depriving it of one of its most valuable characteristics.

Tanks cannot be successfully attacked with the standard armament of light fragmentation bombs and .30 calibre machine guns. Special airplanes, equipped with .50 calibre or 37 millimeter guns, and loaded with the 100 pound demolition bombs, must be used for this purpose. Much the same may be said of the machine gun nest, which proved the bane of advancing infantry in the World War. Primarily the attack of hostile ground machine guns is an infantry function: in its howitzer and 37 millimeter gun, it possesses weapons especially adapted to this work. Experience however, has shown that the greatest difficulty encountered by infantry arose from their inability to locate the hostile machine guns. These were always concealed with all the art at the enemy's command; but since first consideration was given to protecting them from the view of the infantry, it often resulted that they were easily detected by aircraft. Work of this kind is not that for which attack aviation is best suited; but in exceptional cases it may turn aside from its usual duties to render aid to the front waves of infantry.

Railroads are peculiarly easy targets to attack. The airplane approaches from the rear of the train, and endeavours to drop a bomb on the track just ahead of the locomotive, in order to derail it. A quick turn then enables the airplane to sweep the cars with fire. As equipped at the present time, the train has practically no means of defense, and accordingly all railway movement by daylight within the zone of activity of attack aviation, is now prohibited. But such a condition will obviously not continue. In the future, all trains which have to move in the combat zone will be armored, at least to the extent of splinter proofs, and provided on top with numerous anti-aircraft machine guns.

The destruction of lighter-than-air craft is essentially the work of attack aviation. In the World War this duty, like many others which are normally attack functions, was executed by

pursuit aviation. To consider first the attack of balloons, the armament of the balloon company has been described before, and the danger which the airplane ran in such assaults was mentioned. The aim of the pilot was to set fire to the hydrogen with which the balloon was inflated. For this purpose incendiary bullets were employed. Occasionally also the attacker fired on the balloon observer as he descended with his parachute. The protecting anti-aircraft fire usually took the form of a violent barrage, through which the airplane had to pass in diving to the attack, and again as it tried to escape. It may be anticipated that in future wars helium will largely supplant hydrogen as the lifting agency of all lighter-than-air craft in the combat zone. This will render an attack very much more difficult, as helium is inert and non-inflammable. It is, of course, possible to bring down the balloon, if enough machine gun bullets pierce the envelope. But this may require the airplane to make repeated attacks, for a large number of bullet holes would be necessary, and it is difficult for more than one airplane to attack at a time. The superior armament with which the single airplane has to contend makes it probable that balloon "strafing," practiced in the World War, is unlikely to occur in the future. Two methods promise results: the attacking airplane must be supported by others, which neutralize the anti-aircraft defense; and a more general use of bombs must take place. Several examples of the destruction of balloons by bombs occurred in the World War.

To consider now the attack of airships, much the same remarks can be made in regard to the substitution of helium for hydrogen. What the armament of the airship of the future will be, cannot be definitely foretold. But it is safe to assume, that if the airship ever takes the risk of combat, it will be armed with machine guns, so distributed that there will be little or no dead space. The airship however, in addition to the feature of its gas bags, has much the same vulnerable parts as the airplane, namely its crew, gasoline tanks, and engines. It may, therefore, be effectively attacked either by dropping bombs with sensitive fuses on the envelope, or by machine gun fire, in much the same manner as in the attack of an airplane. The airship has an advantage, in that it can afford the

extra weight involved in protecting the crew and gasoline tanks, more easily than the airplane. On the other hand, the airship is so slow and unmaneuverable, comparatively, that the rôle of attacking it may be undertaken by almost any type of airplane. In view however, of the superior armament and protection of the attack airplane, it seems better suited to the part than does the pursuit airplane. Even if the airship be provided with pursuit airplanes, which are hooked on to the ship, and can take off readily from these attachments, the number which can be carried in this way is too small to insure protection against determined assaults by attack aviation. Unless developments occur of so radical a nature that they cannot be foreseen at this time, the vulnerability and slow speed of the airship make it unlikely that it can ever be employed where it may encounter hostile airplanes. Its missions of a tactical nature will be confined to exceptional circumstances.

Hostile sea craft of all kinds are more appropriate targets for bombardment than for attack aviation, whose lighter bombs are ineffective against any but unarmored vessels. Against aircraft carriers however, attack aviation may operate effectively, for even the light bombs may damage the decks of the carrier enough to render them unsuitable for the use of airplanes.

Not only is attack aviation called upon to support ground troops, but it also assists the air force in combined operations. In such cases its rôle usually consists in attacking the anti-aircraft defenses, with bomb and bullet. Gun batteries are practically helpless against such attacks, and only the lighter armament need be feared. At times also, a number of attack airplanes, fitted with the special smoke laying apparatus, will put down a heavy screen to windward of the anti-aircraft defenses, and so tend to blind them. Experience has indicated that a distinct advantage lies with the airplane in this respect, for the smoke screen, if properly made of limited extent, hides the sky from the ground gunners, without seriously interfering with the marksmanship of the airmen.

Attack aviation as a reserve. From the considerations which were discussed in the previous paragraphs, it seems clear that attack aviation is peculiarly adapted to form a mobile reserve, rather than to render immediate and close

support to the leading waves of infantry. It is essentially an organ of the higher command. The function of any reserve is to permit the commander to exercise influence on the combat, in order to turn it in the desired direction. It is held out for the purpose of meeting unforeseen contingencies, or of exploiting unexpected opportunities. Evidently, when its rôle is considered, the reserve is of value just in proportion as it has mobility, since from the very nature of things, an immobile force must be stationed ahead of time, in the place it will be needed. If the commander's prediction as to the course of events should prove to be incorrect (and who can see into the future with any degree of accuracy?), an immobile reserve will be altogether useless. The reserve, in short, is a force of opportunity; this fact stamps attack aviation as peculiarly suitable in this rôle.

Another reason for its employment under the higher headquarters, lies in the fact that the usual targets of attack aviation are not found in that part of the combat zone for which the smaller units are responsible, but farther in rear of this area, where decisions for counter measures come within the sphere of responsibility of higher commanders. The very radius of action of attack aviation suggests the desirability of this step. From a centrally located airdrome, an attack airplane can move to any point on a line hundreds of miles in extent: such extensive fronts belong to commanders-in-chief of theatres of operations, rather than to divisions, corps, or even armies. The reasons which have most often been advanced against retaining attack aviation under the higher echelons of command, have already been shown to be groundless.

It should not, however, be concluded from the above discussion, that attack aviation must be kept in leash for hours and even days at a time, as for example, infantry divisions would be held by general headquarters. As we go up in the hierarchy of command from the division, it is generally possible to foretell with a reasonable degree of certainty that several hours will elapse, before any action by the higher headquarters becomes necessary. Thus it may be figuratively said that the division must think about today, the corps about tomor-

row, and the army about day after tomorrow. It will thus often be possible for the higher command, when it can be foreseen that no crisis will probably arise in the near future, to send its attack aviation out on missions in support of some subordinate unit, or even permit the attack commander to take out his unit "on his own," in search of targets of opportunity. In the former case however, it should be the rule that the attack organizations are not attached, but are merely in support, and that they revert to the control of the higher headquarters after each sortie.

Attack aviation as a reserve. An historical example. On March 21, 1918, the Germans began their final campaign on the Western Front. Its objective was, in the first "drive," to separate the British and French armies, and to hurl the former back on the Channel ports. Ludendorff, who directed this last desperate effort, believed that, once the two allies were separated, they could easily be defeated in detail. The immediate geographical objective was Amiens, the possession of which by the Germans would have been an almost insurmountable obstacle to British and French cooperation.

The main blow of the German attack fell on the British Fifth Army. It made a gallant defense—of that there can be no doubt. But it was at length broken and scattered, and, as an army, ceased to exist. On the right and left of the Fifth Army, the French and the British Fourth Army began to be hard pressed. For days, the integrity of the Allied front, and perhaps the outcome of the World War, hung in the balance. All depended on whether or not these units could hold, until help arrived. The allied reserves were unfortunately distant; the German reserves were near. The former were, of course, put in motion everywhere, to fill the gap left by the Fifth Army, and to buttress up the stubbornly fighting forces on either side of the gap. But the movement of an infantry division over a distance of many miles cannot be accomplished in a few hours; it is a matter of days. Cavalry too, requires time to come into action; and the cavalry strength had been allowed to dwindle to numbers which could no longer be decisive. Meanwhile every road in rear of the advancing German lines was filled with transport and with long columns of troops, pressing for-

ward insistently to exploit the initial success, and to widen the breach which had been driven between the British and the French. It was a critical time in Allied affairs: not since 1914 had so desperate a situation faced the powers of the Entente. The decision, it could easily be seen, hinged on the time factor, and time favored the Germans.

In this emergency, the air force was resorted to: whether in full appreciation of its powers, or merely in desperation, no one can say. Practically all the available air force of the Allied powers was diverted to the work of attack aviation. In the north, the British airmen were ordered to count no cost in men or in machines, but to fling themselves at the German columns in rear of the leading waves, attacking them again and again, to the limit of the physical endurance of the pilots and gunners. In the south, the French airmen received essentially the same instructions. A scene of unprecedented air activity followed. No wonder the Germans were unprepared for the massed air attacks that ensued. Some conception of the effect of these attacks may be obtained from impressions of those who saw them. An Allied pilot, in a letter from the front, quoted by Middleton, gives a vivid picture of the demoralization produced in two German divisions by one of these concentrated air attacks, which he describes, in characteristic fashion, as "a pretty bit of work." "Fully 25,000 Germans," he goes on to say, "were advancing below—under our very eyes, from 10,000 feet above—when from the direction of Chauny there swung round seven French fighting squadrons, 105 machines, glinting in the sun. They maneuvered beautifully. . . . Down swooped the Frenchmen with a whiz. They spread fanwise. A might crescent of 100 pound bombs fell, then another, then small stuff. Hundreds upon hundreds were killed. I saw 5,000 men flat on their faces at once trying to escape."

The attack described above was, of course, only a small part of what was occurring along the entire front of the German assault, and back in his rear areas to include the main supply establishments. By day and by night, the Allied airmen kept smashing away at everything German that moved within range. That these efforts were attended with success is

attested by Ludendorff himself, who states, in regard to his forces in this operation, that "all troops, especially mounted troops, had suffered heavily from bombing by hostile airmen." In a previous paragraph, the records of an Australian squadron were quoted. These operations were, of course, petty enough incidents, in themselves; in the vast drama that was being enacted at the time. But if we remember that these examples constituted only a small part of the work of one squadron in one day, and multiply this by the number of squadrons engaged on similar missions, and by the number of days on which they flew, the sum total of destruction, and above all, of delay, mounts up to a very important whole. The German attack, although it overwhelmed the Fifth Army, nevertheless failed in its objective: Ludendorff frankly admits that, strategically, the Germans had not achieved what they had hoped for.

Many things contributed to the failure. Where many factors, most of which are not susceptible of measurement, enter into a situation, it is absurd to state that any one of them alone caused the defeat. But the Allies were fighting for time. Every hour's delay of the German advance conduced towards its ultimate cessation. The allied airmen may therefore be pardoned if they believe that it was primarily their efforts, which gave to the allied infantry its needed breathing spell, and enabled it at last to stem the German tide.

Attack aviation and cavalry. In a previous chapter, it was pointed out that the advent of aircraft had unquestionably resulted in lessening the importance of cavalry as an agent of reconnaissance. But in compensation, the airplane has really increased the possibilities of cavalry as a combat force. The important characteristic of cavalry, as compared with other ground troops, is its mobility. It is apparent on the face of it, that the effectiveness of cavalry is greatly enhanced, when it can be informed of the situation with certainty and regularity; there will then be offered to it many times the number of opportunities for sudden and effective strokes which it would have if uninformed. This service the airplane can render.

This characteristic of mobility, is, of course, possessed by the airplane in the highest degree. So, it might well be

thought, on superficial examination, that the airplane will finally displace cavalry altogether. But cavalry has, in a certain degree, those qualities, the lack of which constitutes the greatest defect of the air force as an independent combat agency. Cavalry, as compared with aircraft, can exert a more sustained force. It can hold, as well as take.

It appears also, that the airplane can give to cavalry a supporting fire power, which it lacks at present. It is true that cavalry divisions are usually accompanied by horse artillery. But the number of guns is always small, and the high mobility of cavalry renders the necessary liaison extremely difficult. We have seen previously how great a source of trouble this becomes with the infantry. Obviously, this will not be lessened with cavalry. It suggests at once the great results that might be attained by cavalry and attack aviation, operating in conjunction. Of course, there are no historical precedents to guide us, and the practicability of such combined operations must be left to the future to decide. But such a possibility is at least worthy of the most serious consideration.

The air situation. In general, attack aviation works most effectively, in so far as mere percentage of hits is concerned, when its fire is conducted by single airplanes. As the attack unit increases in size, the initiative and accuracy of the individual airman tends to diminish. But other elements of the situation must be taken into account, and these, in general, favor the use of larger numbers. The principle of mass has already been discussed, and its undoubted application to the tactics of pursuit aviation demonstrated. It is perhaps, not of equal importance in the case of attack aviation, but nevertheless is worthy of profound consideration. First of all, a large number of airplanes can, in general, attack ground objectives with greater safety than a small number; for the larger force can bring all the agencies of anti-aircraft under fire, and so effect a more nearly complete neutralization. Another reason—and probably a more important one—is the moral effect of numbers. We have no great amount of experience to guide us in this matter, for in the World War, there were never the large units which are visualized for the future. Nevertheless we cannot doubt the disproportionate increase in moral effect that

will come from an overwhelming, devastating blow, which only mass action can give. In general therefore, the principle of mass will govern the action of attack aviation also.

In general too, the air situation will require the use of formations, at least. At the low altitudes at which attack aviation operates, it is more difficult for hostile pursuit aviation to maneuver, due to the restricted space. But this by no means provides immunity from air attack. For example, in the World War, the activity of German "battle flights" finally caused the American First Army to assign the First Pursuit Group to the sole duty of combating these attack units. In spite of the difficulties, the number of enemy aircraft destroyed by this organization over a given period, did not diminish as a consequence of this change of mission.

The effectiveness of attack aviation, like that of all aircraft, depends in part on the relative combat strength of the two opposing pursuit forces. Beyond a certain point, numbers of defensive airplanes do not increase security from air attack. Nevertheless, the air situation will often require all attack airplanes to operate together so that friendly pursuit aviation can support all of its sorties in full strength.

CHAPTER VII

BOMBARDMENT AVIATION

Progress since the World War. In the development of its tactical power, bombardment aviation has clearly outstripped its fellow members of the air force since the World War. The reasons for this progress are easy to understand when tactical power is analyzed into its elements. It is composed of three essential factors: there must be proper strategical dispositions; the weapons that are employed must be of adequate destructive ability; and tactical methods must be sound and in accordance with the principles of war. Unfortunately, progress in the development of tactical methods is necessarily slow in times of peace. It really demands the impetus of war itself, or at least extensive peace time experiments, which are forbidden by reasons of economy. On this account, the progress of pursuit tactics was halted at the squadron stage by the Armistice; even in the case of attack aviation, although its rôle in air combat is somewhat stabilized, it had scarcely begun its career as a factor in the infantry battle, when peace put an end to further tactical development.

But with bombardment aviation the cessation of hostilities did not produce such prejudicial results, for the reason that tactical methods had reached a fairly high stage of development by the end of the war. Of course, it is not meant by this that bombardment tactics had arrived at perfection, and that no further improvement is possible. Such an idea is manifestly erroneous. But in so far as future development can be foretold, it appears that bombardment tactics are susceptible of no such radical changes as are the methods of attack and of pursuit aviation. It seems, therefore, almost a paradox to speak of the progress of bombardment aviation since the World War, until we reflect that its development has been largely governed by the other two elements of tactical power, the strategical and technical factors. We may, for the present, eliminate all strate-

gical considerations, since they obviously apply to all branches of the air fore equally.

There remains technical, or mechanical development. While this undoubtedly moves at an accelerated pace in war, nevertheless it proceeds on its even advance in peace also. In so far as destructive power is concerned, the weapons of both attack and pursuit aviation were nearly adequate to all their needs, even in the World War. But bombardment aviation was by no means in like case. On the contrary, when the physical power of the modern bomber is compared with its prototype of the World War, it is evident that remarkable progress has been achieved. The bomber now stands forth as the supreme air arm of destruction, with vastly enhanced power. When nations of today look with apprehension on the air policy of a neighbor, it is the bomber they dread. It is this heavy artillery of the air, which drives home to combatants on the ground the importance of air power. When Marshal Foch foresaw the possibility of terminating a war by air attacks on civilian populations alone, it was undoubtedly the bomber he had in mind.

The development of the bomb. In the first days of bombing, early in the World War, the so-called bombs were extremely crude affairs. They consisted, for the most part of 75 millimeter shells, which had been condemned as unsuitable for artillery use, and converted into bombs by adding fins to keep them straight in flight. At times, even the fins were omitted. These projectiles were, as may easily be imagined, thoroughly unsatisfactory. Little was known of the actual trajectory of the bomb in flight. Bomb sights moreover, were primitive, and entirely lacking in accuracy. Consequently, air bombing became in practice a hit-or-miss affair, with an excessive percentage of misses. Indeed the early bomber did little more than heave his cargo over the side, and hope for the best. He could count on hitting a city, if it were a large one. Moreover the converted shells not only had poor "flying" qualities, with a corresponding lack of uniformity in their trajectories, but they were also uneconomical in the size of the bursting charge. A shell for artillery use must have thick steel walls, in order to withstand the high pressures necessary to produce in the gun the initial velocity, which gives the shell its range.

As a result of this requirement, the amount of explosive contained in the shell itself forms only a small proportion by weight, of the filled shell. With the bomb, on the other hand no such pressures have to be contended with, and no such thickness of wall is required: accordingly, it contains, as a rule, the same weight of explosive, as of container. This is many times the proportionate amount of explosive contained by any shell.

When we contrast this beginning with the bomb of today, the amount of progress is apparent. In size alone, there has been a tremendous advance. From the 15-pound projectile of the early days, with its 1¼ pounds of bursting charge, we have progressed to the 4,000-pound bomb, with its explosive charge of approximately a ton; and this huge bomb by no means sets a natural limit in size. Along with increased size has gone increased accuracy. This is due, in great part, to the development of the bomb sight, which will be discussed later. But much improvement has been wrought in the bomb itself. An estimate of the probable line of flight of the bomb is no longer a mere guess. Bombs have been studied and experimented with, until their trajectories are now uniform, and accurately predictable. The general tendency has been to design larger and larger bombs, and since a greater amount of knowledge has been available in each successive effort, it is now the general rule that the larger bombs are also the more accurate "flyers." In consequence of these many improvements, the bombs developed since the World War, are much more effective than their predecessors.

Demolition bombs. The missile more frequently employed by bombardment aviation is the demolition bomb. It consists of a body of steel, to the tail of which are attached fins, generally four in number. Nearly all demolition bombs contain about 50 per cent by weight of high explosive, consisting either of T.N.T., or of a mixture of T.N.T. and Amatol. The effect produced by the demolition bomb in war, cannot, of course be measured with accuracy, for the moral factors enter into it. And even aside from the moral effect, there is an actual physiological effect produced on personnel by a blast of high explosive. In the World War, men were known to pass through barages of high explosive shell untouched by fragments, but so

shaken by the effects of concussion as to be unable temporarily to make accurate use of their physical powers. It must be recalled too, in this connection, that the amount of high explosive in a shell is small as compared with that in the aircraft bomb. It is possible however, to obtain some conception of the effect of the demolition bomb, by the time-honored criterion of the size of the crater it will make in the earth. While this standard leaves much to be desired, it furnishes at least some basis of comparison as to the destructive powers of two different bombs. The following table gives the effect of the more commonly used bombs:

Weight of Bomb in Pounds	Diameter of Crater in Feet	Depth of Crater in Feet	Diameter of Danger Space to Personnel in Feet
100	12	6	200
300	20	6	300
600	25	7	400
1,100	30	7	600
2,000	40	14	1,200
4,000	65	16	2,400

A consideration of importance in naval warfare or in coast defense, is the mining effect of the demolition bomb on sea craft of various types. None of the bombs, smaller than the 600-pound size, has any appreciable effect on armored vessels, when dropped in the water alongside. The latter bomb is effective however to a distance underwater of 15 feet. The mining effect increases, of course, with the size of the bomb, and reaches to a distance of 75 feet with the 4,000-pound bomb. On unarmored vessels, the effect is felt at a much greater distance. Even the 100-pound bomb has an appreciable effect at a distance of 25 feet, with the 4,000-pound bomb is effective up to 200 feet.

The armor piercing bomb. Among aircraft missiles is an armor piercing bomb, which is designed to penetrate the protective deck of the vessel, and to explode below decks through the action of a properly timed fuse. When compared with the

demolition bomb, the armor piercing bomb has the great advantage that its explosive effect is felt in the very vitals of the vessel. The demolition bomb, when a direct hit is secured, creates havoc with the upper works of the ship, but the explosive effect occurs before penetration, and therefore is not applied at the most vulnerable point. But the armor piercing bomb has several disadvantages. In order to obtain the necessary strength for penetrating armor, the case of the bomb must be much heavier. The proportion of high explosive must, therefore, be reduced to an amount comparable with the shell, and one of the advantages of the demolition bomb surrendered. Moreover, the armor piercing bomb must be dropped from high altitudes, in order to obtain from gravity the necessary striking velocity. This is not a serious disadvantage, as a rule, for bombing of this character will usually be done from well above 7,000 feet. In some cases however, it might prove a serious defect; a low ceiling, for example, might render the armor piercing bomb useless, where attacks with the demolition bomb would be feasible.

A further disadvantage lies in the necessity for greater accuracy when using the armor piercing bomb. The demolition bomb is many times more powerful in mining effect, weight for weight, than the armor piercing bomb. The latter is therefore almost useless, unless it obtains a direct hit. The demolition bomb, on the other hand, while it does a great deal of damage on a direct hit, is probably even more destructive, when it explodes in the water alongside the ship, within the distances mentioned above, and from 20 to 40 feet under the surface of the water. For these reasons, it seems probable that the demolition bomb will, in general, prove to be the more useful of the two in attacking sea craft. However, our information is entirely too meager at this time, to draw a positive conclusion. Further experimentation is highly desirable. In particular, the armor piercing bomb has a sphere of usefulness in the attack of certain classes of permanent and semi-permanent land fortifications, where penetration is essential and no mining effect possible.

Chemical bombs. Among those who are unacquainted with the subject, there arose in the World War, a belief that chemical warfare was the very last word in barbarity. Those

who have had opportunities to compare the relative suffering caused by gas and by shell fragments may well doubt this conclusion. In fact, medical statistics indicate that gas was perhaps the most humane of all methods of putting an enemy out of action, since it resulted proportionately in fewer deaths and fewer permanent injuries than any of the other common agencies of warfare. However, the misconception has become widespread, and the matter is definitely settled for Americans, at least. The United States has formally agreed by treaty to outlaw the use of poisonous gases. However, all the nations of the world are not signatories to that treaty; and we possess no assurance that the next war may not find us involved with a non-signatory power, that would not hesitate to use this weapon. Accordingly, for mere purposes of self-defense, it is the part of wisdom for America to continue her investigation of chemical agents. Moreover, many of the agents, which are usually classified as chemical, are not banned by treaty.

There are three kinds of chemical bombs in general use: incendiary bombs, smoke bombs, and gas bombs.

Incendiary bombs. The purpose of the incendiary bomb is sufficiently described by its name. The difficulties that have been experienced in setting fire to different types of targets have resulted in the development of two classes of incendiary bombs. The intensive type of bomb is designed to fire larger buildings or dumps, and is filled with a special thermit or other similar material, which burns at a very high temperature. The scatter type of bomb, on the other hand, is designed to spread burning particles of smaller intensity over a wider space. It is therefore preferred against such objectives, for example, as fields of ripe wheat, which are easy to ignite, but are widely dispersed.

Smoke bombs. The smoke bomb which has been most widely used, weighs 50 pounds, and makes use of white phosphorous as the smoke producing agency. Experiments that have been conducted with this bomb, indicate that it will cover with smoke an area of about 100 yards in diameter, or that it will make a screen about 800 yards in length and 100 yards in width, in a wind of 10 miles an hour. The smoke will remain, on an average, about ten minutes. Another type of

bomb in use by the Navy, floats on the surface of the water. While these bombs have proved quite successful in experiments, the development of the smoke laying apparatus bids fair to replace the smoke bomb in a large class of operations where it formerly was employed. Of course, the smoke bomb will still retain its usefulness, even for laying screens, where the airplane performing this mission runs an unnecessarily great risk of being shot down.

Gas bombs. In the World War, even after both sides had begun to make common use of poison gas, aircraft bombs were rarely used for this purpose. This seems all the more remarkable, when we recall that the bomb may carry a far greater proportion of the chemical than the shell, which nevertheless was often employed. Several reasons were responsible for the failure to make use of the bomb. As a usual thing, gas attacks must attain to a certain concentration, in order to be effective. In the World War, for the greater part of its duration, bombs were small. The 300-pound bombs were certainly but a very small proportion of the total number dropped on the enemy. Moreover, mass operations of aircraft were just beginning to develop. Even by the end of the war, it would have been difficult for any combatant to put over the enemy's lines enough bombing airplanes to produce really effective gas concentrations. It must be remembered, too, in connection with this, as well as with many other phases of air warfare, that the airplane was a new invention, and it requires time for men to realize its many possibilities.

In consequence of these facts the air force was not in the best of positions to wage chemical warfare, which was accordingly left to artillery and to special chemical troops. Furthermore, suitable targets for gas attack were usually well within range of artillery, so that no impetus existed for the development of aircraft chemical bombs. However, the conditions that prevailed in the World War are no longer the same. Many of the objections to gas attacks from the air have already vanished, in so far as physical limitations are concerned; moreover it can clearly be foreseen that the remainder will be altered in the near future. Indeed, no feature of future warfare promises

consequences of so terrible a nature as surprise attacks with poison gas, delivered by aircraft on unsuspecting populations.

Of course, the United States is bound by treaty with the greater military powers to refrain altogether from the use of poison gas, as stated before. Moreover, it seems not unlikely that similar agreements may soon ban the indiscriminate bombardment of populations, which are largely civilian. We are therefore doubly bound to take no offensive steps in this direction. But the results of attacks of this character may be, as Marshal Foch suggests, decisive. In view of this possibility, a nation at war, which sees not other chance of achieving victory or of avoiding defeat, will be sorely tempted to resort to this method, however inhumane it may be considered in the general opinion of mankind. We have ample historical precedent for believing that a desperate belligerent may not be able to resist such a temptation, in spite of the effect of unfavorable public opinion. In emergencies, there is a tendency for control to be seized by the more radical elements. On this account, it behooves us to consider the weapons that may be used, if only from a standpoint of defense.

For most semi-persistent and non-persistent gases, the 300-pound bomb is best suited, as it carries the weight of gas which gives the most effective concentration. For the persistent types of gas however, such as the well-known mustard gas, it is more desirable to use small amounts, and to scatter them more widely; on this account of the 25-pound bomb is considered more suitable.

Fuses. There are a number of types of fuses used in bombs, differing both with the kind of bomb, and with the nature of the target it is to be dropped upon. Chemical bombs, like the fragmentation bombs previously described, are usually armed with instantaneous fuses, in order that the bomb may burst before penetrating the soil. Demolition bombs are similarly fused when intended for use against personnel; however, when employed against such targets as naval vessels of land fortifications, they are armed with delayed action fuses of various lengths of time, depending on the penetration desired. For use against light objectives, such as balloons and airships, supersensitive fuses are employed. Bombs are usually pro-

vided with both nose and tail fuses, in order the better to insure detonation. All fuses are so constructed that they are "safe," until the bomb has been dropped from the airplane, and has been some time in flight.

Bomb sights. Along with the progress that has been made both in the size and in the design of the bomb itself, there has gone a marked development in the bomb sight. The crudity of the earlier sights has already been mentioned. Even by the end of the World War, bombing was very inaccurate except under the most favorable conditions. With the improvements which have taken place, not only has there been a notable increase in target range accuracy, but also many of the tactical disadvantages that formerly obtained in bombing have been removed; so that the tactical power of bombardment aviation has been greatly enhanced.

Within the limited scope of this chapter it is impractical to describe the tactical details of the sights of the past, and to show how the major defects have one by one been eliminated. It must suffice to say that present knowledge in regard to bomb trajectories is much more accurate, and that the necessary corrections have been embodied in the new sight, and to add to this a description of the methods of operating the two. It is perhaps in the latter respect that the tactical disadvantages under which the bomber formerly labored have been most alleviated. In using the older sights it was necessary for the bomber to approach the target either exactly into the wind or else exactly with it. In peace time bombing practice this is not always a marked disadvantage, for the direction of the wind can usually be told with the desired degree of accuracy. This is not always the case, however, even in practice bombing, and any error in piloting the airplane results in a corresponding error in the bombing. Moreover, in war, it is obviously undesirable to be limited in the direction of approach to one azimuth line. Then, too, this line had to be followed accurately. It sounds quite easy to do this, but in fact flying on an exactly straight line is somewhat difficult; and the problems of the pilot were increased with the older sights, because he was unable himself to view the target through the sights, but had to rely on the bombing observer, who could assist the pilot in keeping the airplane properly aligned, only by the crude method of

waving his hand in the direction he wished the machine to be turned.

But the greatest obstacle to good bombing, from both a technical and a tactical standpoint, lay in the fact that his straight course at a constant speed and altitude had to be maintained for several miles, in order that the observation and settings necessary for accuracy might be made. Considering these difficulties, a surprisingly high degree of accuracy was obtained in actual target practice. But it is apparent that the tactical disadvantages which such a sight imposed would inevitably decrease the accuracy of bombing very greatly in war. In a subsequent chapter, it will be seen that the accuracy of anti-aircraft guns depends on the assumption that the speed, course, and altitude of the airplane remain the same during the time of flight of the anti-aircraft projectile, as well as in the period preceding the actual discharge of the gun, during the time of flight of the anti-aircraft projectile, as well as in the period preceding the actual discharge of the gun, during which the observations for the shot were being made. Of course, the pilot of the airplane being fired upon, will take good care to see that these conditions do not obtain, wherever his own mission permits him to do so. But with the older sight, he could not change either speed, course, or altitude, when approaching the target, without sacrificing accuracy; he was, in short, impelled to fly under conditions which were in every respect ideal for the anti-aircraft gunner. The newest sight does much to remedy this defect. The bomber may now approach from any direction, he may change speed, or he may alter his course in either a horizontal or a vertical plane, in order to avoid anti-aircraft fire. He must of course fly a straight line just before discharging his bombs, but for a few seconds only, and not for many miles, as was formerly the case. Furthermore, to assist the pilot in this, a new device now enables him to see for himself when the sight is on the target. Experiments with the new sight show that its accuracy, from the purely technical point of view, is far greater than the old; its tactical superiority in actual warfare is apparent.

History of the tactical development of bombardment aviation. In the World War a marked distinction eventually came to

be made between day and night bombardment aviation. Protected to a large extent by darkness, the latter operated with comparative safety, and was an effective agency of destruction, physically and morally. The history of day bombardment aviation was, however, a chequered one. The single bomber is peculiarly helpless in a fight with a flight of pursuit airplanes. And although bombing airplanes have considerable power of defense, when in formations, nevertheless, if unsupported, they will eventually suffer defeat. For some time in the World War the losses of day bombardment aviation were so severe that there arose a conviction in many minds that the results achieved were not worth the cost. Germany, notably, came to this conclusion, and practically abandoned the use of this branch of the air force. After somewhat similar experiences, the Americans also began to entertain doubts of its value. But from every side there poured in unmistakable proof that the moral effect of day bombing on the enemy was out of all proportion to the small number of airplanes employed and the small weight of metal and explosive they could discharge in one "broadside."

The Americans were accordingly very loath to give up so valuable a weapon, and instead turned their attention to devising means of reducing the truly demoralizing losses. Greater stress began to be put upon formation flying; once the feeling became fixed that safety lay in "tight" formations, and that the straggler was doomed, a forward tactical step had been taken. Equal emphasis was laid on gunnery. When all the gunner-observers had become good shots, capable of ignoring their own assailants, and concentrating their fire on the assailants of their comrades in the formation, there arose that feeling of group confidence, which lies at the basis of effective tactical methods. But perhaps the greatest forward step, in a tactical sense, was due to making suitable arrangement for cooperative measures between pursuit and bombardment aviation. The difficulties of "close" protection have been discussed before; because of these, no such plan was contemplated. But the reaction of hostile pursuit aviation to day bombardment attacks was always immediate and violent. Even where its general attitude was defensive in character, German pursuit units would follow day bombardment aviation

far into the latter's lines, attacking again and again. If other evidence had been lacking, the determination with which these attacks were pressed home was sufficient in itself to show the effect of day bombing on the enemy. Based upon the observed methods of the Germans, a plan of cooperation was arrived at, which was simple enough in principle. A bombing raid would be planned. From a study of the enemy's situation—and in particular his known or suspected listening posts and airdromes—it was usually possible to estimate within reasonably accurate limits, the time and place his pursuit units would fall upon the day bombers. It remained then to bring to this place a superior force of American pursuit aviation, preferably at the time when the Germans had just become engaged with the bombers and so were at a disadvantage.

An example of the results of such an operation as that described occurred on October 4, 1918. On that date, several bombardment squadrons were sent to attack Dun-sur-Meuse and Landres-St. Georges. They flew as directed, in column of squadrons, with the American Ninety-Sixth Squadron in the lead. As was expected, German pursuit units made their appearance, and violently assailed the bombers. The Germans were equipped with Fokkers, and numbered about thirty airplanes. Soon they were thoroughly involved in the attack on the bombers. In the midst of this fight, two squadrons of the American Second Pursuit Group arrived over the scene. In numbers, they approximately equaled the Germans, but the well timed attack caught the latter at a distinct disadvantage. In the resulting combat, thirteen German airplanes were destroyed—nearly half their combat strength—with a loss to the American of only one machine.

Of course, by no means all of the combined operations of American pursuit and bombardment units, were as successful as the example given. But this combat was in striking contrast to the earlier unfortunate experiences, and such a result could never have been achieved except by following sound tactical methods. Even though the results of sorties were not always so favorable to the Americans as in this case, nevertheless, by this time, losses were no longer incommensurate with the damage inflicted. Day bombardment aviation was seen to be

an arm well worth retaining, and this became a settled American policy.

The objective of bombardment. From the very nature of the weapon, bombardment aviation is used for strategical purposes rather than tactical, using these two words in a rather general sense. It is equipped with such powerful means of destruction, that it is obviously uneconomical to employ it when the lighter weapons of attack aviation will suffice. Accordingly, the use of bombardment aviation against personnel is restricted to circumstances where they are well protected, or so concentrated as to warrant the use of the larger bombs. This objective must be regarded as exceptional. Of course, all action in war is governed by the demands of the special situation, and it needs no very vivid imagination to conjure up one, where it would be justifiable to use all bombardment units against the very advanced waves of infantry. Another exception, which will be of more frequent occurrence, is the attack of hostile airdromes in conjunction with attack aviation. But in general, the objectives of bombardment aviation lie well in rear of the enemy's front line, in land warfare.

The general objectives of attack may be grouped under four categories. First, in order of importance, in warfare between states separated by a land frontier, comes the bombardment of large centers of population; essentially, the decision to resort to this measure, is a political one. The next class of objectives to be considered is the enemy's system of supply; this includes the factories where munitions are made, the most advanced depots where final issue takes place, and the intervening means of transportation and storage. A third class of objectives that will most frequently bring bombardment aviation to the land battlefield, consists of fortifications, which cannot be effectively neutralized by other agencies. Finally, in the special case of coast defense, bombardment is a powerful instrument for the destruction of sea craft of all kinds.

The bombing of towns and cities. To the student of air warfare of the future, the status of air bombardment in international law is a matter of profound concern, since it may have far reaching effects on the strategical employment of the air force. It must, therefore, be briefly considered, even though

it is essentially a political matter. In the World War, if we except the bombardment missions which were really attack in nature, a large proportion of bombing raids—certainly the most conspicuous ones—were directed against towns and cities. Paris and London were the favorite targets of the Germans, while the Allies in turn operated against the Rhine towns. In actual fact, the bombardment was practically indiscriminate. The civilian population nearly always suffered more casualties than the military forces; nor was this result entirely accidental and unpremeditated. There can be no doubt that the effect on the civilian population was often the real motive of the attack. But, on the other hand, it is equally clear that neither side intended or hoped, to achieve a decision by paralyzing the “home front” and slaughtering untold numbers of non-combatants. Throughout the war both sides maintained the pretense that their bombing attacks were directed solely against military objectives. For example, some German aviators, who were forced to land and were made prisoners in the course of a raid on Paris, were found to have orders prescribing the targets they were to bomb, and specifying that the objects of attack were used “solely for military purposes.”

All this, of course, may be dismissed as a mere mask, to cover a criminal purpose and to protect the perpetrators from the fate of the war criminal. But it is scarcely just to jump to this conclusion. The true motive of the attacks is revealed in the statement of Ludendorff, which is corroborated by von Hoepfner, who commanded the German air forces in the latter part of the war. The latter states that one of the main purposes of the attacks on London was to compel England to “retain a large portion of her air strength at home,” instead of putting it on the front, where military considerations alone, untinged by the political, would almost certainly have placed it. Of course, it is quite clear from this statement that the attacks were intended to frighten the civilian population. Had soldiers alone, or even dumps and munition factories been the true objectives, it would have been rather unnecessary to go all the way to London to find them. The Germans believed that the clamor of civilians for protection would find a ready echo among the governing politicians who would force the military

authorities to protect the city. The event seems fully to have justified their belief.

But we do not need the *ex parte* statements of German leaders to prove that the Germans intended to inflict no more damage on the civilian population, than was absolutely necessary to accomplish a direct military purpose. The facts speak for themselves. No military man can regard the sporadic raids on London and Paris as a serious effort to accomplish a decisive military result. They were, after all, quite petty affairs, compared with what the Germans might have accomplished, even with the limited means of that time; there was none of the mass effect, none of the thoroughness, which characterized every major German operation. If sheer "frightfulness" had been the aim, a mass attack with gas bombs on London, for example, would have produced an infinitely more demoralizing effect on the unprotected population. The very aspect of these air attacks bespeaks their purpose: a diversion, pure and simple, and a remarkable successful one.

History then, contains no example of a serious major air campaign directed against the unarmed portion of the enemy's population; nor can anyone accurately predict the future. But that such a campaign may well be a feature of the next war, is evidenced by the opinion of Marshal Foch, which was previously mentioned. Moreover he is not alone in entertaining such an idea. Captain René Fonck, leading French "ace" at the end of the World War and later member of the Chamber of Deputies, clearly foresees such a menace to the future of France. In his able treatise, *L'Aviation et la Sécurité Française*, he estimates that a fleet of airplanes, each capable of carrying a useful load of slightly more than 2 tons, could destroy a square kilometer of any town or city in a single night. "In two or three weeks of war," he concludes, "a city of the importance of Paris could be annihilated, over the greater part of it." The imagination recoils in horror from the contemplation of the suffering that such a systematic night-by-night destruction of a large center of population would inflict. Moreover, aside from the humane aspects of the thing, such destruction might seriously jeopardize all military operations. The annihilation of Paris, for example, would all but paralyze the French lines of communication, and render impossible the

proper supply of a huge army. It can readily be conceived that a calamity of this magnitude would create a demand for peace that could not be denied.

From the military point of view, there is nothing inherently impracticable in such an operation as the destruction of a city. The difficulties of defense are almost insurmountable. The best defense is indeed a vigorous offense. If we carry this conception to its logical conclusion, we find the situation of two belligerents each conducting a systematic destruction of the other's cities, until one or the other is no longer able to stand the punishment, and sues for peace. Of course, this is an extreme case. Needless to say, each would also take steps to destroy the other's air force. But once a belligerent had determined on the destruction of hostile cities, as a means of bringing the enemy to terms, this course would be followed largely to the exclusion of other objectives. It is by no means certain however, that the next war will witness devastation on so huge a scale. Two forces will tend to prevent the contestants from resorting to such extreme measures.

The present trend of international law, as witnessed by tentative agreements among the major powers, definitely forbids the bombardment of civilians for the purpose of intimidation, and restricts legitimate attacks solely to military objectives. The skeptic will at once advance a doubt that any rule of international law will hold up against the dire need of a combatant, and he can find ample historical precedent to reinforce this doubt, some of it quite recent; but in this connection, the political consequences of German contempt of international law should not be forgotten. Of course, in strict logic, under the modern conception of the "nation in arms," with every member of it a "war worker" of some kind or other, there is no sound reason for granting immunity from attack to any class of enemy subjects. But fortunately perhaps, humanity is not always governed by strict logic. There has always been a sentiment among mankind to mitigate the horrors of war, as far as the nature of the thing permits. Among peoples in whom the spirit of sport has been strongly inculcated, it is peculiarly abhorrent to contemplate the waging of war on unarmed civilians of all ages and sexes. One type of realist may see in this

only unreasoning emotion. But any attempt to understand war, without a high evaluation of the emotions and instincts, is foredoomed to failure, for they enter into the warp and woof of the thing.

Furthermore, even though no sentiment may exist in support of international law, nevertheless a potent restraint will always be exercised by the fear of reprisals. The World War offers examples of this. When the Allies answered attacks on Paris and London with similar operations against the Rhine towns, there was a very marked growth of German sentiment against the bombardment of civilian populations, which notably increased as the Allied attacks grew in number and in intensity. Indeed civilian groups tried on several occasions to induce the German authorities to open negotiations with the Allies with a view to banning the bombardment of towns. We may expect this motive to appear in full force in wars of the future. A belligerent will hesitate a long time, before beginning an attack on a city, when he himself lies open to reprisal. In such circumstances, an agreement, either expressed or understood may take place. Every veteran of the World War is familiar with such understandings, for there were, on both sides, certain quiet, or "nursery" sectors, where, by tacit agreement, each belligerent refrained from all but a slight pretense of military activity. Of course, where one of the contestants is so situated that he can bomb the enemy's cities without fear of having to undergo the same punishment, international law will be subjected to its severest trial.

The bombing of supply systems. Napoleon's epigram that "an army moves on its belly," expresses a truth that is of far greater consequence today, than ever before in the history of war. In the time of Caesar, for example, the soldier could carry on his own person almost his entire needs in both food and in munitions of war, for several days of hard combat. Indeed, if sufficient food were available, the general could usually dismiss all further consideration of supply from his mind, and concern himself only with tactical and strategical matters. Moreover, with the small armies of earlier times, the food problem rarely assumed a position of dominance in the situation. Of course, communications had to exist, as at present. But

they exercised no such constraining effect as they do in the modern army. The modern composite soldier—if we can imagine such—needs a long list of munitions, besides rations. And even in respect to the latter, the modern army, with its millions of men, gathered as a rule in a restricted space, presents a difficult problem. The commander of today is tied fast to his roads and railroads. The modern system of supply is a thing far more complex than in former days, and perhaps even more vital.

It was stated before that any decision to bomb cities is necessarily political in character. War, according to Clausewitz, is merely a continuation of politics; it is accordingly difficult to draw a clearly defined boundary line between the political and the military aims of a state; indeed the latter are necessarily subservient to the former. But in common usage, the meanings are sufficiently distinct, and there is little fear of misunderstanding in making the statement that the military objective of bombardment aviation, *par excellence*, is the hostile system of supply.

Before discussing the operations of bombardment aviation against the supply establishments, it is desirable to outline briefly the modern system of supplying a large army in the field. Of necessity, the system will vary with every campaign, for each will differ from the others in the needs of the troops, in the distance of the theatre of operations from the centers of manufacture, and in many other respects. However, there are certain features common to all systems, so that a description of a type system will be found to fit nearly any situation, with some modifications. In the beginning of course, all munitions of war exist as raw material, which is taken from field, mine, or forest, and carried to industrial centers to be fabricated into the desired articles. From the factories the finished products of various kinds are carried, either by railroads or by ships, to a place of storage and trans-shipment, which may be called the base depot of the army. Now these munitions will arrive at the base depot, as a rule, irregularly and in large quantities. On the other hand, it is desirable that all supplies for the army leave the base depot in a continuous and regular flow, in the amounts needed for the period. Thus, a base depot might

receive on one day a definite amount of each commodity needed, or what may be referred to as a balanced stock. It is apparent that the base depot must keep on hand at all times a certain reserve of commodities of all kinds, as a reservoir, if the irregular inflow and the regular outflow are to be maintained. From the base depot, supplies of all kinds, in the form of a balanced stock of the amount needed for the period, are transported to the railheads, where they are turned over to the organizations for which they are intended.

Of course, this is a mere skeleton of the supply system. Many other elements enter into it. For example, in proportion as the communications between the base depot and the railheads are long and subject to interruption, there must be other depots, where suitable working reserves of balanced stocks are kept. Thus, there might be thirty days' supplies of all kinds in the base depot, six days' in an intermediate depot, three days' in an advanced depot, and even a small reserve at the railhead, to meet unexpected contingencies. This brief sketch of the supply system will suffice for a consideration of the proper objectives of bombardment aviation.

The long rang of the bomber should be utilized to the full, and every sensitive point and nerve center of the system put under pressure, in an effort to paralyze the whole. This does not mean however that everything pertaining to the enemy's supply system should be indiscriminately bombarded. Such a course would almost certainly result in dispersion, and a consequent decrease in the effect of the bombing as a whole. Not a mission should be executed, which does not fit in with a well defined strategical plan.

It is apparent from the description of the typical supply system, that the selection of the class of objectives to be attacked, will be influenced by the factor of time. Ordinarily, the industrial centers constitute the logical targets: for this strikes at the very roots of the supply system. When a factory is completely destroyed, its rebuilding is a matter of months or even years; it can usually be eliminated as a factor in the war. Obviously if all the key plants in the munitions industry of a belligerent were destroyed, his power of waging effective war would be limited to the length of time his reserve supplies

would last. Generally this would not exceed two or three months. However, in certain cases, it would be poor strategy to concentrate on the attack of factories and industrial centers. If a situation should arise in which the decisive battles were expected to be fought out within a month or two, it would have little or no influence on the campaign to conduct a concentrated air offensive against the industrial centers of the enemy. The pressure to be brought on him must be immediate, even though it be of shorter duration. The proper objects of attack in this case would lie nearer the front, and bombing operations would be aimed at the various depots and places of storage, or at the lines of communications.

The bombing of industrial centers. In the modern conception of war, the mobilization of the army and navy is accompanied by a mobilization, similar in all respects, of the entire industry of the state. This is an exceedingly complex arrangement, and this very quality of modern industry renders it vulnerable. It would be quite impossible to attack every factory of the enemy, which was engaged in fabricating munitions of war. Their very number would forbid this, even if all of them were within range of the bombers. However it is not necessary to accomplish this extreme result, in order to cripple any given industry. In general, the finished product does not come from one self-contained plant, which takes in only the raw materials, or from any number of similar plants. Industry consists rather of a complex system of interlocking factories, each of which makes only its allotted part of the whole. This is an era of specialization. Accordingly, in the majority of industries, it is necessary to destroy certain elements of the industry only, in order to cripple the whole. These elements may be called the key plants. These will be carefully determined, usually before the outbreak of war. They will be accurately located at the same time, preferably by air photographs. On the declaration of war, these key plants should be made the objective of a systematic bombardments, both by day and by night, until their destruction has been assured, or at least until they have been sufficiently crippled.

It is probable that the importance of this class of bombing operations has not been widely appreciated. Not every man

realizes how closely modern war depends on modern industry: the destruction of one would render the other impossible, unless the enemy were similarly situated. We are accustomed to think of war as being decided only on the battlefield, and indeed this is true: only the courage of mankind can ever win victories and secure safety to the nation. But industrial efficiency can give to its possessor a tremendous advantage, when at length he arrives on the battlefield. Accordingly the destruction of an enemy's industries assumes a tremendous military importance. Bombing raids of this character are none the less important, because their effects are not immediately visible. They may be likened in this respect to sea power, which, though unseen, yet may throttle the military strength of a nation.

An example of bombing operations of this class occurred in the World War. Convinced of the necessity of striking at such German industries as were within range, the British organized a special force for this purpose. It was known as the Independent Air Force, and was commanded by Sir Hugh Trenchard. From June, 1918, to the end of the war, this force conducted a systematic air offensive against German industrial plants at Saarbrücken, Frankfurt, Mannheim, and other German centers. These hazardous raids were kept up by day and by night, more than 500 tons of bombs being dropped on the German factories during this period. While it is difficult to evaluate the work of this unit in mathematical terms, it can be stated that the results were well worth the cost, even though the latter included the lives of many gallant officers.

The bombing of lines of communications. It may often occur that the industrial centers of the enemy are beyond the reach of the airplane, or that results at the front must be achieved more quickly. In these cases, the lines of communications generally offer the most promising targets for bombardment aviation. For purposes of this discussion, the various depots mentioned above may be included in the lines of communications, since they are in effect the termini of the lines. Where supplies must be transported over land, the railroad is far and away the important agency. It is true that motor transport has come to play an important part in the

supply system. In some situations, it may indeed vie with the railroad in importance : such was the case in the battles of 1916 about Verdun, where the road from Bar-le-Duc to Verdun became the chief supply artery of the hard pressed city, and was handed down to fame as the *Via Sacra* of the World War. But at the present time at least, motor transport is chiefly useful in distributing supplies from the railhead to the organizations. The railroad is the backbone of overland transportation, and as such is the commonly selected objective of air attacks on the lines of communication.

The best results in the attack of railroads are achieved by combined operations of attack and of bombardment aviation. The functions of the former consist in the attack of all moving trains, in the manner previously described, and in cutting the rails at many points. So long as approximately the present conditions continue to exist, attack aviation can definitely stop all train movements by day within range of its activities. The cutting of rails may seem to be of little importance, since such an injury can be quickly repaired. But attack aviation can readily execute such demolitions with accuracy, and with little danger to itself, since it would be quite impossible to protect every point of a long line; and a large number of these minor injuries, although each in itself may be small, may mount up to a significant total of delays. In particular, attack aviation may accomplish important results against ammunition trains : a successful attack of this kind in the World War, resulted in stopping all traffic on that line for more than two days.

The heavier tasks in the attacks of railroads however, fall to bombardment aviation. Against the line proper, it will direct its blows chiefly against such sensitive points as tunnels, bridges, and other defiles. But it will conduct also a systematic attack of stations and depots, paying particular attention to the larger stores of ammunition. A vivid picture of the results of the successful bombing of a large ammunition depot, is given by Major Oliver Stewart in "The Strategy and Tactics of Air Fighting." A British pilot flying towards France over the Channel noticed a thick layer of smoke in the sky, which grew heavier as he approached nearer to France, "until

it resembled a thunder cloud." Investigating, he discovered that the pall of smoke extended from Cape Gris-Nez to Audruicq, a distance of 20 miles. It all came from the huge British ammunition dump at the latter place, which had been set on fire that morning by German bombers. The effect of this must have had on the British ammunition supply can be appreciated, in the light of an example, which will be given later.

From the statements made before, it is evident that the plan of attack on a line of communication must be based upon the specific case. First of all, the enemy's supply system must be studied, in precisely the same way that the intelligence service attempts to ascertain the strength, dispositions, and intentions of the hostile combatant elements. From this, the sensitive points of the system may be ascertained, and concentrated upon; as in the case of industries, it is idle to attempt to destroy all: it is sufficient to destroy certain parts only, for the system is not vital in all its members. In particular, the attacks must be so directed that it will be impossible to divert traffic over parallel lines, and so attain the same end.

The vital importance of the lines of communications, and the disaster that may follow on their destruction, is witnessed by many historical examples. Even damage which falls far short of destruction of the whole may nevertheless exercise a decisive influence. An incident that occurred in the opening days of the World War serves to illustrate the possible results of any derangement of the railroads of a combatant. At one stage in the negotiations, which at length ended in war, the German Emperor contemplated a change in the plans of concentration, with a view to transferring certain troops from the French frontier, for which they were destined in the original plans, to the Russian border. He consulted with his Chief of the General Staff, von Moltke, as to the practicability of this modification of the plans. Von Moltke was quite emphatic in his view that the change was wholly inadvisable. The plans, he insisted, had been worked out to the minutest detail; the exact schedule of every train had been prescribed, to the very minute. Any attempt to alter the scheme, even in details which seemed unimportant, might well jeopardize the success of the

campaign. Von Moltke sorrowfully relates that the Emperor seemed displeased at this opinion, and made invidious comparisons between the former and his famous uncle.

One is tempted to believe that von Moltke did indeed exaggerate the difficulties of the proposed change; nevertheless, a rapid concentration of large forces in the shortest possible time cannot be made unless every detail be prearranged, and every railroad be used to its full capacity of trains. This of course, necessarily implies that schedules must be followed exactly. It requires little imagination to understand what the results would be on such a concentration as that of 1914, if the lines in rear of the covering forces had been subjected to systematic air attacks. Indeed, under such circumstances, the concentration would become impossible. It may safely be said that one of the consequences of air development has been to force the concentration, which takes place immediately upon mobilization, to be made out of range of serious airplane attack.

Another example of the effect that may be had on major operations by air attacks against the lines of communications, is given by Col. the Hon. M. A. Wingfield, in the *Army Quarterly* for January, 1926. In considering the vulnerability of the supply system of the Second British Army in 1918, he states that in the base depots, there were kept supplies for thirty days; in front of the base depots, "there would rarely be more than a maximum six days' supply." The railroads leading to the front were so few that it required three-fourths of their full capacity to supply the troops at the front in active operations, even when all other railway movements were suspended. He concludes from his studies that "the complete blocking of the lines for six days would have emptied the entire echelons and reserves available at the front, and much less than this would have been sufficient to dislocate the whole system and prejudice the success of any operations in progress. If one ammunition train were to have been blown up on one of the double lines, sufficient damage might have been done to reduce our transport facilities by two-fifths for perhaps two or three days, and the mere threat of such a catastrophe was sufficient to cause serious dislocation in the railway programme, since it

became the practice for trains to stop and damp down their fires whenever the enemy's bombers were known to be over our lines by night."

The study made by this writer clearly shows the difficulty that will exist in future warfare in supplying the huge armies of the World War type, where active air operations are undertaken with modern bombing equipment. One is compelled to agree with his conclusion, that "it does not seem impossible. . . . that action from the air could definitely prevent trench warfare occurring again as we knew it in France." One might go even farther, and venture the assertion that this is among the probabilities. It is unlikely that any future war, in which the United States may become involved, will be fought in the theatre more plentifully supplied with roads and railroads than was France in 1918. If these lines of communications were taxed almost to the limit of their strength, in supplying the huge army at the front, when bombing was in its infancy, there seems little probability that an inferior network of railroads can accomplish the result, when bombing becomes the serious menace which is presaged by recent developments.

Overseas Communications. When a line of communications crosses the sea, the problem of supply may prove more difficult of solution than is the case with railroads. Of necessity, cargo must be carried on merchant vessels, which are peculiarly vulnerable to air attack. The World War is still fresh in memory, and everyone is familiar with the desperate straits to which Great Britain—and the Allied Powers as a whole—was put as a result of the operations of a comparatively few submarines. This danger was at length met and overcome, but it would be idle to deny that the German submarine campaign narrowly missed success. At that time bombardment of vessels from the air was never seriously undertaken. What the result would have been if the Germans had concentrated their air force against shipping, even with the inadequate equipment of that period furnishes an interesting theme for speculation. But of course while this was not done, and accordingly we have no data from this source from which conclusions may be drawn, it is nevertheless instructive to compare the mer-

chant vessel's means of defense against the submarine, with those she has to employ against the airplane.

Both submarine and airplane can launch projectiles powerful enough to sink any merchant vessel; so in this respect, there is little choice, although the airplane bomb contains a larger charge of high explosive. The faster merchant vessels may often evade the torpedo of the submarine by zigzagging; in theory, the same tactics may be employed against the airplane, as will appear in a subsequent chapter; but in practice, the speed of the falling bomb is many times that of the torpedo, and the vessel has comparatively little chance of evading a well directed shot. The vessel was often faster than the submarine, and when apprised of the latter's presence, could run out of danger; this is quite impossible against the airplane. When the vessel reaches the safety of a harbor, all danger of submarine attack is usually past; airplane attacks will generally be directed against harbors, as well as the sea approaches to them. Finally, by means of convoys, the danger of the submarine was greatly reduced in the World War; some similar system may be attempted in the future to guard against air attacks, but as will appear from the general discussion of the defense of vessels, in a subsequent chapter, this method offers little hope of providing a really adequate protection.

From the above considerations, a few conclusions are warranted. So vulnerable is merchant shipping to air bombardment, and so far reaching are the results of repeated attacks of this kind on the hostile lines of communications, that no other objective can compare with it as the appropriate target for bombardment aviation. Indeed, when the difficulties of air defense are considered, it is questionable if any nation will ever again undertake to supply a large expeditionary force overseas, unless its base ports are beyond the reach of hostile bombardment aviation, or unless the strength of the latter is negligible.

Bombardment in the combat zone. It is only rarely that bombardment aviation will be used against objectives lying in the combat zone and within reach of artillery fire. Nor, in the general case, is bombardment aviation suited for the attack of personnel. But where important groups of the latter are gath-

ered together in definite localities, which are defiladed from artillery fire, or are provided with adequate protection except against vertical trajectories, bombardment aviation may be used against them. Such localities are apt to be chosen as the sites for the larger headquarters, which will be attacked in an effort to disrupt the chain of command. An example of a very successful attack of this nature occurred in Allenby's campaign in Palestine, previously related. Of course too, where the urgency of the situation is great, and enemy troops must be halted at all costs, bombardment aviation, along with all other air going branches, will be diverted temporarily to the missions of attack aviation.

Bombardment aviation in coast defense. No phase of the development of air warfare is more striking than the possibilities of the bombardment airplane as an agency in coast defense. In a subsequent chapter, the general subject of bombing attacks of shipping, and particularly of vessels of war, will be discussed in detail. It is enough here to state that bombs are sufficiently powerful to sink any vessel now afloat, that defense of sea craft against air attack has nearly all the defects inherent in the defensive in general, and that airplanes operating from a land airdrome have a great natural advantage over those operating from a floating base. These facts make the bombing airplane a powerful instrument to direct against hostile expeditions attempting a forced landing. It may or may not be true, as some authorities believe, that aircraft alone can insure the defense of a coast line against overseas expeditions. Certainly, it has never been done in actual war; but this proves nothing, since it has never been attempted. Indeed all the information we have indicates that vessels cannot hope to operate, without suffering severe losses, within range of hostile bombardment aviation. When we consider the outstanding features of a forced landing on hostile shores—the protecting vessels of war, the transports crowded with troops which they are discharging into “beetle” boats destined to land on the hostile beaches—and further reflect that all these targets will be within range of bombardment aviation, it seems to be a desperate undertaking with small chance of a successful outcome. So true is this, that a nation which is adequately

guarded by its air force, has little to fear from direct attacks from the sea; it may look for its enemies towards the land alone.

Day and night bombardment. In the World War, there was a very clearly defined line between day and night bombardment units, as regards their design and their tactical employment. The latter, having little to fear from hostile pursuit aviation, habitually operated individually, relying on darkness for safety. But the trend of development seems now to be in the direction of obliterating this distinction. Obviously this would be an advantage from the standpoint of procurement, since it would result in one type of airplane the fewer. Moreover, it is clear that in so far as the objectives of attack in general are concerned, there is no difference between the two classes of bombardment; both are employed against the same essential targets, in accordance with the same strategical plan. As night pursuit develops in effectiveness—which may well be anticipated as a feature of the next war—it will become necessary for night bombardment to defend itself in the same way as day bombardment: by flying in close formations for mutual support. Obviously too, there are other reasons that favor the employment of bombing airplanes in large numbers. The effect of mass should always be sought, not alone for its moral effect but also because of its greater destructive effect, even comparatively: thus, for example, a single fire started by a single bomb each hour could be put out by the defenders, whereas ten such fires might easily get beyond all control, if started simultaneously. Moreover difficulties of navigation are usually better solved, when all airplanes follow one skillful leader, instead of proceeding individually. These reasons all indicate that future warfare will see day and night bombing executed by the same units.

Effect of the air situation. In principle the missions of bombardment aviation are determined by the land or naval situation. But the successful execution of the tasks that are allotted to it, depends in no small measure on the elements composing the air situation. Of these the most important is the reaction of hostile pursuit aviation. Bombardment aviation has considerable defensive power, and is by no means help-

less, even when attacked by superior numbers of hostile pursuit airplanes. Nevertheless, its lack of offensive power in the air will subject it in the long run to unnecessarily high losses and the consequent deterioration, if it is compelled to rely for security entirely on its own powers. This was clearly shown in the World War; and an even greater menace to bombardment aviation may arise, if pursuit or attack aviation should develop an effective method of bombing the bombers themselves—a possible contingency, in the future.

At the present time, bombardment aviation may be considered as capable of temporary resistance, but it must be supported eventually by friendly pursuit aviation. This is true of bombardment aviation to a greater extent than of the other branches of the air force. In land warfare, attack aviation, for example, habitually dashes in on the enemy's lines, and penetrates to a short distance so rapidly, that it will often return without having to fight its way against hostile pursuit aviation. Much the same thing is true of observation aviation. But bombardment aviation will usually penetrate deeply into hostile territory. Its speed too is so slow that an effective ground defense system will generally give hostile pursuit units time to attack the bombers. Frequently, it will be impossible for the former to fall on the raiders, until the bombing is completed, but usually they are able to intercept the bombers before the latter can return to the friendly airdromes.

These conditions make it highly important to have bombardment operations supported, as a rule, by friendly pursuit aviation. The pursuit airplane has a cruising speed which exceeds that of the bomber by from 40 to 60 miles an hour. Its fuel capacity, on the other hand, is only about half that of the bomber. It is therefore obviously impracticable for the two to cruise along in close company on a distant sortie, even if this were desirable. Sometimes, in fact, the more distant objectives of bombardment aviation are altogether beyond the cruising radius of the pursuit airplane. But it is apparent that on some portion of the bomber's trip, it will be practicable to have friendly pursuit within supporting distance. The combined operation of these two branches of the air force should always

be so timed that this support will be provided during the period when hostile pursuit is most apt to attack.

It is apparent that the objectives of bombardment aviation are of such vital importance that they must be protected by all the resources at the disposal of the defender. It is due to this fact that the higher authorities of the state may be called upon in some future war to arrive at a decision, very difficult to make.

Let us assume, to illustrate, two combatants, Red and Blue, separated by a land boundary. On the outbreak of war each begins bombing attacks against the sensitive points of the other, which were enumerated before. Each combatant also uses its pursuit force only to support these raids. It is evident that, in such a situation, there would come from the people of each state, civil and military, an insistent demand for protection. The authorities on each side may give out to the public vivid accounts of the damage inflicted on the enemy, but this will scarcely still the clamors of those who see only the havoc wrought among themselves by an enemy who is seemingly unopposed. At length, the Blue authorities, forced to yield to the pressure, place their pursuit force on the defensive, with orders to attack hostile bombardment aviation, ignoring all other objectives. The Red authorities, on the other hand, hold out, determined to endure their punishment, and intent only on directing all their strength towards increasing the power of the blows they are raining on the enemy. The Red raids continue and in nearly every case are violently assailed by the Blue pursuit in obedience to their orders. In every case, the Blue squadrons, always at a disadvantage in a fight selected by the enemy, are attacked in their turn by Red pursuit, and suffer heavy losses as compared with the latter. After a time, as a result of these repeated battles, the superiority of the Red pursuit force becomes so marked, that it not only can continue to support the bombers, but can also begin determined attacks on the Blue bombers, secure from molestation by Blue pursuit units.

Of course, in actual warfare, no situation will ever have the clear cut simplicity of the above; nor is it possible to carry the offensive idea invariably to its logical conclusion. But it serves

to illustrate the necessity not only of maintaining a general offensive spirit, but also of having the fortitude to endure punishment—two qualities which will certainly have to belong to the victor in air warfare.

If the attacks of bombardment aviation on land objectives call forth strong reaction, which in their turn give excellent opportunities to friendly pursuit aviation to establish control of the air, they will have even more marked effect where seacraft are the targets of bombardment. In this case, the necessities of the moment must over-ride all other considerations. A pursuit force supporting sea craft cannot be permitted to assume a strictly offensive attitude, but must, at all costs, protect the surface vessels. This is perhaps the one case in air warfare, where the strictly defensive attitude is justifiable and necessary.

The actions of bombardment aviation must be coordinated not only with pursuit, but also in many cases, with attack aviation. Bombardment aviation, in spite of the improvement which has come in this respect as a result of better sights, is still more vulnerable to anti-aircraft fire than the other branches of the air force. This is not due so much to larger vulnerable space, as to the fact that the bombardment formation is the slowest and least maneuverable of all. Furthermore, the targets of bombardment aviation, from their value, will generally be better protected by anti-aircraft artillery than the objectives of the other components of the air force. While the experience of the World War shows that anti-aircraft fire can never stop a determined force, nevertheless it is undeniable that the effectiveness of bombing raids is increased as hostile anti-aircraft units are neutralized. This shows the desirability of synchronizing the operations of bombardment and of attack aviation. In fact, it should be the rule of the air force to fight as a whole, the sweep of the pursuit squadrons affording protection from air attack to the other two components alike, while attack aviation in its turn, puts down a neutralizing fire on all hostile anti-aircraft batteries within range. Thus proper coordination will increase the strength and effectiveness of the force as a whole.

CHAPTER VIII

ANTIAIRCRAFT DEFENSE

Importance of defense. It is universally admitted that the best defense against aircraft is provided by other aircraft—another exemplification of the familiar rule that like cures like. This agency of defense has already been discussed. In previous chapters the inherent difficulties in any form of defense, whether active or passive, were pointed out. Since no positive and adequate defense is practicable, either under present conditions or under any future conditions which may be foreseen, it follows that each belligerent must seek a remedy for hostile attacks, by similar offensive action against the enemy. But if defense lags far behind offense in air warfare—a peculiar reversal of the conditions in land warfare—and is inadequate, it does not follow that all attempts at defense should be abandoned. Too much must not be expected; aircraft cannot be held, or thrown back, even by a large force, in the way we are accustomed to see attacks repulsed in land warfare. But nevertheless, the employment of means of passive defense is not an entirely futile thing. The vast importance of some localities in war demands that they be protected to the utmost; every effort must, therefore, be made, even though the protection furnished fall short of that desired. It must be remembered that in war the ideal is never attained, and seldom approached; where destruction is impracticable, often neutralization will prove an acceptable substitute.

It is intended in this chapter to discuss only the passive means of defense. These consist essentially of anti-aircraft cannon and machine guns, with searchlights and listening apparatus as the principal means of locating the enemy.

Anti-aircraft cannon. The anti-aircraft cannon, or gun, is usually of approximately the 3 inch calibre, although larger guns have been designed, and are contemplated for future use. The anti-aircraft gun, quite naturally was developed from the similar

piece employed by light artillery. The most obvious modification of the latter was that which enabled the anti-aircraft gun to fire at greater elevations: present types, for example, fire with elevations as high as 85 degrees. They cannot fire vertically, so that a cone of "dead space" exists above each battery, which necessitates grouping the batteries so as to provide mutual protection. Other modifications that are eagerly sought after for anti-aircraft guns, are higher muzzle velocities, and more rapid rates of fire. The tactical significance of these qualities is great. In a subsequent paragraph, it will be seen that a great decrease in accuracy may result from increasing the time of flight of a projectile, and this in turn, is partly a function of the initial velocity. In so far as rate of fire is concerned, its importance is manifest with so fleeting a target as the airplane. Anti-aircraft guns are motorized. Contrary to some popular beliefs however, they do not attempt to fire while moving, but must be emplaced in the same manner as other artillery. The anti-aircraft gun fires both shrapnel and high explosive shells.

The accuracy of anti-aircraft guns. When the unbiased student of air warfare attempts to arrive at an opinion as to the accuracy of anti-aircraft guns, he encounters great difficulty. This seems strange in view of the vast mass of facts in regard to anti-aircraft fire that were accumulated in the World War. But apparently these have not yet been collected and treated in the scientific historical manner; for authorities vary widely in their opinions. Scarcely any other subject of importance shows such diversity of belief. It seems at times as if no choice were left between hopelessly irreconcilable statements.

Since the value of anti-aircraft fire is derived from its physical and moral effect on airmen, it is important to learn their opinion of it. Captain Rickenbacker, in the story of his adventures in air fighting, gives interesting testimony as to his own reaction to fire from the "Archies," as anti-aircraft guns were called by British and American flyers in the World War. In the vivid description of his first flight over the lines led by the veteran Lufbery, he frankly confesses how perturbed he was when anti-aircraft artillery suddenly opened fire on his airplane; he could scarcely restrain his indignation at the older

pilots, then safely on the airdrome, who had made light of anti-aircraft fire, and had assured him it was utterly harmless.

It is interesting to contrast this impression, made under the stress of his initial sortie, with his more mature judgment, when some months later, he had become a veteran of many fights, and had achieved the distinction of being the premier American "Ace." Speaking of his opinion at that time of anti-aircraft fire, he states: "To the pilot whole has actually experienced these daily straffings by Archy the whole danger resolves itself into a question as to whether or not he will permit his imagination to terrorize him into fleeing away from so appalling but so futile a menace. In other words, he knows that the actual danger is almost nil." It may be said in passing, that this represents rather closely the consensus of opinion of the pursuit pilots of the World War. It must be borne in mind, however, that the pursuit airplane, as will appear later, due to its speed and maneuverability, offers the poorest of all targets to the anti-aircraft gunner.

Rickenbacker's later opinion as to the effectiveness of anti-aircraft guns, receives strong confirmation from Brigadier General P. R. C. Groves. The official position of General Groves was such that the record of the British anti-aircraft defenses was intimately known to him, and his statements therefore carry authority. In the *Atlantic Monthly* for February, 1924, he says: "Early in the late conflict the British Ministry of Munitions estimated that in order to score a direct hit upon an aeroplane flying at 8,000 feet and capable of a speed of 100 miles per hour, no less than 162,000 guns would have to fire simultaneously. The experience of the war bore out that estimate. There is a difference of opinion as to the number of aeroplanes brought down by anti-aircraft fire over Great Britain in the course of the recent conflict, but the total can be placed fairly safely at under six."

From another source comes testimony of the same character. Writing in the *Journal of the United States Artillery* for February, 1921, Major Knerr approaches the problem from the technical point of departure. After discussing the various inherent difficulties under which anti-aircraft artillery have to

labor, he concludes with the following sentence: "It is submitted that the entire anti-aircraft idea is a snare and a delusion."

On the other side of the questions, there is also a considerable amount of evidence. Writing in the same journal for June, 1922, Captain Harmon states that "during 1918 every aerial attack was broken up by the Archies outside the walls of Paris. Of 483 planes attacking, 13 were shot down and only 37 actually penetrated the defenses." Of course, these statements lose some of their value as testimonials to anti-aircraft accuracy, when we consider the evidence of Ludendorff and von Hoepfner, previously mentioned, to the effect that these German raids were only a diversion, and that the German authorities had no intention of making truly effective attacks. The repulse of a feint is in a different category from the defeat of a determined attack.

However, the figures given by other authorities differ very greatly from those of General Groves. The French anti-aircraft service states that in 1918, they brought down an airplane for every 7,500 rounds fired; while American batteries made a far better score. According to Captain Harmon, in the article previously quoted, "considering all the American batteries in France that fired, one plane was brought down for every 1,050 rounds fired." This figure is notably lower than the claims of any of our allies.

It is obviously somewhat difficult to reconcile these conflicting figures. However, before we attempt to do so, and to arrive at some reasonable mean, it is advisable to glance briefly at some of the problems of anti-aircraft firing.

Difficulties of anti-aircraft firing. Probably the difficulties inherent in anti-aircraft fire may best be understood by comparison with other classes of artillery fire. Let us consider first the case of a battery of light artillery firing at a stationary target on the surface of the earth. The procedure consists in firing, first of all, for adjustment. Experience has shown that, no matter how much care is exercised in procuring the firing data for the first shot, it is nevertheless often inaccurate. Accordingly, before proceeding to fire for effect, the inaccuracies of the first shots are closely observed and estimated, and the firing data is changed so as to bring the center of impact of the

projectiles on the target. Not until that has been accomplished is the battery ready to begin truly accurate and effective fire. Unfortunately for accuracy, no such procedure is possible in anti-aircraft gunnery. The airplane moves too rapidly, and the pilot will instantly change his course and altitude, if shells begin to come unpleasantly close. Accordingly, adjustment of the type practiced in the usual artillery firing, is quite out of the question for anti-aircraft guns. Each shot must, as it were, rely on its own data. It cannot be corrected by observing the deviation of preceding shots.

It is probable however that this difficulty does not exercise as great an influence as does a second inherent defect. All fire on moving targets depends for its accuracy on the truth of the assumption that the target will continue moving on the same course at the same speed during the time of flight of the projectile. When the target is slow and is confined to a single plane—the usual case in firing on moving targets in the past—the difficulties are not very great. But with the advent of the airplane, an entirely different order of things has come about. Let us assume, for example, a pursuit airplane over hostile territory. The anti-aircraft gunner procures his data, and fires on the intruder. However, between the time of firing and the moment of the projectile's arrival at the point where it is calculated the airplane will be, there may elapse a period of the order of 20 seconds. This is time enough for the airplane to cover a considerable distance; and it may be safely assumed, in the general case, that the pilot will be aware of his danger, and will not be so obliging as to continue a straight course at constant speed. If we calculate the probability of a hit by the roughly approximate method of taking the ratio of the danger space of the bursting shell to the total space at any point of which the airplane may be at the expiration of 20 seconds, the chance of a hit on the airplane is less than one in a million. Of course, with bombing airplanes, and with others of a lower maneuverability factor, this figure would be materially reduced. But it would still remain prohibitively high.

A consideration of these factors alone might lead at once to the conclusion—which is unhesitatingly held by many serious students of national defense—that anti-aircraft guns are inher-

ently incapable of offering effective resistance to air attack, and are a drain on the economic resources of a country, for which no adequate return is received. But so radical an opinion is not justified, if the advantages and disadvantages of anti-aircraft guns are further considered.

Other advantages and disadvantages. From considerations such as those outlined above, there has been an increasing tendency to regard anti-aircraft artillery as hopelessly out-matched in a contest with pursuit airplanes, and to restrict its targets to the less maneuverable classes of airplanes. Some authorities go so far as to state that anti-aircraft guns are to be employed solely against bombing airplanes. This idea has much to commend it. The guns are primarily designed to protect ground establishments, and the bomber is the greatest menace to these. Moreover, the bomber undoubtedly offers a better target than the pursuit airplane. For example, a comparison between typical airplanes of the two classes shows that the pursuit airplane has a maneuverability factor five times as great as the bomber. Since the maneuverability factor takes into account speed, rate of climb, and minimum radius of turn, we may accept as a rough rule of thumb that the probability of a hit on the bomber, as compared to the pursuit airplane, is proportional to the maneuverability factor. However it should be remembered that improvements in bomb sights make it no longer necessary for the bomber to maintain a constant course and speed over a distance of many miles. These conditions of 1918, so highly favorable from the anti-aircraft point of view, no longer exist, and with them passes one of the former advantages of the gun.

On the other hand, the airman will not always be aware of the presence of anti-aircraft guns, and be maneuvering to avoid them. He will sometimes be surprised, and caught in the first burst of fire. At times too, even when not surprised, the importance of a particular mission will occupy his attention to the exclusion of all else, and he will ignore the threat of the anti-aircraft guns in pursuance of his own purpose. Under circumstances such as these, the accuracy of the guns will, of course, be greatly increased.

Then too, there is a factor in the tendency of modern development which will unquestionably enhance the value of the gun. The employment of masses has a two-fold effect: the maneuverability of large units will inevitably be less than that of the single airplane, while at the same time, the size of the target will be increased. Probably these two developments will add more to the worth of anti-aircraft guns, than all other improvements combined. They may indeed cause the guns to become a formidable agency of defense. But as the latter become more menacing, the air force will undoubtedly pay greater attention to counter-battery measures. Such measures have been almost neglected in the past. It is true that in the World War, anti-aircraft guns in the front areas were sometimes fired on by artillery counter-battery guns. But those in rear areas, protecting supply establishments and other important points, were safe from this danger, and suffered from air attacks only rarely. Occasionally, of course, they received a salvo of bombs—which usually had been destined for some other target. But there was no systematic counter-battery action, as a definite phase of the normal air attack. These conditions will certainly never continue if anti-aircraft artillery grows in power and effectiveness. As a routine thing in air operations, units of attack aviation will be told off to silence anti-aircraft batteries.

An advantage of anti-aircraft artillery that will never be entirely lost, lies in its moral effect. This has been referred to before; and indeed, it may be accepted as an axiom, that no man will ever execute his allotted task when under fire, with precisely the same degree of efficiency as when unmolested, even though he has no very high opinion of the effectiveness of that fire.

Another advantage of anti-aircraft guns that is not always given its true value, lies in the assistance, direct and indirect, which they may render to friendly aircraft. The difficulty of detecting one airplane from another, while in the air, has already been described. This may often be overcome with the assistance of friendly anti-aircraft guns. The latter may signal the location of hostile airplanes, and so either guide the friendly pursuit to the attack, or permit other friendly air units to escape.

In concluding this enumeration of advantages and disadvantages, there must be included the fact that the anti-aircraft guns cannot be traversed with sufficient speed to fire on low flying airplanes. This rôle accordingly must be undertaken by machine gun units.

Anti-aircraft fire to harass rather than to destroy. From the foregoing discussion, it is manifestly impossible to reduce the effect of anti-aircraft gunfire in war to any mathematical formula upon which authorities may agree, and which may be applied, even in an approximate manner, to the widely differing conditions of service. If this result cannot be achieved from a study of the great mass of data that was obtained in actual warfare, how much more difficult is the problem when one attempts to solve it by peace time tests and experiments. These have, of course, their value. They may, for example, afford a fairly accurate comparison between two different types of gun, or two different classes of fire control apparatus, on the score of technical efficiency. They may, also, have some tactical value, where the conditions of war may be closely simulated, or where the necessary differences between war and peace may be approximately evaluated. But anti-aircraft accuracy tests, which are conducted against targets proceeding on a straight course at uniform speed and altitude, are worthless as an index of tactical effectiveness. This is apparent from the previous discussion, for a coefficient of error may be introduced from this cause, amounting, in theory at least, to more than a million—obviously, not a very close approximation.

From the above discussion, it is obviously impossible to say, with any approach to accuracy, that one airplane may be destroyed, under average conditions, by a thousand shots, or ten thousand shots, or any other definite number. It is equally inexact to state that a certain number of batteries can insure a positive defense of a locality against a certain number of air squadrons. No rule of this nature can ever be more than a very general index.

In considering the effectiveness of anti-aircraft artillery, entirely too much emphasis may easily be laid upon the destructive power of the weapon. This may easily lead to serious error. In fact the anti-aircraft doctrines of practically all nations agree

that the destruction of hostile aircraft is not the primary mission of these arms. Their purpose is rather one of neutralization. They aim to force aircraft to higher altitudes where their efficiency in observation or in bombing will be materially reduced; to weaken or destroy the integrity of formations, so that the scattered airplanes may fall an easier prey to their enemies; and finally, to assist friendly aircraft by timely information and support. Of course, in strict logic, the ability of anti-aircraft guns to accomplish these aims, is in part a function of their potential destructive effect. But in practice, the proper criterion of the worth of anti-aircraft guns is the extent to which they accomplish their stated missions, and not the number of hostile aircraft they destroy. Their fire is, in effect, harassing rather than destructive. But this is no sound reason for deeming them of small value. Their utility does indeed bear the negative stamp that is characteristic of all agencies of purely passive defense: but they are none the less a valuable adjunct. No general military organization can afford to dispense with them. Nevertheless, anti-aircraft guns, despite their great value, cannot, in any numbers which are likely ever to be encountered in war, definitely stop a determined attack by aircraft.

Location of anti-aircraft guns. The tactical considerations which govern the location of anti-aircraft guns are derived from the technical characteristics of this type of artillery, as well as from the demands of the special situations. The guns are normally grouped in batteries of four each. Since they cannot fire vertically, it is apparent that the guns must not only be placed at a certain distance from the line or area they are to protect, but must also themselves be protected by a neighboring battery, in order that hostile aircraft immediately overhead may not attack the batteries with impunity. The minimum distance is usually such that the battery may reach aircraft directly over the point to be protected, even when the flyers are at their approximate ceiling. In existing types of anti-aircraft artillery, the guns are usually placed on this account, at a distance of at least 1,500 yards from the point. The maximum distance is dependent, of course, on the range of the gun. It must not exceed the range at high altitudes, and for present types, may be taken as approximately 6,500 yards.

Subject to these technical limitations, the locations of the batteries depend on the tactical situation. While, of necessity, each situation must be dealt with according to its own peculiar characteristics, nevertheless there are often many elements in common in different situations. They may therefore be grouped, for convenience of discussion, into three general categories. First of all, may be considered the protection of columns of troops or of transport, moving on the roads. Such columns are the natural targets of attack aviation. Since the anti-aircraft gun is ill suited to firing at low flying airplanes, this defense must depend largely on the fire of small arms, which will be treated in a subsequent paragraph. However, it is always within the bounds of possibility for attack aviation to remain above the effective range of small arms, or else for bombardment aviation to be diverted from its customary role to the attack of ground troops. It is therefore highly desirable to provide for the support of the column by anti-aircraft guns. Usually the batteries will be distributed along the line of march at a distance of at least 1,500 yards from it and separated from each other by a distance of from 1,500 to 6,500 yards. When the batteries are placed at the maximum distance apart, a regiment (of three-gun batteries) in this way can bring the fire of at least one battery to bear on an airplane flying over a column 15 miles in length. By disregarding the need for mutual support, this distance could be further increased, to about 22 miles. Of course, where the column is materially shorter than in the above figures, it is possible to provide a greater volume of fire over the column as a whole. As the column marches, the batteries are also displaced forward, the last one on the line of march "leap frogging" through to the head of the column. In this way, nearly continuous protection may be afforded.

A second class of situation is the defense of a line. This method is particularly applicable to such situations as that of the Western front in the World War. It may however be provided whenever two forces are in contact, or when a large area must be given an all-around defense. In this class of situations, the defense consists in effect of two lines of batteries, roughly parallel to the line to be protected. The distance between the latter and the nearer line of batteries is never less than 1,500 yards. When counter-battery by hostile artillery is to be expected, this

distance is increased to at least 2,000 yards, and may, when the attitude of the army as a whole is defensive in character, be further increased to 5,000 yards. The two lines of batteries are usually from 2,000 yards to 5,000 yards apart. These figures are based, of course, upon the technical characteristics of present armaments. Increased technical characteristics will tend to enlarge these distances, without however altering the character of the dispositions. In the defense of a line, the gun batteries of a regiment of anti-aircraft artillery are usually placed at the three apices of a triangle, whose sides vary from 4,000 to 6,500 yards in length. One regiment will have two batteries in the first line and one in the second; the next regiment will reverse the order, having only one battery in the front line; and so on, by alternate regiments. By this arrangement, a fairly deep band is provided, over which hostile aircraft must pass in order to attain their objectives. Unfortunately, this method of defense requires a large number of guns. There must be one battery for approximately every two miles of front. When areas of large extent—such, for example, as the concentration area of an army—must be protected by such an arrangement of guns about its perimeter, the cost may well prove prohibitive.

A third class of situations is that which calls for the defense of an area of small extent. These areas, as a rule, are well to the rear of the combat zone, and contain such supply establishments as depots or railheads. They are far removed from any danger of counter-battery fire by hostile artillery, and have to contend in general, only with bombing airplanes. The disposition of the batteries is essentially the same as that described above: they must be so located as to give each other mutual support, and must, of course, be able to place their fire over the point to be protected. Some consideration must be given to the probable lines of approach of the hostile bombers, but this fact must not be unduly stressed: by day, bombers may approach with equal ease from almost any direction; by night landmarks such as streams or rivers may exercise an important influence, but it cannot ever be safely assumed that these aids to navigation positively preclude any other line of approach.

The general location of anti-aircraft batteries is determined in accordance with the principles described above. Within the

limits prescribed, the exact emplacement is determined chiefly from the character of the terrain. There must, first of all, be a good field of fire for the guns. Antiaircraft guns, unlike artillery in general, cannot employ indirect firing: it is essential that the gunners at the piece be able to see and follow their target. Accordingly high ground, which is usually eschewed by other kinds of artillery from motives of security, is sought after as emplacements for antiaircraft artillery. It is desirable also that the emplacement be free from surrounding obstacles, so that a view may be obtained from just above the horizon. Within range of hostile artillery, concealment is important: full advantage is taken of natural cover, which is perfected by the arts of camouflage. It is however quite impossible to conceal the guns when in action, from airplane observation, and no effort is made to do so. Communications are essential, and the location of the emplacements must facilitate their establishment. As antiaircraft guns are motorized, the emplacements must be convenient to the road net.

Antiaircraft machine guns. The antiaircraft machine gun differs very little in general characteristics from the machine gun used in infantry combat, and is in fact an adaptation of the latter. For antiaircraft purposes, the machine gun must be capable of being rapidly aimed and fired at all elevations, and must be readily traversed. It is generally mounted on a tripod, and provided with special sights to assist the gunner in estimating deflection, similar in principle to the airplane sights described in a previous chapter. As in the case of the airplane, ammunition may be either the ordinary service cartridge or else consist in part of armor piercing or of tracer bullets. As the latter are visible even in daylight to a distance of several hundred feet, they form a valuable adjunct to the sights.

Antiaircraft machine guns are of two sizes, the .30 calibre and the .50 calibre. The latter weapon is particularly useful against airplanes carrying light armor. Furthermore, it has both a horizontal and a vertical range nearly three times that of the .30 calibre gun, and is accordingly useful in some situations where the latter would not be. The rates of fire of the two types of gun do not differ greatly. On account of these advantages there is a tendency to replace the .30 calibre with

the .50 calibre gun in all units whose missions are specifically anti-aircraft in nature. It is easy, however, to overrate the advantages of the larger calibre. Aircraft, as a rule, operate either at altitudes well beyond the effective range of both calibres, or else at such low altitudes that either gun may easily reach them. On this account, in the great majority of cases, the added range is not an important asset.

Moreover, the vulnerability of the airplane to fire from the larger gun is not materially greater. There is, too, an excellent reason for retaining the .30 calibre gun for troops in general, even against aircraft. To an ever increasing extent, infantry and cavalry must be prepared to resist with their own weapons, assaults by hostile aviation. It is obviously desirable that ground troops be able to use the same weapon in all combat, whether the enemy come from the air or from the surface of the earth. This will tend to favor the retention of the smaller weapon for anti-aircraft purposes, so long as it remains the calibre in general use. In the case of artillery however, its machine guns are employed almost solely against aircraft; only in grave emergencies would it be necessary to use them against ground troops; on this account, purely air considerations may be allowed to govern, and the larger calibre may well be employed. Both calibres of machine guns are transported on trucks.

In addition to these weapons there is being developed a 37 millimeter anti-aircraft gun, similar in many respects to the German "flaming onions" of unhappy memory. This gun is, in most respects, a mean between the machine gun and the anti-aircraft gun proper, having both a range and a rate of fire between the two. It fires a high explosive shell. Whether the weapon will find general tactical application or will be confined to such missions as the protection of balloons, is a question which must be left for the future to decide.

Missions of anti-aircraft machine guns. The anti-aircraft machine gun exists primarily for defense against attack aviation. Its practical rôle, therefore, depends necessarily on the methods and practices of this branch of the air force. When compared with its natural enemy, the anti-aircraft machine gun does not labor under as great disadvantages as the anti-aircraft gun. It is true that the low-flying airplane offers a very

difficult target; its angular velocity is high, and the ground gunner must traverse his gun with great rapidity. But the range is short, and the movement of the airplane during the time of flight of the bullet is correspondingly restricted. Moreover, in so far as accuracy of fire is concerned, it is obvious that the rapidity of motion of the airplane operates in equal measure to disturb the aim of the air gunner. The latter, of course, has certain advantages. Being the attacker, he has the initiative; he will, therefore, always try to effect surprise, and to retain for himself the most favorable conditions from the point of view of gunnery, while denying these to his enemy below. For example, the airplane might dive in on the ground gunner from the direction of the sun, where it would offer a nearly invisible target. On the other hand, concealment often operates to the advantage of the antiaircraft machine gunner. The airman may be able to approach unseen, "hedge hopping" and taking advantage of all available cover, but often too, the ground gunner will be able to remain undiscovered until such time as he opens fire. After balancing the conflicting considerations, it is not matter for surprise to discover that the airman has a respect for ground machine gun and rifle fire that he does not always give to the other antiaircraft weapons.

In a previous chapter the methods of attack aviation were discussed in detail. Briefly to summarize the conclusions there drawn, the natural targets of attack aviation are found where troops must move in the open, and in formed bodies. The column is particularly vulnerable, and all ployed masses—such as are found in assembly and in bivouac areas—fall into much the same category. Another rôle of attack aviation is the support of friendly bombardment aviation, by neutralizing the antiaircraft defense; in effect, this may be called an air counter-battery mission. These positive aims of the offensive necessarily define the negative aims of the defensive: the rôle of antiaircraft machine guns is therefore to prevent attack aviation from accomplishing the purposes described.

The defense of columns against attack aviation. The significance of movements by columns in mobile warfare, has been mentioned before, but it needs to be emphasized. In these movements the time factor is all important: the success

of any coordinated effort depends in large measure on the accuracy with which the times have been calculated, and the closeness with which they are adhered to in the execution of the plan. It is in this respect that the interference of attack aviation may upset the best devised schemes. Accordingly the defense of columns constitutes one of the most important of anti-aircraft measures.

This duty cannot be entrusted solely to anti-aircraft machine guns. It demands the utilization of all practicable means and methods. Foremost among these is movement by night. It may be accepted as a principle that troop movements within striking distance of hostile aircraft must be executed under cover of darkness, unless pressing reasons exist for daylight operations. The time has passed when infantry can march down the road in closed columns of squads in broad daylight, unless it is willing to sustain heavy losses in doing so. There is, in reality, nothing new or unproven in this fact. The development of rapid fire weapons has long since compelled infantry to develop its main columns into smaller and less vulnerable ones, as it comes within range of hostile artillery, and to deploy into thin lines as it reaches the zone of hostile machine gun fire. The advent of the airplane has merely extended widely the limits of the area in which these measures of defense must be taken.

When movements by daylight must be made, two steps are taken by the column itself for defense against attack aviation: elongation of the column, and provision for the rapid development of fire by infantry weapons. Men will march either in columns of files or in columns of twos on both sides of the road. Advantage will be taken of all cover, particularly of trees, which often will hide the column from air observation. In case of attack from the air, dismounted men seek protection against fragmentation bombs by remaining prone, preferably in the ditches. Often they will leave the road altogether, marching across country, where all the protection afforded by the accidents of the terrain may be utilized. Vehicles of all kinds are not, however, so fortunately situated, and are, therefore, the more vulnerable. They are, as a rule, confined to the roads, and cannot readily escape or take cover. They will however, be distributed at fairly great dis-

tances apart in the column, in order to localize losses, and to prevent traffic congestion if a single vehicle should be injured near the head of the column.

The second defensive measure, the rapid development of anti-aircraft fire by infantry weapons, necessitates first of all an adequate alarm system, by which the column will be notified immediately of the approach of hostile airplanes. To distinguish hostile from friendly aircraft is not always an easy matter. It is true that the airplanes of every nation bear a characteristic insignia of some kind; but these are difficult to distinguish at a distance, or when the lighting effect is bad. Greater reliance can usually be placed upon recognizing the peculiarities of the silhouette of the airplane. This, however, demands familiarity with many types of aircraft, and necessitates the training of a certain proportion of infantrymen in the quick recognition of these characteristics. Friendly aircraft will, of course, assist these measures by remaining at a distance from the column, unless compelled to come near it, in which case a prearranged signal may prove desirable. This measure is worth paying careful attention to, for in the World War many flyers had the disconcerting experience of being fired upon by their own troops. Too often the latter, unable to distinguish between friend and foe, adopted the simple expedient of firing indiscriminately upon all. When the lookouts designated by the column, perceive hostile airplanes, the alarm is instantly sounded by bugle, whistle, or some other equally rapid means.

On every march, a certain portion of every rifle organization is designated for anti-aircraft defense. In some cases, the entire organization may be held on alert for this purpose. These men are prepared at all times to open fire on aircraft within a few moments of the sounding of the alarm. Individual fire by riflemen is by no means to be despised as an anti-aircraft measure; furthermore it prevents demoralization among the riflemen, by removing the discouraging sense of utter helplessness in the face of a threatening danger. The backbone of the defense however should consist of machine guns. These are of two kinds: the weapons of the regiments of anti-aircraft artillery (which include in each regiment not only the three-gun batteries previously described, but also three batteries of machine guns), and the

infantry machine guns. These are designed primarily for use against hostile infantry, and are not readily adaptable to anti-aircraft purposes at present; however, future design will undoubtedly adapt them to both purposes. The methods of employing the two weapons show no substantial differences. They may be mounted on vehicles and move forward with the column, or be emplaced near the line of march, advancing by bounds in much the same manner as the anti-aircraft guns.

The anti-aircraft defense of columns of cavalry is unusually difficult. Rifle fire may be employed, in the manner outlined above for infantry. But this method necessitates dismounting, and often time does not allow this. Motorized machine guns seem to offer the best solution. But cavalry is highly vulnerable in any case to the attacks of low flying aircraft, and must on that account, utilize all its natural characteristics to avoid such attacks. By moving in small bodies and by taking advantage of its mobility, it can often succeed in giving no opportunities to the hostile attack squadrons. The advance of a body of cavalry will consist of a series of bounds, from one locality offering good cover against air attack, to the next, usually at the trot or at the gallop.

Defense of anti-aircraft guns against attack aviation. Anti-aircraft guns are especially vulnerable in two respects: they cannot fire vertically, and they cannot fire successfully at low flying airplanes. The former defect is compensated for by grouping batteries for mutual support, in the manner previously described. The latter disadvantage is overcome by the support of anti-aircraft machine guns. Ordinarily a platoon of machine guns is emplaced near each gun battery to protect it against attack by counter-battery airplanes.

Defense of a line by anti-aircraft machine guns. The defense of a line by anti-aircraft machine guns is essentially the same in principle and in general dispositions, as that previously described for anti-aircraft guns. The distances, of course, are not the same, due to the differences in range of the two weapons: the distance of the nearer line of machine guns, for example, from the line to be protected varies from 800 to 1,700 yards. The defense usually consists of two lines of machine guns, arranged in the same manner as described for the guns, except that the

triangles are smaller. In exceptional cases, the number of lines may be decreased to one, on a broad front; or they may be increased to three, where the zone of action is narrow.

It may however be doubted that this scheme of defense will find frequent application in future warfare. It is essentially an outgrowth of the World War, peculiar to that contest, and of doubtful value even in situations of that kind. Troops in trenches in stabilized situations have little to fear from attack aviation, and therefore have little need for a strong anti-aircraft machine gun defense. It is true that airmen in the World War often "strafed" the trenches; but this can scarcely be regarded as more than a gesture, meaningless in its military effect. Even in mobile warfare, attack aviation will not ordinarily concern itself with the thinly deployed lines of the assault units. It is in rear of all this, among the supports and reserves, that attack aviation will reap its harvest. It is therefore in these places that machine gun defenses must be installed. Moreover a linear defense by machine guns cannot protect an area in the same manner as that prescribed for guns. The latter can reach to the highest altitudes; the former cannot. Attack aviation will naturally adjust its activities to these conditions: it will fly well above such lines of machine guns, then dive down to the attack of its chosen objective. Machine guns must therefore be sited to fire on points or on definite and restricted areas.

Defense of areas by anti-aircraft machine guns. It is essential that all areas where formed bodies of troops assemble, whether for bivouac or in preparation for an attack, be well protected by anti-aircraft machine guns. There are also, as a rule, certain sensitive points, such as telephone centrals, balloons, command posts, bridges, and railheads, which must also be protected by machine guns. In general however, rear area establishments such as those enumerated, are vulnerable in high degree only to the heavier assaults of bombardment aviation, and need not concern themselves unduly with the lighter attacks.

The locations of anti-aircraft machine guns follow the principles already outlined. They must be in close proximity to the area to be defended; also they are placed along the most probable routes of approach of hostile aircraft, where such exist.

Antiaircraft accessories. It is not practicable within the limits of this chapter to describe in detail the numerous devices employed in fire control by antiaircraft artillery. Two of these aids however are particularly important in their influence, both on antiaircraft fire and on the tactical methods of the air force. These consists of listening apparatus and of searchlights, which will be briefly described.

Listening apparatus. In a previous chapter it was noted that the presence of an airplane, even in daylight, is almost invariably first detected by sound; at night, of course, reliance is placed almost solely on this sense. To enable the listener to determine the direction of the sound with accuracy, instruments called listening apparatus have been devised. These are of two general types. The paraboloid listening apparatus consists of a parabolic sound reflector, which can be readily moved both in elevation and in azimuth. The sound waves from the motor of the airplane are reflected to a focus, where listening trumpets are placed. By means of these the direction of the loudest sound can be readily determined. This is of course the direction of the airplane, and after correction the data obtained in this way can be set off on the searchlights. A second type of apparatus consists of a group of megaphones, the apices of which are connected to the ears of the listener by rubber tubes. The latter type is somewhat more accurate, but is also more bulky and less mobile.

While, in general, the listening apparatus is effective in locating airplanes, there is always a chance that a ruse may destroy their value. Often the night bomber, having located his target from a fairly high altitude, cuts off his motor, and glides in to discharge his projectiles. In such a case, it is very difficult to locate the almost silent attacker. Then too, there is the possibility of the development of a suitable muffler. This has not yet been shown to be worth while. It reduces the power of the motor, which is of course particularly undesirable. Furthermore, it is claimed that the noise of a rapidly revolving propeller is almost as easily heard as that of the motor itself. However this may prove to be a factor with which the anti-aircraft defense must reckon at some future date.

The most common mission of the listening apparatus is to give the direction of the hostile airplane to the pilot light of a searchlight unit, so that it may be turned in the proper direction before being flashed. Sometimes, also, the data obtained from the listening apparatus may be employed for firing by sound. The location of the listening apparatus is governed largely by its former mission. It is placed near the pilot light and preferably in a quiet spot.

Searchlights. From the tactical point of view, the searchlight is of great importance: but for it, the defenses at night would be almost useless. The light in common use is the 60-inch size, which can project a beam of great illuminating power to a distance of 5,000 feet. However, in practice, it is rare indeed that an airplane can be picked up at that altitude. Its truly effective range is much below that figure. The light is carried on a truck, whose motor also furnishes the power for running the electric generator.

The location of the lights depends on the mission assigned them. If they are to assist the antiaircraft guns, they are usually placed at the four corners of an approximate square, whose center is the battery emplacement, and whose sides vary in length from 2,000 to 3,000 yards. This distribution is not however followed with such rigidity as to permit the accurate location of the battery from the visible lights. On account of the impossibility of concealing searchlights at night, they are kept at a distance from other locations of tactical importance. When searchlights are to assist aircraft, an effort is made to establish one or more belts of continuous illumination about the area to be defended. When this is impracticable, the lights are concentrated along the most probable avenues of approach.

Defensive balloon barrages.¹ At various times and places, efforts have been made to protect areas of great importance by balloon aprons, or barrages. These consist in effect of a netting of wire cables, surrounding the area to be protected, and supported by captive balloons. Barrage balloons are in ascen-

¹"Free and Captive Balloons," a volume of the Ronald Aeronautic Library, contains a section about barrage balloons.

sion only at night. The cables are heavy enough to wreck any airplane colliding with them, and at night, they are invisible from an airplane.

This method of defense is an excellent one, in very special cases, for very limited areas. It is doubtful however if it will ever find wide enough application to warrant its general adoption as an important means of anti-aircraft defense. It is limited to rather low altitudes, as aircraft fly: accordingly aircraft, when aware of its existence, are merely forced up a few thousand feet, with some slight loss perhaps in accuracy. The balloon barrage is very cumbersome, and also expensive. It will certainly exercise a strong deterrent influence on low flying wherever its existence is suspected. According to British belief, its moral effect on the German raiders over London was well worth the cost of the barrage. But as the sole anti-aircraft defense, it may be dismissed from further consideration.

The air force and anti-aircraft defense. As stated in the beginning of this chapter, it is intended confining this discussion to the passive means of anti-aircraft defense. This intention will not be departed from, but it must be recalled that the agencies of passive defense have both an independent rôle and also a subordinate one of assisting the friendly air force in its more aggressive functions. The discussion hitherto has been confined largely to the former class of duties. But it may be questioned whether the greater value of the anti-aircraft defenses proper, does not proceed from the aid they are capable of rendering to the air force. This view is certainly held in many quarters, and several nations have assigned their anti-aircraft artillery as an organic part of their offensive aviation. Whether views may be held on this subject, there is no disputing the necessity of the most intimate cooperation between the two agencies. Certain aspects of their relationship will be briefly considered.

The service of anti-aircraft information. Perhaps the most important source of information in regard to ground troops is the airman; it is in some sort a compensation that the service of anti-aircraft information depends for its effectiveness primarily on ground establishments. By means of listening apparatus and other agencies, anti-aircraft artillery keeps a very com-

plete record of all hostile air activity coming within range of its vision. In certain cases, where previous arrangements for offensive action have been made, the presence of hostile aircraft is immediately made known to the friendly pursuit force, which bases its further action on the information as to the strength and location of the enemy given by the antiaircraft service. From time to time, as the situation warrants, the latter also makes a résumé of enemy activity. By carefully studying this the air force commander is often enabled to obtain a fairly complete picture of the hostile situation, and even to deduce the hostile intentions. While of course, the air commander avails himself of all possible sources of information—reports of his own airmen, photographs of hostile airdromes, interrogation of prisoners, etc.—nevertheless the bulk of his information is derived from the reports of the antiaircraft artillery units.

Support of friendly aviation. Upon the approach of hostile airplanes, antiaircraft units not only fire upon them but also signal any friendly aircraft in the air at the time. This is done either to warn them of danger, or to enable them to attack the enemy, as the case may be. By properly placed shells, according to a pre-arranged code, information can be given which might otherwise escape the notice of friendly aviation. Antiaircraft units continue their fire on the enemy, until the approach of friendly aircraft into the danger zone causes them to cease fire.

At night, so long as existing conditions hold, pursuit aviation is entirely dependent on antiaircraft units for its effectiveness. The usual procedure is for friendly pursuit aviation either to remain at its airdromes on the alert, or else to patrol a definite air space. When warned of the hostile approach, pursuit aviation flies to the general vicinity of the enemy, as indicated by the searchlights. The success of the attack then depends almost entirely on the latter. If they can catch the hostile airplane in the beam, and hold him there long enough for the pursuit pilot to dive in with a good burst of fire, there is an excellent chance of scoring a victory. If however, the searchlights are unable to find the enemy, or if he succeeds in

maneuvering out of the beam immediately, there is little likelihood of successful action by defending pursuit aviation.

Defense of airdromes. The infrequency of determined attacks on hostile airdromes in the World War has been mentioned before. This is the more noticeable, when it is appreciated how helpless aircraft may become under certain unfavorable circumstances. Probably every pursuit pilot has dreamed at some time of "roosting" just above a hostile airdrome, and spraying pilots and mechanics with bullets every time they attempt to run out a machine for the take-off. The possibility of some such action as this emphasizes the necessity of providing every airdrome with a strong machine gun defense. Of course, anti-aircraft guns and their accessories are desirable, but it is especially necessary to insure that hostile attack or pursuit aviation, in attempting an assault on an airdrome, will meet with a formidable defensive fire.

CHAPTER IX

NOTES ON AIR LOGISTICS

Lessons of the World War. Logistics is defined as that branch of the military art that embraces the details of transport and of supply. It is apparent from the definition itself that the word covers a wide field of activity, and that many volumes might be written about logistics without exhausting the subject. As may be seen from this title of this chapter, any attempt to cover the subject in an adequate manner is expressly disclaimed. It is intended here only to note in a very general way certain phases of the subject that have a direct bearing on tactics.

In all matters pertaining to air warfare we are influenced with peculiar strength by our heritage from the World War. The necessity of subjecting all our methods in that contest to a critical examination, with a view to determining their suitability for future use, has already been explained. In the case of logistics, this is particularly necessary. In France we fought in a limited area; the whole theatre of operations was only a few hundred miles in length. From a centrally located airdrome it would have been entirely feasible for a bombing airplane to fly to either the northern or the southern flank of the front lines, and to return to its home base without refueling. If our next contest should take place in a theatre of markedly greater extent, the logistical methods current in the World War will have to undergo considerable modification. Another distinguishing feature of that contest was the fact that stabilization ruled, almost to the exclusion of mobility; and this was reflected in logistics to an even greater extent than in tactics. In warfare of movement—which we conceive to be “normal warfare, and which we anticipate as the probable warfare of the future—the methods of the World War will certainly not apply fully.

The airdrome. The typical airdrome of the World War had an unmistakable air of permanence. It required much

time to construct, and once established, was used for months and even years. Under these circumstances, airdromes were naturally complete in almost every respect; they left little to be desired on the score of either utility or of comfort. This was of course altogether admirable; but it unquestionably led to the formulation of a standard that was dangerously high. Men became accustomed to luxuries, and soon came to regard them as necessities. There was a general feeling that hangars and houses were as necessary as airplanes. Few men attempt to distinguish between what is absolutely essential, and what is only desirable. It is not meant by these statements to stamp as unworthy the efforts on the part of air commanders to provide their men and their machines with protection against the elements, and to give the former every reasonable care and comfort. On the contrary, there is no more certain mark of the amateur in war than a failure to do those very things. Only the inexperienced permit their men to endure unnecessary hardships. The veteran contrives somehow to extract the greatest possible measure of comfort from every situation.

Nevertheless, there was a decided tendency in the World War to demand too much in the way of airdrome facilities. This sometimes had unfortunate results. For example, on one or two occasions a rapid movement of the lines left certain airdromes too far in rear to serve as operating bases. As airdromes of the desired standard were not immediately available, the practical consequence was that the air organizations, for a time, were put completely out of action. Undoubtedly such incidents would rarely or never have happened if the World War had ever become truly mobile, and the methods employed in air movements had been modified to meet these conditions. But such was not the case; incidents like those described were not common enough to become a serious matter, and accordingly no great effort was made to change the system. But it is evident that provisions for future warfare must visualize more frequent movements of airdromes. They will not, of course, have to be changed with every advance of the infantry; probably airdromes will have to be moved forward only once for every three or four forward displacements

of the artillery, for example. But there must be far greater mobility in this respect than was demanded in the World War. This may necessitate a decided lowering of standards for service airdromes. For example, protection of the airplane against weather may have to be dispensed with; but with cockpit and engine covers, and with means to stake down the machine, this is not a serious defect; moreover, hangars make it quite impossible to conceal the nature of the airdrome. In fact in mobile warfare of the future, air units may consider themselves fortunate if the personnel obtains better shelter than that afforded by canvas.

There is some reason to believe also, that if the personnel situation were studied with a view to greater mobility, it would be found that the number of men formerly considered necessary for a service squadron in the field, could be sensibly reduced without depriving units of their really necessary numbers. Obviously such a reduction would simplify both supply and transportation.

Personnel in movements of air units. If we accept as an invariable rule that air squadrons cannot operate unless provided with approximately their full quota of men, as laid down in tables of organization, then it follows that the mobility of the air force, outside of the restricted area of the cruising radius of the airplane, is no greater than that of foot troops. For example, if we should wish to move an air division of three brigades a distance of 1,000 miles, all the airplanes of the division could be moved in a single day, under exceptionally favorable circumstances. If the order for such a movement were issued one night, the next night would see the airplanes of the division at their new destination, barring of course the small percentage of those having forced landings. At that time however, the enlisted men of the squadrons, only a small proportion of whom could be taken by airplane, could just be boarding the troop trains to take them to their new station. Even if a large number of trunk lines connected the two places, and the most favorable conditions existed, the full strength of the squadrons would not be available at the new airdrome for more than four days after the issuance of the orders. The

movement would be completed in exactly the same length of time as though they were foot troops.

This seems, on the face of it, to be imposing an unnatural restriction on the mobility of air units. It is certainly illogical to have enormous speed of movement just up to a certain distance, and then to be reduced to the mobility of the least mobile of combatant arms. And in fact, this is not a natural restriction, imposed by inherent limitations. It results simply from the fact that the problem has never presented itself in war, and accordingly has not been solved. But experience and common sense alike show that air movements are restricted in fact only by air conditions, and not by railroad schedules. A possible solution of the difficulty is furnished by the common peace time practices of cross-country flying. While the majority of such flights are from one operating airdrome to another, nevertheless numerous flights are made to landing fields where none of the facilities of the airdrome exist. The pilot and the observer must perforce be their own mechanics; but experience shows that they can operate for days in this manner, with some slight assistance from outsiders. Where several airplanes are together, the difficulties of the situation are all the more easily overcome. Of course, if the airplane meets with a somewhat serious accident, the pilot is helpless to remedy the matter until assistance arrives from the airdrome. But with skillful pilotage, these mishaps are infrequent, and a large number of airplanes could make such a movement as that described above with only a very small percentage of casualties from this cause.

If considerations of supply be excluded, there is no good reason why a large number of airplanes cannot accomplish with equal ease, what a few have shown to be entirely practicable. It is well within the bounds of the reasonable, to expect an air division to effect a distant move, and to operate for several days thereafter, without a single mechanic. Of course, under these conditions, there undoubtedly would be a larger percentage of airplanes out of commission, than would be the case if all the facilities of the organization were on the landing field. But the losses from this cause would be only temporary,

and would never be large enough to exercise a determining influence on the tactical situation.

Fortunately, in the general case, it is unnecessary for the air units to operate under conditions quite as severe as those described above. It is always practicable to take along a certain number of mechanics by air. While attack, pursuit, and observation aviation have no extra room for mechanics, there are squadrons of transport airplanes assigned to the larger units of the air force. These airplanes can each carry eight men in addition to the pilot. Bombing units are also provided with transport airplanes, and in addition can carry a certain number of extra men in the bombing airplanes themselves. If the airship ever be properly developed, the utilization of these promises a ready solution of the problem. It is true that airships are never assigned as an organic part of heavier-than-air units, but they would unquestionably be attached, when available, to facilitate air movements.

Of course, even with the facilities enumerated above, all of the men of a large air unit cannot be transported by air in one move. Many of them would have to go by rail or by motor transport. But by carefully selecting the key men in the organization, it could operate for days and even weeks, with only a small loss in efficiency.

Supply of air units during movements. In general, each airdrome is occupied by a group. In regulating movements by air, where the distances are such that intermediate landings for refueling are necessary, every effort is made to allot one intermediate landing field to each group. This is very generally practicable in America today, and will become easier to assure with the passage of time, and the consequent increase of air transportation. Air movements therefore consist as a rule, of simultaneous flights by groups, each along its own designated airway. The problem of supply therefore becomes a group matter. Rationing cannot follow the usual procedure, since the transportation of cooking facilities is impracticable. It is, of course, always possible to carry cooked rations for the flight. In general however, local purchases can be depended upon for the supply of rations.

As the number of flying men in a group will average about 150, this will rarely put a strain on local resources. In exceptional cases, special provision must be made for the transportation of rations by air. One transport airplane in each group will generally suffice for this purpose.

The supply of fuel may offer more difficulty, and may require special preliminary arrangements by the military authorities. Usually however, local resources can provide for the needs of the group. For example, a group of four observation squadrons will need approximately 4,000 gallons of gasoline at each refueling. Airdromes however are invariably near towns or villages, and in the United States, this amount of gasoline can be obtained in even the smaller places, either immediately or upon a few hours' notice. It is true that high-test gasoline of the grade used for airplane motors cannot be widely obtained in large quantities; where time permits, preliminary arrangements should be made to obtain this. But, in emergencies, the ordinary commercial gasoline may be used. Much the same general remarks apply to the supply of oil.

Certain common minor injuries to the airplane may be readily repaired on the spot, provided spare parts be available. In movements of this character, a small store of spare parts may be carried by airplane.

Regulating the movement. Intermediate landing fields are chosen at such distances that the airplanes can make the flight within their fuel capacities, with a reasonable factor of safety for head winds and slight deviations from the course. The time required for the completion of an air movement where intermediate landings are necessary, will be greatly influenced by the fueling facilities at the designated landing fields. The quickest method of refueling a small number of airplanes is the use of special gasoline trucks, which can run alongside the airplane and pump gasoline into it. But there will rarely be a large number of these available. For units the size of a group, probably the quickest method is to refuel from 5 to 10 gallon tins. This enables all the airplanes to be refueled simultaneously.

The manner of conducting the flight is determined largely by the nature of the intermediate landing fields. If the latter are spacious, the group proceeds as a whole. If on the other hand only a few airplanes can be accommodated at a time, the movement must be made by flights, time being allowed for each flight to clear before the next attempts to land. The latter procedure requires, of course, a much greater period of time.

To illustrate by an example, let us assume a group movement of 100 pursuit airplanes, to a new airdrome 1,000 miles away. The cruising speed of the airplane is assumed to be 140 miles an hour, and its fuel capacity at this speed to be $3\frac{1}{4}$ hours. Two immediate landing fields are necessary, which will be designated as *B* and *C*, the initial airdrome being called *A*, and the destination, *D*. If *B* and *C* are spacious airdromes, suitable for group operations, the following approximate schedule may be followed. It is assumed that the distances between airdromes are the same, and the movement takes place in summer. Daylight lasts from 5:00 A.M. to 8:00 P.M.

Unit	Date	Take-off at <i>A</i>	Arrives over <i>B</i>	Take-off at <i>B</i>	Arrives over <i>C</i>	Take-off at <i>C</i>	Arrives over <i>D</i>
1st Group.....	<i>D</i> day	5:00 A.M.	7:23 A.M.	9:53 A.M.	12:16 P.M.	2:46 P.M.	5:09 P.M.

The above figures are based upon speed in still air. If there were a following wind, the times would of course be reduced. On the other hand, if there should be a head wind of 40 miles an hour, a third intermediate landing field would be necessary and the movement would require two days, if flying were restricted to daylight. Let us now compare this schedule with the one below, which is based upon the assumption that *B* and *C* are small landing fields with poor facilities, where not to exceed one flight at a time may land and refuel.

Unit		Date	Take-off at A	Take-off at B	Take-off at C	Arrives over D	Remarks
Sq.	Fl.						
1st	"A"	"D" day	5:00 A.M.	9:33 A.M.	2:06 P.M.	4:29 P.M.	} Refuels and spends night at C
	"B"		7:12	11:45	4:18	6:41	
	"C"		9:24	1:57 P.M.	--	--	
2d	"A"	11:36	4:09	--	--	} Refuels and spends night at B	
	"B"	1:48 P.M.	--	--	--		
Serv.	"A"		4:00	--	--		
1st	"C"	"D" plus 1" day	--	--	5:00 A.M.	7:23 A.M.	} Refuels and spends night at C
	"A"		--	--	5:10	7:33	
	2d		"B"	--	5:00 A.M.	9:33	
2d	"B"	--	7:12	11:45	2:08 P.M.	} Refuels and spends night at B	
	"C"	5:00 A.M.	9:33	2:06 P.M.	4:29		
3d	"A"	7:12	11:45	4:18	6:41		
	"B"	9:24	1:57 P.M.	--	--		
3d	"B"	11:36	4:09	--	--		
	"C"	1:48 P.M.	--	--	--		
4th	"A"	4:00	--	--	--		
3d	"A"	"D" plus 2" day	--	--	5:00 A.M.	7:23 A.M.	} Refuels and spends night at C
	"B"		--	--	5:10	7:33	
	4th		"C"	--	5:00 A.M.	9:33	
4th	"A"	--	7:12	11:45	2:08 P.M.	} Refuels and spends night at B	
	"B"	5:00 A.M.	9:33	2:06 P.M.	4:29		
	"C"	7:12	11:45	4:18	6:41		

In the above table, it is assumed that only one flight at a time may be refueled at *B* and *C*, but that nevertheless two flights at a time may be accommodated for the night, by moving part of the machines off the landing field.

Of course such schedules as the first one would not be attempted unless there were especial reasons for urgency. Even with the fast pursuit airplane, it requires over seven hours of almost continuous flying to cover this distance in a day. With the slower types, this time would be much increased. Flights of this duration subject the personnel to great fatigue; they should therefore be avoided, much as one would avoid requiring a forced march of infantry. It is of course also practicable to conduct air movements at night; but this too introduces an extra hazard, which is justified only by an emergency.

Normal supply methods. As the general scheme of supply of the World War is studied, it appears at once that the problem of changing such a plan from the supply of one front to that of another front a thousand miles away, cannot be solved in a few moments. Of course the needs of an air unit, even if it be a division, are small compared with the gigantic consumption of men and material on the Western Front. Nevertheless the problem of supplying air units must be carefully studied and worked out beforehand, or the mobility of the air force may be greatly restricted through failure of the supply system to function. It is highly desirable that base depots, containing reserves of all kinds of supplies needed by air units, be located so that they may readily be reached from any theater that is at all likely to be the scene of future air operations. Even with the most carefully planned arrangements however, distant movements will generally cause a dislocation of the supply system for a time. Several days may elapse before a normal flow of supplies can be established to the new front, if the usual methods of transport are utilized. On this account, it seems to be particularly necessary to study the question of transportation by airship. As a basis of organization, there should be constructed, for every air division contemplated, enough airships to transport the essentials for operations, during the time the usual methods will probably be inadequate. Such a reserve of airships would also be of great value where roads and railroads were lacking, or had been temporarily interrupted for any reason.

Chapter X

NAVAL AVIATION

Terminology. A science so new as that of aviation necessarily produces a host of new technical terms, which sometimes greatly confuse the nonprofessional reader. This is unfortunate, but is unavoidable unless brevity is to be wholly sacrificed. But the reader is indeed in a sad plight, who encounters two different sets of technical terms, existing side by side, and applying to the same science. When, to add to this, the same words occur in the different vocabularies with entirely different meanings, confusion becomes worse confounded. To some extent, this is now the case in the technical terms used by the air forces of our Army and of our Navy. Many words have the same significance in both arms of our national defense. But many others, among which may be mentioned such common words as *flight* and *division*, mean wholly different things in the two services. The preceding chapters of this volume have adhered to the words and phrases current in the air force of the army. To avoid burdening the reader with an unnecessary hardship, it is purposed continuing the use of this terminology, even in a discussion of naval aviation. Of course this rule can be followed only where there is a correct word available. Where any term is peculiar to naval aviation, and has no counterpart in the sister air force, recourse must be had to the expression employed in the navy.

Points in common with army air forces. The mere fact that it is possible to adopt the procedure described above suggests at once that the air forces of the army and of the navy have many things in common. While a superficial examination shows remarkably few dissimilarities between the two, a more thorough study, far from changing this view, tends rather to confirm it. It is impossible, in the space of this chapter, to enumerate the countless points of similarity. But a few of the more notable examples may be cited to show the general character

of these common possessions. It is obvious on the face of it that such characteristics as speed, useful load, and rate of climb, have precisely the same significance and are governed, in their mutual relationships, by the same laws, whether the aircraft belong to land or to naval aviation.

Going from the technical to the tactical field, let us assume that a commander of a force of pursuit aviation is about to join battle with the enemy. Many considerations enter into his plan of action; but an analysis of numerous typical situations shows that his decision is usually based upon purely aeronautical grounds. He is concerned in the solution of the problem immediately at hand, and cares very little, until the fight is finished, whether his home airdrome is a field ashore or the deck of a carrier. To enter another and broader field, the principles of war—many of which were discussed in a former chapter—obviously apply in all their fullness, whether the war be waged in the sky above the land or in that over the sea. A catalogue of these points of similarity might be continued indefinitely. But enough has already been said to show that a complete study of naval aviation, even in a general way, would result in needless repetition of previous statements. To avoid this, the method of discussion adopted in this chapter consists in noting the various ways in which naval aviation differs from that of the army.

History of naval aviation in the World War. From the standpoint of the student of tactics, it is unfortunate that the World War left us so little historical information in regard to what may be called purely naval air warfare. Such air battles as occurred were almost without exception over the land, and between air units operating from land bases. Even in this category of air fighting, the war by no means developed air tactics to its full possible growth. As stated previously, little was accomplished in the employment of pursuit aviation beyond the school of the squadron. But at least, in air-land warfare, sound methods of employing the smaller units were devised, and the trend of future development was unmistakably indicated. This experience, inadequate though it may be for our future needs, is nevertheless a priceless heritage to the air tactician. The foundation is laid.

In air-sea warfare, on the other hand, this seems to be lacking. Air combats, or air force operations based on a high seas fleet—which alone may be called purely naval in character—were not exemplified in the World War. It is true that naval aviators rendered invaluable services, and gave to history a long list of heroic names and deeds. But the operations in which they participated were either overland expeditions or else seaplane patrols. In the case of the latter, the aviators almost never found an enemy in the air. Their principal objective was the submarine, and their accomplishments belong to the annals of the sea, rather than to those of the air; no lesson in air warfare can be deduced from their activities. The enemy they had to contend with was nature and not man. In the first named class of operations also, there was nothing peculiarly naval in character. These overland expeditions may have had a direct naval motive, as in the bombing of submarine bases, but they were executed against land-locked objectives from land bases, and differed in no way from similar expeditions by the army. They, too, teach us little of the special form of air warfare which is purely naval in scope.

It is apparent then that naval aviation suffers under a handicap in having no foundation of historical fact on which to rear the edifice of its tactical doctrine. The difficulty, however, is apparent rather than real, and is largely overcome by the close correspondence that naturally exists between air fighting over the land and that over the sea. The greater part of the methods found satisfactory in the former may be bodily transposed to the latter, and used with little or no modification. For this reason, the gaps in naval air doctrine, which experience has left to be filled, either by pure reason or else by the results of peace time experiment, are not as great as would appear on first examination.

Characteristics of naval aircraft. It is evident that the basic principles in the design of military airplanes, that were discussed in a previous chapter, apply fully to naval aircraft also. For instance, the highest speed should be sought consistent with the performance of the mission for which the airplane is designed. Also the load to be carried, subject to the same reservation, should be reduced to a minimum. It is in respect to the latter qualification that naval aircraft make

demands on the designer which are more sharply conflicting than those of the land airplane. Naval aircraft, from the very nature of their service, find it highly desirable to be able to alight safely on the surface of the sea, as well as to be able to take off from it. Another quality that would greatly enhance their value as naval craft, is that of complete seaworthiness. Unfortunately, the possession of these desirable features carries with it a large addition in weight, the evil consequences of which have been fully discussed in a previous chapter. As in the case of the land airplane, it is necessary that the fundamental purpose for which the airplane is designed be kept in mind. This must not be disregarded or jeopardized, in the interests of what is merely desirable.

For example, let us consider, first of all, the pursuit type of airplane. In so far as its flying characteristics are concerned, the desirable naval pursuit airplane differs in no way from the land pursuit machine, the tactical specifications for which have been previously outlined. But if we disregard distinctively air attributes and attempt to convert the pursuit airplane into a seaplane by the addition of floats, its worth in an air fight is at once compromised. Both speed and rate of climb are sensibly reduced; maneuverability, which is a function of both, suffers in even greater degree. Of course, this constitutes no grave disadvantage, if the enemy follows the same policy. If navy has to contend only with navy, and the characteristics of the naval pursuit airplane become standardized throughout the world, no handicap exists on either side. But if, on the other hand, the enemy, intent only on the fundamentally air nature of the problem, should employ a pursuit airplane of the land type,—disregarding the minor claims of safety, in the interests of victory—the addition of weight might well have serious consequences.

It is not too much to say that the difference in flying characteristics between the two airplanes might, and probably would, make the difference between defeat and victory. As so often happens in war, an action based essentially upon considerations of safety, defeats its own purpose. Against a vigorous and aggressive enemy, the losses incurred in air combat by providing floats for pursuit airplanes, would probably far

exceed the number of lives saved from drowning by those same floats. Of course, for peace time training, or for any operation where the enemy is poorly equipped, the float type of pursuit seaplane may well be employed. It is so designed that wheels may be substituted readily for floats, and the seaplane thus converted into a land type. The latter type, from the foregoing considerations, will probably be the machine normally used for the naval pursuit operations. It will differ only in minor details from the pursuit airplane designed specifically for land-air use. It may well be provided with air-bags, which may be quickly inflated when a forced landing in the water is seem to be imminent, and which will keep the machine afloat for some time. These can be installed without materially injuring the flying qualities of the airplane, and serve to provide a reasonable safety device. The airplane, however, cannot take off from the surface of the water when thus equipped.

While the disadvantages of extra weight patently outweigh the advantages in the case of the naval pursuit airplane, the decision is more difficult, when we come to consider the other branches of naval aviation. Like their counterparts in the army air force, they must carry so large a useful load, in order merely to perform their air missions, that all hope of meeting hostile pursuit aviation on an even footing of airworthiness, must be abandoned. They must rely for safety in combat, not on speed or on maneuverability, but solely on the defensive power of the mutually supporting guns of a formation. On this account, the sacrifice of flying qualities in order to be able to alight on the water, does not present quite the same aspect as in the case of the pursuit airplane. Obviously, however, when other things are equal, the provision of floats or other means of sustentation, cuts down by just that much the useful load of the machine. From the purely air point of view, this is always undesirable, though undoubtedly justified in some cases.

Sea airdromes. Since the fuel capacity of the airplane is quite limited, it must return to its base at definite intervals. Obviously the base should be able to afford facilities both for the take off and for the landing. This requirement seldom presents any great difficulties on land, where spacious air-

dromes are frequently found, except in case of forced landings. But when we consider that a land plane of the observation type, for example, requires a run of about 400 feet for the take off, and about 800 feet for the landing, the problem facing the naval flier, when he wishes to use the deck of a ship as an airdrome, is a difficult one. However its solution has been undertaken in good earnest, and a new type of seacraft, the airplane carrier, has taken its place in every modern navy. But airplanes are not confined solely to the carrier as a base. Provided that they be able to alight safely on the surface of the sea, they may be attached to battleships, cruisers, destroyers, or indeed to almost any type of surface seacraft. Tenders are especially assigned as a base for the operation of aircraft.

Airplane carriers. From the air point of view, the carrier is merely a floating airdrome. It contains a flight deck, from which airplanes can take off, and on which they can alight. In order to keep the flight deck free, lower decks are utilized to accommodate airplanes until actually ready to operate, when they are transferred to the flight deck by elevators. The carrier presents a notably different appearance from other ships, due to the fact that the upper works are either removed altogether during flying, or else are placed together in an "island" on one side of the ship.

At the present time, the United States has only one carrier in commission, the *Langley*, which was originally designed for other purposes, and is both too small and too slow to be considered first class. Two other carriers are under construction, the *Lexington* and the *Saratoga*, both of which were originally laid down as battle cruisers. Under the terms of the Washington Conference, the United States is limited in tonnage of aircraft carriers to 135,000 tons, but as there seems to be no inclination on her part to build up to this allowance, it can scarcely be regarded as a truly restrictive clause. The carrier is also provided with armament, in the later types.

In utilizing the flight deck of the carrier, the airplane may take off in two ways: either sufficient runway may be available for it to gain flying speed under its own power, in the same manner as on land, or else it may be launched from a catapult, the power being furnished either by compressed air, or by a

powder charge. In general the take off offers few difficulties; the problems have been satisfactorily solved. But so much cannot be said of the landings. In the case of a ship of the *Langley* type, a successful landing depends very largely on the operation of an arresting device, which applies a constantly increasing force to the airplane, until it is brought to rest. While the carrier is habitually headed into the wind, so that the relative speed of the airplane is reduced by the velocities both of the wind and of the carrier, nevertheless it is a delicate feat of pilotage to land and hook the arresting device in just the proper way. Moreover, the pilot is not given the same chance of recovery as on land, where a timely use of the motor has saved many a rough landing from ending in a crash. Then too, in a heavy sea, where the carrier itself is subjected to considerable motion, the difficulties of the airplane pilot are notably increased. On the whole, the problem of landing is so much more formidable on the carrier than on the land air-drome, that it will inevitably result in a larger proportion of crashes. This fact may enter as a serious drawback in a long campaign, where daily operations must be undertaken during unfavorable weather conditions.

But the carrier has an even more serious disadvantage, from the tactical point of view, in the element of time. This has a particularly important bearing on the operations of pursuit aviation. Where airplanes must take off and alight under difficult conditions, one at a time, there is considerable loss of time. It is no unusual thing for a pilot to make several unsuccessful approaches to the carrier, before the final attempt at landing. This is of no serious consequence for a flight of three airplanes; but when we consider the squadron and even the group—which is envisaged as the normal complement of the largest carriers—time enters in decisive fashion. The pursuit airplane carries only some two to three hours of fuel, nor can this amount be increased without sacrificing other qualities. As an example of the influence of time, if it should require fifteen seconds for each airplane to take off, and one minute to land, the commander of a group of 100 airplanes would be able to operate with his command as a whole for less than one hour. Two-thirds of his cruising time would be spent above his

carrier, forming his unit on the take-off, or breaking it up by degrees for the landing. Of course, these figures present an unusually adverse case. Moreover, with the improvements which may confidently be expected with time and with the advent of more modern carriers, some of these difficulties may be removed, and all of them ameliorated.

Nevertheless, the carrier, as compared with land airdromes, where many airplanes may take off and land simultaneously, possesses so many inherent defects, that it will probably always rest under a serious disadvantage, if the airplanes of the enemy are operating from a land base. We may therefore expect to see this factor assume an ever increasing importance in naval strategy and tactics. It is no mere accident that naval battles of the past have taken their names, almost without exception, from nearby points of land. It may well be that in the future, tactical locations for airdromes, rather than trade routes or fortified harbors, will determine the place of battle.

Other ships and airplanes. The airplanes attached to ships other than the carrier, usually take off by means of the catapult. Upon completing the sorties, they return, and alight on the surface of the water alongside the vessel. All are, of course, provided with some means of flotation, and in some cases it is practicable for them to refuel at sea. In general however, they must either seek the shelter of the land, or else be hoisted aboard the vessel, in order to refuel. The latter operation is attended with numerous difficulties, and of course, cannot be accomplished without taking up much of the time of the vessel. In spite of these objections, the method is practicable so long as peace time conditions obtain, and the weather is reasonably good.

When, however, the conditions are those of war and of battle, it is doubtful if these methods can apply. Let us consider first of all, the case of pursuit aviation operating from vessels other than carriers. If the airplane is to function as described above, it must have floats; for the reasons stated above, these are almost enough of a handicap in themselves to bring about the defeat of the pilot in case he falls in with hostile pursuit equipped with land planes. Moreover, in battle the vessel from which the airplane took off, will seldom, if ever, be able to take

the time necessary to hoist the airplane aboard again. Under these conditions, the unfortunate pursuit pilot would depart on the execution of his battle mission with the assurance that even if he were fortunate enough to survive the fire of his more advantageously situated enemy, nevertheless he could look forward only to a final landing in the sea, from which his rescue would be wholly a question of good luck. Human nature being what it is, the pilot could scarcely be blamed if his morale were not of the highest order. Indeed, some psychologists hold that the very essence of the will to fight is contained in the hope of victory; once this goes, little is left save in rare and exceptional spirits. Certainly, the moral factor is one of great importance and cannot be lightly passed over. If on the other hand, the pilot were equipped with a plane of the land type, not only would he feel on even terms with the enemy, but he would also have the pleasant assurance of being able to land on the deck of a friendly carrier should his fuel run low. But in any case, whether the plane fall in the sea, or reach the deck of the carrier, it is precluded from returning to its original ship during the battle. One mission, and only one, is allowed each airplane aboard ships other than carriers, at least in so far as the commanders of the ships may influence the action.

In addition to these objections, there are other tactical considerations which must be taken into account. The necessity of adhering to the principle of mass in pursuit combat has already been discussed. This principle is seriously violated by parceling out pursuit airplanes by ones and twos among the ships of a fleet. With the best intentions in the world, intimate cooperation and team work would be almost impossible to achieve under these circumstances. From these considerations, the conclusion seems inevitable that the only suitable base for pursuit aviation with a fleet, is the carrier. It is true that the facilities with the fleet are limited, and that, from sheer necessity, all of them must be used. It might also be reasoned that the airplanes from the battleships may on their second sortie, serve merely as replacements for the planes which will inevitably be lost from the carriers in the first sortie. But these reasons can scarcely outweigh the strong objec-

tions to this procedure. On the carrier, the pursuit force can at least land and take off, and its members are better situated to achieve the tactical team-work, which is essential to victory.

When we come to consider the desirability of assigning observation aviation to vessels other than carriers, it is evident that many of the objections cited above still hold. They do not however, apply in the same degree. The observation has greater fuel capacity than the pursuit airplane, and therefore stands a better chance of remaining in the air for the duration of an action. Moreover, observation is a service rather than a combatant arm, and the principle of mass does not apply, as in the case of pursuit aviation. Furthermore, its cooperation must be secured, not with other airplanes, as in the case of the pursuit pilot, but with the ship it serves. Here there should be liaison of a most intimate character. These reasons strongly suggest the advisability of assigning observation airplanes to battleships and cruisers. The amphibian plane, which can alight either on land or on water, is suitable for observation requirements, though it would be quite useless in the rôle of pursuit aviation. If such a machine, on returning to its ship at the end of a sortie, were signalled not to land alongside, it could proceed to a carrier, refuel, and rejoin its ship when circumstances permitted.

Observation. The service of observation in naval warfare is analogous in many respects to the similar duties performed for the land forces. But, though alike in purpose and in general scope, the two differ altogether in details. A pursuit pilot, thoroughly trained in his work, would meet with little that was new or unexpected in transferring his activities from the air over the land to that over the sea. But with the air observer, the transition would be into a notably different realm. The observer for infantry must have a thorough knowledge of infantry tactics, if he is to know what to look for, and is to understand the significance of what he sees. If such a well trained observer were suddenly called upon to execute a mission of naval reconnaissance, he would find most of his knowledge, purchased by years of labor, of little value in his new sphere of activity. He is now concerned with naval vessels, and must know the various classes and the functions of each of them. He must have a thorough

knowledge of naval tactics, not only in order that he may give to his commander a complete picture of the strength, location, and dispositions of the hostile fleet, but also that he may, as was illustrated in recent maneuvers, even suggest a certain course of action, when the situation seems favorable. In short, the services of observation for land and sea forces differ enough to warrant complete specialization.

The principal duties of the service of observation, in the navy as in the army, are embraced under the headings of reconnaissance, and of the adjustment and observation of artillery fire. In the navy however, the functions included in these categories are considered to differ among themselves enough to warrant specialization. Accordingly there are several types of observation airplanes, designed for the different classes of missions. The observation airplane proper executes limited reconnaissance duties, and furnishes to the ship it serves the necessary data for the control and adjustment of fire. For battleships, it consists of a three-seater airplane of the amphibian type. The pilot and the observer occupy two of the seats, while the rear seat is reserved for the gunner, who is also a radio operator. For scout cruisers and submarines this type is impracticable, and accordingly is replaced by a two-seater and a single-seater respectively. In addition to these classes, there are two other types for distant reconnaissance (scouting and patrol). In both, a marked characteristic is great fuel capacity and a consequently increased cruising radius.

Missions of distant reconnaissance demand great skill in navigation for their successful accomplishment. As they are executed beyond the range of support by friendly pursuit aviation, they must depend for protection on their own resources. Since the airplanes of this type are comparatively slow, once they are sighted by hostile aviation, there is little prospect of escape, for pursuit planes can overtake them at a rate of some 60 miles an hour. They are also comparatively unmaneuverable; the single airplane of this type, though well armed, would therefore fall an easy prey to a flight of pursuit aviation, once the former were brought to heel. Tactical considerations therefore dictate that missions of this character should be executed by a formation, to provide mutual support. This also provides

the possibility of rescue, in case of a forced landing, and tends in general to heighten morale—there is a definite desire for companionship in flying over the lonely wastes of the sea.

The observation of gunfire, or spotting, does not differ in principle from the same mission with artillery in land warfare. In general however, naval guns fire at ranges much greater than those usually met with in combats on land. Largely on this account, the airplane assumes an increased importance in sea fights. Due to the height it may attain, and to its ability to move rapidly to the point of vantage for visibility, the airplane can furnish more accurate observation than can be obtained from the main-top of the ship. As on land, communications still fall far short of perfection; but unquestionably they will be improved with the passage of time. Spotting planes also habitually fly in formation for mutual protection.

Bombardment aviation. In warfare of the past, battles on land have been, in the final analysis, conflicts of infantry. Once this was true of sea fights also; they were little else than a succession of conflicts of infantry on shipboard, in which missile weapons played a part, but in which shock action was the determining factor. This is no longer true; naval battles of the past few centuries have been essentially artillery duels. Shock action, once the paramount consideration, has long ceased to be a characteristic or even a possible combat form. The battle is now distinctively an affair of missiles. It was, therefore, entirely natural that when a missile weapon was developed whose range was measured, not in thousands of yards, as with the big gun, but in scores and even hundreds of miles, and whose accuracy was practically independent of range expressed in horizontal distances, it should suggest to many minds the birth of a new influence of magnitude in naval warfare.

Whatever might be the influence of bombardment aviation in land warfare, it was felt that this could be no exact criterion of its power in a sea fight; for, on land, however important missile weapons have become, they are by no means recognized as the final arbiter of battle. It is unfortunate that here again, naval history offers little help in the solution of the problem, for the last great sea action antedates the development of an effective bombardment aviation. We are, therefore, compelled to rely almost

entirely on the results of peace time tests and experiments for such conclusions as may be drawn, although certain war experiences are of some assistance. Unfortunately this subject has aroused the most bitter controversy, which has naturally tended to obscure reason. It is no part of this volume to perpetuate such a conflict. But since the employment of the air force in naval battles of the future will revolve about the aerial bomb, it is necessary to reopen this question, since any discussion of naval aviation would be incomplete without it.

The bombing tests. In 1921, off the Virginia Capes, and in 1923, off Cape Hatteras, the air force of the United States army succeeded in sinking, with aircraft bombs, a destroyer, a cruiser, and several battleships. Among the latter was the former German battleship, the *Ostfriesland*. This vessel is sometimes said to have been obsolete at the time of the sinking. The use of this word, however, is apt to be misleading, since it is sometimes given a technical meaning which differs from that in current usage. The facts are, that the *Ostfriesland* was not the latest type in battleship design; in both the British and American navies, there are several classes of battleships, which were completed after the *Ostfriesland*. On the other hand, she was sufficiently modern to have participated in the first line of battle at Jutland, and there are (in 1924) in both the British and American navies, battleships which were completed prior to the *Ostfriesland* and are still rated as first line. The other battleships sunk in the tests were unquestionably obsolete in any sense of the word. As a result of these bombing tests, the highest authorities of the army and navy arrived at the opinion that aircraft bombs were sufficiently powerful to sink any vessel afloat at that time. While this conclusion is significant, its tactical bearing is obviously limited.

These tests were, of course, conducted under peace time conditions. To accept them blindly as indicative of the results to be expected in battle, is wholly unjustified. But on the other hand, it would be equally unwise of us, lacking as we do any examples from war to guide us, to throw away the lessons of these tests as meaningless and without value, merely because they did not take place under battle conditions. The obviously wiser course is to consider wherein the conditions surrounding

these tests differed from those of actual warfare, to evaluate these differences—wherever they are susceptible of evaluation—and to modify accordingly the conclusions that would be drawn if the tests were regarded as a demonstration of war time possibilities. In the succeeding paragraphs, an attempt will be made to approach the subject on this basis.

Stationary and moving targets. The vessels sunk in the tests were all stationary. In war on the other hand, they would unquestionably be moving, and earnestly endeavoring to present as difficult a target as possible for the bombers. In theory, it would be a very simple matter to conduct a series of tests under the same conditions, and to ascertain the relative accuracy of bombing a moving target, as compared with the same target when anchored. Something of this sort is habitually done in the course of bombing training, in which towed targets are employed. It is interesting to note that the results show practically the same accuracy as in bombing a stationary target. However, this indicates very little, since the towed target is slow, and cannot zigzag. Unfortunately it has not yet proved practicable to obtain a target which has the speed and maneuverability of a cruiser or battleship, although ingenious attempts have been made to solve this difficulty by bombing the shadow of a moving airship. Nevertheless, it is possible to evaluate the factor of the ship's motion, with an accuracy, which, if not of the highest degree, is yet sufficient for all tactical purposes.

Accuracy of bombing would be unaffected by the ship's velocity, provided the vessel should maintain a constant speed and course during the time of flight of the bomb. This, of course, is precisely what the vessel will not do, if aware of its danger—which will usually be the case. But the vessel, it must be recalled, is confined to a single plane, and the radius of the arc on which it may turn has a well defined minimum for each type of ship. Accordingly, the area out of which the vessel cannot escape between the release of the bomb and its arrival at the surface of the sea, is a limited one. It is roughly a fan shaped surface, whose size depends on the speed and tactical radius of the vessel, as well as on the altitude from which the bomb is discharged.

Let us call this, for lack of a better term, the area of possible locations. Now the bomb is considered effective not only if it secures a direct hit on the vessel, but also if it strikes within 50 feet of the vessel's sides, where a mining effect is secured. Let us call this the danger area. Now if we assume that the vessel may have changed course and speed at any moment during the time of flight of the bomb, the ratio of the danger area to the area of possible locations gives a coefficient which expresses, albeit only approximately, the extent to which the probability of a hit is reduced by the maneuvers of the vessel. This coefficient has been calculated for a number of different cruisers and battleships, as well as for different altitudes of the bomber—all however, above 5,000 feet. It varies, of course, for each case; but an average of a number of calculations, based upon assumptions of a kind often met with in service, shows 1:2. For example, if the probability of securing a hit with the vessel stationary were taken as 1:3, the probability of obtaining the same result when the vessel is zigzagging would be 1:6.

The fact that the vessels in the tests were anchored was wholly unlike the conditions of actual warfare; on the other hand, it must be borne in mind that a serious attack on a vessel would seldom in actual warfare be undertaken by a single bomber, as was the case in the tests. The danger of attacks by hostile pursuit aviation would in itself preclude such a method. Furthermore, the tactics of the attacking air force would naturally be based upon the probability of the vessel attempting to escape by zigzagging; or would, at least, take this into account. The formation of bombers can be so arranged, or the timing of the release of the bombs so adjusted, that there will be discharged, not a single bomb, but a number of them so distributed that at least one will fall within effective distance of the vessel, no matter what maneuver the latter may execute during the time of flight of the bomb. For example, a flight of three bombers, in the customary close formation, would make such a pattern, if it attacked in a direction opposite to that in which the vessel is going, Nos. 2 and 3 in the formation dropping simultaneously with the leader; or the same result may be reached, if the attack is

made in the same direction as the vessel is going, and Nos. 2 and 3 drop their bombs approximately four seconds after the leader. Bombing in war will be by salvo rather than by single shots. There will be no such economical husbanding of bombs, as must of necessity exist in times of peace.

Bombers and antiaircraft artillery. During the tests, for obvious reasons, no attempt was made to endanger the bombing airplanes. In this respect, they differed more widely than in any other, from the realities of war, where the vessel would avail itself of every agency at its disposal to destroy the attacking bombers. Because of the fact that no account was taken of the possibilities of antiaircraft interference, things were done which would be wholly impracticable in war. For example, trial shots were used, the altitude of the bombers was lower than would ordinarily be permissible in war, and the airplane was under no compulsion to release its bomb until the conditions were favorable. All of these factors made for greater accuracy than would be attainable in war. Had the vessel been provided with antiaircraft artillery, the task of the bomber would have been more difficult. He would certainly have been compelled to operate at greater altitudes, and would have been subjected to harassing fire during the attack. On the other hand, the tests were conducted with a type of sight which has now become obsolete, and has been replaced by one whose marked superiority has already been described. Many of the practices which were essential to accuracy in the tests, are no longer necessary.

It may fairly be concluded, on the whole, that accuracy of bombing in any peace time test, will be greater than can ever be the case in war, where the enemy has antiaircraft guns. On the other hand, it is difficult to avoid the conclusion that such a defense alone can never halt a determined attack. It may harass, but it cannot destroy. The general subject of antiaircraft defense has been fully discussed in a previous chapter, but certain special phases of it may be mentioned here.

Let us take a concrete example. The latest class of American battleship, the *West Virginia*, has (according to Jane's "Fighting Ships") eight antiaircraft guns. Let us assume a flight of nine bombing planes, bent on the attack of the vessel.

They are provided with modern sights; accordingly, it is not necessary for them to maintain a constant course and speed over a distance of several miles, as was formerly the case. This is necessary only for the last score of seconds before the bomb is released. As the bombing flight comes within range of the anti-aircraft guns, it changes speed, altitude, and course, at irregular intervals, in order to make itself as difficult a target as possible. Prior to the moment of releasing the bombs, the flight is within range of anti-aircraft guns approximately two minutes. The task facing the guns would therefore be to destroy or neutralize the bombers within this short period. If the gunners should fire at their maximum rate, which is assumed to be 10 rounds a minute they could send up in all some 160 rounds. If we compare this number with the figure most favorable to anti-aircraft artillery, given in Chapter VIII, the contrast is striking. It must at once be added, that such a comparison is by no means conclusive proof of the inadequacy of this defense. It is well to be chary, as a rule, of mathematical demonstrations in matters of tactics. Nevertheless, they often afford an index.

Equipment of the vessel. The vessels in the tests had been stripped of nearly all movable equipment. It has been alleged that they might have been kept afloat, and even in the line of battle, if they had been provided with pumps and suitably manned, as they would have been in war. It is, of course, impracticable now to ascertain whether the destruction of the water-tight integrity of the vessel was too nearly complete for pumps to cope with. Possibly they could have done so. But on the other hand, the presence of the usual equipment and supplies aboard the vessels would not have been an unmixed benefit. The history of modern naval warfare shows that the proximate cause of the destruction of many vessels in battle, is not the immediate action of hostile projectiles, but rather the force of internal explosions. The underlying cause is of course the projectile, but it needs the presence of boilers and magazines to effect such thorough destruction.

A consideration that has sometimes been lost to view, in the numerous discussions of the tests, is the fact that, from the tactical point of view, the actual sinking of a hostile war-

ship accomplishes the desired purpose with a wholly unnecessary degree of thoroughness. It is enough merely to put the vessel out of action—which may be accomplished by many a blow that would leave it still afloat.

Future construction. The menace of the bomb will undoubtedly have an influence on future naval construction. Additional deck armor will be provided in an effort to neutralize the effect of explosions on deck. Since much of the destructive effect of the bomb comes from mining, this too must be guarded against. Older vessels will be provided with “blisters”; future construction will endeavour to localize underwater injuries by further internal subdivision. But there is an obvious limit to all of this if the naval vessel is to retain its useful characteristics as such. Meanwhile the bomb also increases in power. The *Ostfriesland* was sunk with 2,000-pound bombs. Already a 4,000-pound bomb has been constructed, nor does it set a natural limit. What this may be no one can foretell.

Protection by pursuit aviation. The vessels in the tests were, of course, unprotected by pursuit aviation. It is chiefly in this respect that war may wholly reverse the results of these peace time experiments. All the other variations from actual battle conditions were of minor importance, when compared with this one; for it is now generally recognized that the only hope of an adequate defense against aircraft lies in the action of other aircraft.

The inherent difficulties of the defensive in air warfare have already been discussed. The problem however presents peculiar features in naval warfare, which justify a further consideration of this special class of operations. By way of illustration, let us assume two hostile fleets, both of which are operation beyond supporting distance from land airdromes. The only air forces which may influence the situation are those on board the carriers of the two contestants, who may be designated for convenience, as the Red and the Blue fleets. Let us further assume that the Red fleet is inferior in major calibre artillery to its adversary, but that it is superior in air force, consisting of attack, pursuit, and bombardment aviation. The Blue air strength, on the other hand, consists in pursuit aviation alone. In all other respects, the two fleets are on a sub-

stantial parity. In such a situation, the Blue intention undoubtedly is to close with the Red fleet, where the superior gun power of the Blues can make itself felt. To defend itself against Red air attack, the Blue fleet plans to make an intensive use of its pursuit aviation, which is superior in numbers to that of the enemy. Since it is extremely difficult, in the general case, wholly to prevent observation, each fleet may be assumed to have reasonably accurate knowledge of the strength, location, and dispositions of its adversary. The Red intention in such a situation, is obviously the converse of the Blue; the former purposes remaining beyond range of the Blue guns, but within striking distance of aircraft; in this position, the Reds will repeatedly attack the Blue fleet with bombers, supported by the other elements of the air force, with the ultimate aim of reducing the Blue superiority in gun power to a point where a general action becomes advisable.

From the point of view of the commander of the Blue pursuit force, the problem is, strategically at least, a purely defensive one. But there are certain notable differences between this situation and that usually met with in the defensive on land, the difficulties of which were dwelt on in a previous chapter. In the latter case, the location of the hostile airdromes is rarely known with exactness; and the objective of any given matter, so widespread are the establishments of an army. In naval warfare however, there are usually two well defined areas, about which the interest of the air commander centers: in this case, they are the Red carriers and the Blue fleet. In this respect then, the situation is clarified for the Blue commander. On the other hand, he has to reckon with the inherent difficulties of operating from carriers, a handicap which is by no means completely offset for the defensive by the fact that the enemy labors under a similar burden.

A plan of defense. Several plans of defense are open to the Blue air commander. First of all, he may elect to hold his airplanes on the alert, taking off only on warning of the approach of hostile bombers. The success of this plan depends upon the timeliness of the warning, for these are always certain necessary preparations. Motors must be warmed up; while this phase of the preparation may be reduced appreciably, it can

never be entirely dispensed with. Then too, the pilots cannot take off in formation, but must proceed singly, afterwards assembling by flights, then by squadrons, and then by groups. Finally the assembled units must climb to an altitude above that of the approaching bombers, who should be intercepted far enough away from the fleet, to allow the air battle to develop its full effect before the bombers can strike at their objective. All this takes time. The estimate most favorable to the Blues can scarcely be under twenty-five minutes, even for a unit no larger than a squadron of 25 planes. It will often exceed this figure. It is evident then, that the warning must reach the Blues, while the Red bombers are, at the very least, 50 miles from the fleet, if the defense is to avail anything.

Service of anti-aircraft information. Considerations other than those of anti-aircraft defense generally require the presence of a screen of destroyers and fleet submarines. These can also transmit to the fleet information of the approach of hostile aircraft. There is, of course, the possibility that the enemy may drive in these craft on the main fleet, just to prevent this service of information. Thus in the situation outlined above, the commander of the Red fleet may decide to do this, at the same time utilizing the equal speed of his fleet to remain out of range of the guns of the Blue battleships.

In land warfare, the service of anti-aircraft information, can be performed only rarely by aircraft. This duty is essentially the rôle of ground organizations. At sea however, the conditions differ somewhat. In this situation, for example, it is necessary only to keep vigilant watch on the carriers, in order to receive ample warning. No matter how much time the pursuit units may require to reach their battle stations, it will be less than that required by the bombing planes, in the general case; so that, if Blue observation airplanes should send in by radio immediate information of activity on board the Red carriers, Blue pursuit forces would nearly always be successful in intercepting the bombers. It may be anticipated however, that the Reds would take counter-measures against this very possibility, and with every probability of success. An observation airplane which gains contact with the enemy, rapidly ascertains his dispositions and strength, and then endeavours to

escape, has an excellent chance of succeeding. If however, it attempts to remain in constant surveillance of the carriers, it is almost certain to be discovered and brought to combat, with the inevitable result of being either driven off its station or destroyed. This source of information cannot therefore be relied upon. Of course, all possible means of obtaining information must be utilized, however uncertain they may be in their functioning. But it appears that at sea, as well as on land, antiaircraft information must depend primarily on a surface organization. In this connection, it is important not to overlook the possibility of ruses.

Ruses. The Red commander has, of course, a fairly accurate knowledge of the physical characteristics of the Blue air force. Since he will try to time his attack so as to strike the Blue fleet, when its protecting pursuit is at the greatest possible disadvantage, the advisability of a feint at once suggests itself. Let us suppose, for example, that the two fleets are approximately 100 miles apart. The Red bombers take off and head towards the Blue fleet. They are preceded by a few monoplace scouts equipped with radio, who made a rapid reconnaissance to ascertain the enemy's reactions. This discloses that the Blue pursuit force, which has received timely warning of the approach of the bombers, is preparing to meet them in the manner previously outlined. The Red commander, appreciating that his bombers have fuel for five hours, while the Blue pursuit airplanes have only some two and one half hours, simply changes course, and delays his attack. When informed by his scouts that the Blue pursuit units, whether from choice or from shortage of fuel, are returning to the carriers, he then drives home his attack.

Of course, so simple a ruse as that described cannot be expected to work automatically. For instance, the Blue pursuit force may take the chance of being eluded, and attempt to run down the Red bombers. But the possibilities of a feint such as that described, show the tremendous difficulties that face defending pursuit aviation, due solely to the time element.

To avoid failure, this must be calculated with accuracy, although, in many cases, important elements entering into the calculation can only be surmised. Nevertheless, failure to esti-

mate the time factor within rather narrow limits, may make the difference between the defending pursuit aviation being found on its station, fully prepared to give battle, and, on the other hand, its being found abroad its carriers, engaged in refueling, with only a small fraction of the force able to meet the impending attack.

The air battle. The essential weaknesses in the defensive employment of pursuit aviation, which were just discussed, arose from the difficulty of insuring contact with the hostile bombers, in time to bring them to combat before they could launch their bombs at the Blue fleet. However, even when these obstacles have been overcome, the safety of the fleet from air attack is by no means assured. There remains to be taken into account the outcome of the air battle.

The Red attack, in its general aspect, will consist of a preliminary assault by attack and pursuit aviation, preparatory to the main blow, which is delivered by the bombers. Units of attack aviation will direct their efforts principally against anti-aircraft guns and machine guns. They may also operate against the carriers. While the armament of attack aviation is too light to inflict permanent injury on the carriers, the flight decks may be damaged and casualties thus caused to the air force. In order to interfere further with the anti-aircraft defense, a smoke screen may be laid to windward of the fleet. Experience has shown that this partially blinds the defense, while causing little inconvenience to the attacking airplanes. Since the all important objective of the Blue pursuit force the Red bombardment aviation, the Red attack units will be ignored, and left to the anti-aircraft machine guns to combat.

The mission of the Red pursuit force is to defeat or neutralize the Blue pursuit force, and thus leave the Red bombers free to drive home the main attack. The mission of the Blue pursuit, on the other hand, is to destroy or drive back the bombers. Indeed the basic doctrine of the former force requires it to ignore all but the hostile bombers, and to push straight to this goal. But obviously such a doctrine expresses only an ideal. In war, we seek, of course, the complete fulfillment of our purpose, but from the very nature of the thing, we expect to achieve only so much of it as our enemy is unable to

prohibit. It is quite impossible to ignore an opponent who obstinately refuses to be ignored. The Red pursuit force, as the hostile fleet is approached, will fly above the bombers but in such close proximity that it may intercept any threatened attack upon the latter. Even though inferior in numbers, it will not hesitate to attack whenever a favorable opportunity presents itself. If the enemy should follow too literally the precepts of his doctrine and ignore these attacks, the task of the Red pursuit force will be all the easier, since it will have to deal with a practically defenseless foe. It is apparent then, that whether or not it wishes to do so, the Blue pursuit must first settle its account with the Red pursuit force, before it can proceed to the execution of its principal mission of attacking the bombers. In a previous chapter, the indecisive character of single battles was described. There seems to be nothing in this special situation to alter in a material fashion the general conclusions which were arrived at in that discussion.

With the above considerations in mind, the Blue pursuit commander, as the battle nears, will be faced with the necessity for a decision; he must either concentrate his attack on the Red pursuit, in the hope of defeating it in time to attack the bombers; or else, he must attempt to occupy the Red pursuit with part of his force, while assaulting the bombers with the remainder. The former plan is, of course, the one that will make the stronger appeal to the Blue pursuit commander: from the point of view of air tactics, it is the only sound plan. Unfortunately for the Blue pursuit commander however, his decision cannot be based upon principles of air tactics alone, but must take into account his mission of stopping the bombing attack at all costs. If the bombers are within a few miles of their objective—which will generally be the case—there will not be time enough to defeat the hostile pursuit and then the bombers in turn, before the latter will be over their objective. The adoption of this plan will almost certainly cause the Blue pursuit to fail in performing its primary mission. In general therefore, the Blue pursuit commander will probably decide to split his forces—unsound tactically though this may be—and attack both the enemy's pursuit and bombardment aviation.

The attack on the bombers. The part of the Blue pursuit force designated to attack the bombers then proceeds to the execution of that mission, while the remainder attempts to contain the Red pursuit. Let us assume that the latter mission is successfully executed, and that the first Red force has only the Blue bombers to contend with. Now, from the characteristics of the two forces, and from the very nature of the offensive, determined attacks by pursuit aviation in large numbers will eventually destroy bombing units, which are unsupported by friendly pursuit. But this result, where numbers are involved, can never be expected from a single fight. Even under conditions favorable to pursuit, it can come only in consequence of many successful combats. Moreover, in this situation, the Blue pursuit force has been compelled by circumstances to surrender some of the advantages of the offensive. The choice of time and place of fighting, for instance, belongs not to the attacking pursuit but to the defending bombardment aviation. It is latter, for example, which would insure to itself such advantages as might come from the direction of the sun, or from the clouds.

It is scarcely necessary to state that the bombers will not attack—as was done, from motives of economy, in the tests—by single airplanes. Such a procedure in war would be suicidal. They will of course, fly in strong close formations. These formations are far from defenseless; on the contrary, they are capable of offering a determined resistance. Although the offensive alone offers decisive results in the air, the bombers will perform their missions successfully if they merely succeed in avoiding defeat, in the air. Time is on their side, as is generally the case of the defender. They have merely to hold off defeat for a certain length of time, and their work will have been finished. Even if the part of the Blue force assigned to the attack of the bombers should outnumber the latter, it does not necessarily follow that all, or even a large part of the bombers would be destroyed. Some of them would go down, and take with them some of the attacking pursuit. No one can state definitely what the results of such an air battle would be. But if past experience be a good guide, the greater portion of the bombers would attain to their objective, unless, of course,

there be a vast disparity between the two contending air forces—a condition that is inconsistent with war itself.

There remains one other recourse for the attacking Blue pursuit: deliberately to ram each and every bomber. Indeed, it is accepted naval doctrine that this course must be resorted to, when attacks of the usual character have failed in their purpose. The grave defects of shock action as a form of air warfare have been described in a previous chapter. Indeed, raming seems a veritable act of despair. Nevertheless, it cannot be diminished as the wholly impracticable requirement of a doctrinaire. Should this teaching be thoroughly inculcated *before* battle, there will be many cases of ramming *in* battle. But one is tempted to suspect that, in many other cases, the conditional character of the requirement—that is need be executed only after fire action has failed—may lead all but the very stoutest of heart to persist in attacking with fire, in eternal hope that success will crown the next dive. Furthermore, it must be realized that this weapon is a sword of two edges. Neither side will have a monopoly of the spirit of determined self-sacrifice. When heroic remedies become in order, both pursuit forces may resort to them in equal measure.

A second plan of defense. From the foregoing discussion it is seen that a grave defect of the first plan of defense lies in the time factor. It is always difficult, and sometimes impossible to devise a scheme whereby the Blue pursuit force may be sure of gaining contact with the enemy in time. A plan of overcoming this disadvantage at once suggests itself. A part of the defending pursuit force may be kept in the air continuously during the time that an attack is feared. The objections to this plan however, are serious ones. Due to the wear and tear on men and machines and the limited fuel capacity, it would be impracticable to keep more than a third of the force in the air continuously. While this could be done by carefully timing the reliefs, it would necessitate approximately three hours, as a matter of routine, for every pilot available, in the course of a long summer's day. In addition to this, every pilot whose machine was not actually undergoing repairs or being reserved, would take off whenever the alarm sounded.

Of course, this plan has one great advantage; it would preclude complete surprise by the Red force, and would insure its being met by at least some portion of the Blue pursuit units—which is not always assured under the first plan discussed. Then too, when this method is combined with a well organized service of anti-aircraft defense, it offers the best promise of getting the bulk of the force into the air in the shortest time.

If, on the other hand, the alarm should come at an inopportune moment, a full third of the force would be unable to participate in the fight. This might well prove to be the difference between victory and defeat. Moreover, there could never be thrown into the fight, no matter at what time the alarm was sounded, as large a number of airplanes as would be mustered under the first plan. The most serious objection to the second plan however, lies in the excessive strain it would impose on men and machines. In many situations, the plan would be justifiable—particularly so, where there existed a great preponderance of pursuit aviation. But it cannot be carried out over a considerable period of time, without a marked deterioration in efficiency.

A third plan of defense. Since it has passed into a truism that the best defense is a vigorous offensive, this is naturally suggested as a possible plan for the defense of the Blue fleet in the assumed situation. It seems on first inspection, to be peculiarly applicable; for pursuit aviation, of all combat forces, is the one most specifically adapted for offensive action. But while this is true, nevertheless the offensive power of pursuit aviation is confined rather rigidly to its own medium, the air. Where it is a question of destroying the enemy by demolishing his shelter or his support, pursuit aviation is comparatively impotent.

Let us examine this further by assuming, in the situation outlined before, that the Blue commander decided on a rigorous offensive with his pursuit force. He might of course, by sheer good fortune, succeed in catching the Reds in an awkward predicament. If, for example, the arrival of the Blue pursuit force over the Red fleet should occur at a time when the Reds had determined on a sortie, but had succeeded in getting only half their force in the air, the Blue force would have

almost an ideal tactical advantage, and should inflict serious losses. But such a surprise could occur only if the Red service of anti-aircraft information were wholly deficient—an unlikely contingency. In the general case, the Blue pursuit force would run very serious risks. If it should leave the Blue fleet unprotected for so long a period, there is always the chance that the enemy, by taking a circuitous route, might arrive in the absence of the defenders.

Air forces cannot rely on gaining contact with other air units, with any degree of certainty, as may be done in the comparatively slow, and single plane, movements of land and sea forces. Even in the event that this chance is taken without serious consequences, the Blue pursuit force cannot accomplish anything decisive over the Red fleet, if the latter have a reasonably effective service of security. Such a sortie will probably find the Red air force secure on its carriers. Against these the pursuit force alone can accomplish very little. In all probability, there would result merely an inconsequential engagement between the Blue pursuit and the Red anti-aircraft units, until diminishing fuel supply forced a Blue withdrawal. Thereupon another danger would exist for the Blues; for the Red units might immediately take off, and following closely on the heels of the departing Red pursuit, catch it as a hopeless disadvantage, from shortage of fuel.

The inherent weakness of the defensive. The situation outlined above has been dwelt upon at some length, because it has, as its central theme, a naval policy which is not without its apparent advantages, and its advocates. This postulates that the fleet which is inferior in major calibre artillery should even the odds by the use of bombardment aviation, and that the superior fleet should meet the threat of the latter by putting its entire air strength into defending pursuit units. However attractive such a scheme may appear at first blush, it is fundamentally unsound. It compels the adoption of the defensive in that element where the offensive has its most powerful stronghold. Only by a determined retention of the spirit of the offensive can favorable results be expected. Deliberately to assume the defensive is truly to invite disaster. It is however, difficult to avoid this, unless the air force be organ-

ized with an eye to its essentially offensive character. The peculiar conditions surrounding air-sea warfare demand for the true offensive, a two-fold striking power—against the enemy in the air, and against his floating air bases. Pursuit aviation alone cannot do this. It is perhaps possible to dispense with attack aviation, without running risks too grave. But it is essential that force contain both bombardment and pursuit aviation.

The contest of fleets with balanced air forces. If now, we again assume the situation previously described, except that the Blues also have a balanced air force, similar in all respects to the Red force, the problem undergoes a marked change of aspect. No longer will the Blues be faced with the necessity of a defensive rôle. Both sides will therefore seek a favorable opportunity to strike the first blow. Most important will be the facilities—including both training and organization—which permit the air force to get into the air quickly, and as a whole; for the factor of time may enter in a predominating manner. We may indeed expect the maneuvering of the two fleets, as they approach the danger line of the range of aircraft, to be conditioned very largely by the hope of striking an overwhelming blow through the air, before the enemy can do so. The direction and intensity of the wind may prove to be important factors in the situation. Fog banks of fairly well defined boundaries, such as occur over certain areas periodically, may become the key to the tactical situation. What the outcome of such a contest may be, no one can say, except that leadership and the will to win, will probably write the answer.

Chemical bombs. The status of this country in regard to chemical warfare has already been discussed. It is sufficient to add that naval warfare offers unusually good opportunities for the effective use of gas. The ventilation system of the naval vessel consists in taking air from the upper decks, and forcing it by suitable blowers to all parts of the ship. If chemical bombs were dropped on the decks, the ventilating system would operate with equal effectiveness to distribute the poisonous gases. Of course, this menace may be met by masks, or by similar devices in the ventilating system. But experience shows that gas attacks, no matter how nearly complete the

defense may be, often produce casualties, and always result in some discomfort and loss of operating efficiency.

Night bombing. Night bombing over land is a well established feature of air warfare. It may be questioned, however, if the methods of the World War can be transferred bodily to the work of naval aviation. Navigation over land by night has always been markedly dependent on such aids as lights and landmarks; these will seldom be present at sea. Moreover the very act of flying is dependent on the visual perception of some feature, such as the horizon or a flat field, which enables the pilot to judge when he is approximately horizontal. This is far more difficult to obtain over the sea than over the land. Until such time as many distant missions shall have been executed over the sea at night, the practicability of night bombing of a hostile fleet on the high seas may well be questioned. However the matter is largely one of successful navigation. The great progress that has been made in the last few years in the development of instruments to enable the pilot to navigate in fogs, leads to the belief that it will eventually be crowned with success. When this time arrives, night bombing in air-sea warfare must be reckoned with as a serious factor.

Torpedo airplanes. A development that is peculiar to naval aviation is the adaptation of the torpedo to air warfare. The torpedo plane, so far as its flying characteristics are concerned, is essentially the same as the bomber. The former, however, must discharge its projectile from a very low altitude, within some 10 to 20 feet of the water.

As in many other phases of naval aviation, torpedoing from aircraft is a peace time development. On this account, its tactical employment, with no foundation of war experience on which to build, is a subject of some debate. The rapidity of the torpedo plane, as compared with surface craft, is of course, a great advantage. Due to this, it may approach within close range to discharge its torpedo, with correspondingly increased accuracy. However, its low altitude of approach, and the direction it must hold, permit artillery to be traversed fast enough to fire on the airplane. Moreover the torpedo plane is vulnerable to a type of attack, which could not be employed against any other class of aircraft. A barrage may be placed across its

line of approach participated in by all the artillery of the fleet. This could put up large splashes of comparatively thick columns of water, which would extend to a considerable height above the altitude at which the torpedo must be dropped. If the airplane should strike such a column of water, a crash would probably result.

The similarity between the torpedo and the bombing airplane naturally leads to a comparison between the two. The bomb can carry a greater proportion of high explosive, and therefore may effect greater destruction than the torpedo. Probably also, the bomber will be subjected to less danger in the execution of a normal mission than will the torpedo plane. However, at the present time, our experience is entirely too meager to carry the comparison much further. The true tactical value of the torpedo plane must, of necessity, be left to the future to determine.

Conclusions. There is no longer room for doubt in the mind of any thinking man that the advent of the airplane has introduced a factor of great importance into naval warfare. The bombing airplane in particular seems destined to exercise a far-reaching influence. The chief of the Bureau of Aeronautics of our Navy has said: "Potentially, the aircraft bomb, is, I believe, the most serious menace which the surface craft has to face today, not even excepting gunfire." With this opinion, few airmen can be found to take issue; but it is a far cry indeed from this opinion to a belief that the invention of aircraft has removed all need for a navy. Such a conclusion could only be reached by very superficial reasoning from the known facts. It can indeed be maintained with some show of logic, that the old type of oversea expeditions will never be able to effect a landing with large forces in the face of an active and strong air force, and that on this account, a nation which possesses a strong air force and is content to wage defensive warfare on its own shores, can afford to dispense with a navy.

But even this conclusion ignores two fundamental truths which are pertinent. Whether a nation fights offensively or defensively, the throttling effect of sea power remains much the same, and slowly saps the strength of its victim; and sea power cannot exist without a navy. Furthermore, no nation in

its right senses will wage defensive warfare, unless the offensive be beyond its grasp. The unpopularity of the aggressor in war has tended to cajole us into loose thinking on this subject. We Americans are thoroughly, and perhaps justly, convinced that we are a peace loving people, who will never bring on a war. But we ignore both our history and our common sense, when we conclude from this that we will voluntarily assume a defensive attitude, once war has begun. It is true that we did go on the defensive in both our Revolutionary War and in the War of 1812. But we did so, only after our offensives against Canada had failed, and the overwhelming sea power of our opponent, left us no other choice. How different was the course of the United States in the Mexican War, the Civil War, the Spanish War, and the World War. The sea power fought against the enemy, and the United States sensibly saw to it that her own territory should not bear the scars of fighting. It can be predicted with certainty that, in the event of another war, we shall strive again to assume the offensive. To do so, we must have a navy.

But the fact that a navy is indispensable, does not prove that the present type of navies is destined to last in all its details forever. Nor does a complete acceptance of the doctrine that the backbone of the navy is the capital ship, necessarily lead in logic to a belief that the prevailing type of all-big-gun ship is the proven capital ship of the future. Already, within the memories of men still young, the capital ship has undergone profound changes. It is idle to deny that so epochal an event as the growth of aviation may effect changes even more profound. Precisely what these modifications may be, it is as yet, impossible to say. It is possible that the carrier will altogether replace the battleship. It is more probable that there will be developed a type of major artillery carrier; press reports regarding the new British battleships, the *Rodney* and the *Hood* indicate that they have more than a suggestion of the carrier about them. But whatever changes may come about, it is certain that this subject is worthy of our best thought.