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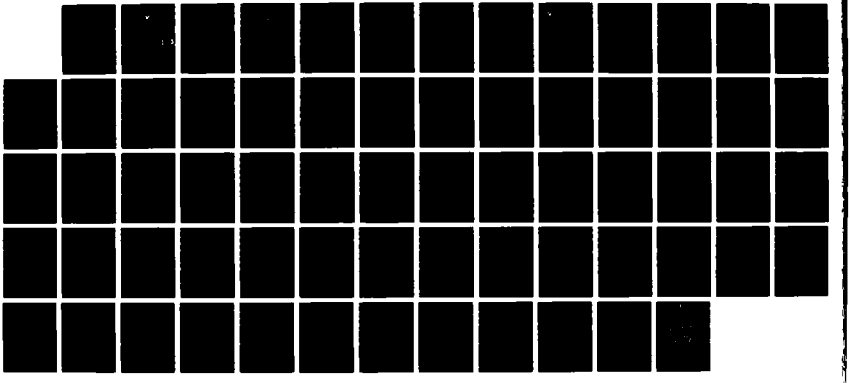

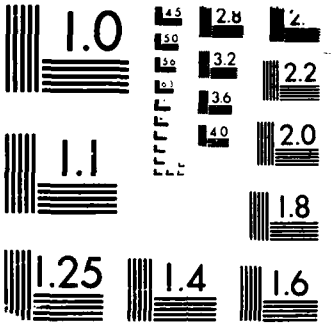

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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

THE EVOLUTION OF INSTRUMENT FLYING IN THE U.S. ARMY

Maj David M. McIntosh 88-1760

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Submitted to the faculty in partial fulfillment of requirements for graduation.

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This study describes how the U.S. Army developed training programs and management systems for instrument flying between 1918 and 1948. The study addresses the factors, such as attitudes, people and events that influenced the Army's development of an instrument capability during this period. This period of development is significant because the practices the Army evolved are still used by the Air Force today.

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PREFACE

This historical study reviews how the U.S. Army developed the capacity to conduct all-weather operations. The story begins immediately after World War One when the Army Air Service was limited to clear weather only and covers the period through the Berlin Airlift crisis of 1948 when the newly independent USAF demonstrated an unparalelled all-weather capability. During the thirty years between these events, the Army slowly, and sometimes painfully, evolved training programs and management practices that allowed it to complete an operation like Berlin with no special preparation. The training and management systems of 1948 are essentially those still used today. This study focuses on the instrument training programs and management efforts and the personalities, operational events, and other influences that caused them to change and mature.

This material is being submitted to the faculty of the University of Alabama in partial fulfillment of the requirements for the Master of Arts in Military History degree.

ABOUT THE AUTHOR

Major David M. McIntosh is a senior pilot in the United States Air Force. He has been on active duty in the Air force since August, 1973. Major McIntosh's assignments have included tours as a B-52 copilot, T-37 instructor pilot, instructional systems designer, and training staff officer. During most of this time he has been primarily concerned with conducting, preparing, and managing flying training.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

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"insights into tomorrow"

REPORT NUMBER 88-1760

AUTHOR(S) MAJOR DAVID M. MCINTOSH, USAF

TITLE THE EVOLUTION OF INSTRUMENT FLYING IN THE U.S. ARMY

I. Purpose: To describe how the U.S. Army developed training and management programs for instrument flying between 1918 and 1948.

II. Discussion: In today's Air Force, all pilots are instrument pilots and the USAF routinely undertakes operations in adverse weather conditions. Instrument flying is a given and a necessity. This was not always the case. The instrument flying programs now in use in the Air force were developed by the Army over a thirty-year period. The development process, which I describe as evolutionary, began at the end of World War One and continued until the late Forties. During this period, the Army was at times in the forefront of technological development, at times lagged behind, and was occasionally caught unprepared for operational requirements. Many factors influenced the Army's instrument development process. These factors, the problems the Army encountered, and the solutions it devised are the substance of this study. The story involves prople, technology, and events, and how they interact to produce progress.

III. Findings: Adopting new technologies and techniques in the military is a complex process. Attitudes of military members, funding, the technology itself, and operational requirements all influence the rate at which new ideas are accepted. In the case of instrument flying, it took the Army thirty years to evolve the programs which gave the Air force an all-weather capability.

CHAPTER ONE

INTRODUCTION

Military organizations do not normally adopt new technologies and doctrines quickly. Innovation in the military is an evolutionary process. This process may proceed smoothly, but it is usually erratic. The attitudes of military people, the availability of funds, technological advances, and operational requirements, among other factors, control the pace at which new ideas become accepted practices. This is true even for ideas that are fundamental today, such as the idea that military aircraft must operate in bad weather.

Instrument flying[1] developed erratically in the United States Army and Air Force,[2] subject at different times to all of the influences mentioned above. The evolutionary process during which instrument flying changed from non-existant in this organization to a basic combat requirement took approximately thirty years. It began with experimental work in the twenties, progressed to tentative operations and training programs in the thirties, and was complete by the end of the forties when extensive instrument training for pilots was the norm and large-scale operations in bad weather were possible.

Instrument flying can be considered fully evolved by the end of the forties because the instrument management and training practices that had been developed by that time were essentially the

same as those used today. The major features of instrument flying in the Air Force today are: (1) Instrument flying is a basic skill that all pilots must master and maintain. Instrument qualification is carefully managed. Pilots must fly a minimum number of instrument hours annually and take periodic written and flying examinations to remain qualified.[3] (2) Instrument training is extensive. Of 190 flying hours in the Undergraduate Pilot Training (UPT) syllabus, fourty-one hours (21 percent) are devoted to instrument training. In addition to instrument flying training, student pilots accomplish thirty hours of instrument academinc courses. (3) Simulators are used extensively to teach instrument flying. The UPT syllabus requires thirty-one hours of simulated instrument training.[4] (4) The Air Force uses a flying technique, called control and performance flying, which is based on the gyroscopic artificial horizon.[5]

This study describes how these characteristics developed. The major elements of the story are the growth of instrument flying technology and technique; the aviators who performed the experiments and built the training programs; the training programs themselves and how they changed; and the military operations that periodically served as measuring devices to show how well, or how poorly, the service was progressing. The process took three decades during which the Army incrementally adopted instrument flying. The Army was typically reluctant to make large changes to its operations quickly and settled for partial measures until an operational event forced a rapid period of adjustment. This pattern repeated itself several times until the system was mature.

Events divide the story neatly into three parts, one for each decade. The end of World War One left the Army permanently in the aviation business. The Air Corps was very active in aviation research, including instrument and navigation development, during the twenties. Its research pilots and engineers participated in the rapid development of instruments, radio-navigation devices, and airways. The operational Air Corps, however, did not adopt instrument flying during this time. It remained essentially the daytime, fair weather service of World War One.

This changed in 1930 when the service, recognizing that the technology had matured and reacting to recommendations from some of its members such as Jimmy Doolittle and William Ocker, introduced limited instrument training for pilots. This first program, which was little more than an introduction, was proved to be inadequate by the disasterous Air Mail project of 1934. The aircraft and personnel losses and the attendant publicity caused the Air Corps to take instrument flight more seriously. It increased training, put instruments in its aircraft, and began to introduce management practices to ensure that the pilots were instrument capable. During the thirties the Air Corps also adopted warfare doctrines such as strategic bombing that required instrument capability. This added to the momentum but was not enough to overcome long-standing attitudes. By the end of the thirties, Air Corps pilots had been trained to fly in the weather but the practice was still considered to be a nuisance, not a combat requirement. Pilots were not proficient, training was lax, and the service as a whole was not all-weather combat capable.

World War Two, with its requirement for large-scale weather operations such as the bombing campaigns in Europe, quickly revealed the shortcomings. The Army Air Forces had to frantically adjust training programs for students and regular pilots and completely revise its management of instrument flying in order to satisfy operational demands. The effort was successful and the AAF, soon to become the USAF, emerged from the war with an all-weather capability and the training and management system required to maintain it.

In the post-war period, the Air Force retained the emphasis on instrument flying adopted in World War Two and continued to refine training and management. USAF's system was put to the ultimate test in the Berlin crisis of 1948. This operation not only showed that instrument flying could be as important as bombs or bullets in pursuing military objectives but that the Air force system for preparing aircrews was mature. The same system, differing only in details, is still in place today.

An indispensable part of this story is the development of the Link Trainer. This device, which the Army first purchased in the mid-thirties but did not use on a large scale until World War Two, revolutionized instrument training. The Link made instrument training inexpensive and safe which allowed the Army to provide more of it during the critical World War Two period. The Link and its descendants, today's simulators, played an important role in facilitating the complete integration of instrument flying into military flying.

This study is not intended to be critical of the Army's evolution of instrument flying but to show how the process worked. The Army never rejected new ideas or technology but occasionally slowed its advancement because of the numerous influences at work. The Army never fell too far behind and always retained the capacity to adjust rapidly to changing requirements.

CHAPTER TWO

THE TWENTIES

Throughout the twenties, the Air Service conducted research into instrument flying but did not equip its aircraft or train its airmen for all-weather operations. There were a number of reasons for the lack of progress. Instrument flying technology was available but crude, especially navigation equipment. Many military airmen were not enthusiastic about flying in clouds. They had learned to fly in World War One without instruments. They either distrusted instruments and avoided clouds, or were "seat-of-the-pants" flyers who believed they could fly in the weather without artificial aids.[2] Other reasons were low peacetime budgets and lack of an operational requirement because pursuit aviation, a clear weather activity, was the predominant role of military flying at the time.

This state of affairs changed by the end of the decade when the Air Corps inaugurated its first instrument training for pilots. A combination of engineering achievements, some furnished by military flyers, and the efforts of instrument enthusiasts in the military brought this change about. Improved technology made routine weather flying possible and the pro-instrument pilots convinced the heirarchy that it was time the Air Corps had some weather capability. The first requirement was adequate technology.

Basic flight instruments were developed before and during the World War One. There are two categories: control instruments which are used to keep the aircraft flying correctly, and navigation instruments which are used for orientation. Three types of control instruments, altimeters, airspeed indicators, and vertical velocity indicators (which show rate of climb and descent), were widely available in the early twenties from unused war stocks.[3] These operated using air pressure. The magnetic compass was the only navigation instrument commonly used at the time. This was adapted from the nautical compass and was unreliable and difficult to read in aircraft.[4] The Air Service played an important role in expanding this limited capability.

In 1920, the Army established an Instrument Section as part of the Air Service Material Division at McCook Field, Dayton, Ohio. The Instrument Section's function was to work with instrument manufacturers and other government agencies to improve flight instruments and determine Army requirements.[5] Its pilots and engineers perfected a breakthrough control instrument, the turn and bank indicator, in the early twenties.[6] This device, first produced by the Sperry Company in 1918, consisted of a gyroscopically operated needle to indicate direction of turn and a steel ball in a glass tube (like a pendelum) to indicate bank. After testing and improvement at Dayton, the turn and bank indicator became the primary control instrument for the first two decades of instrument flight. It allowed pilots, for the first time, to precisely control their aircraft when they could not see the horizon.

Navigation improvements came in the form of stable and readable heading (direction) indicators and radio-navigation equipment. The McCook experimenters began working with the predecessor of the gyrocompass in the early twenties. The Air Service used one of their early developments, the earth indicating compass, on its around-the-world flight in 1924.[7] The Sperry Company perfected the true gyrocompass, a more compact and reliable arrangement than the earth indicator, in the late twenties along with the first gyroscopic artificial horizon. The Air Corps began testing these in 1930.[8]

Radio-navigation developments during this decade made the first all-weather airways and large scale air operations possible. The Air Service cooperated with the U.S. Post Office and the U.S. Department of Commerce, at the request of these agencies, in developing equipment for commercial application. In the early part of the decade, the Air Service flew the first Air Mail routes before civilian contractors took over and also surveyed and published the first airways in the United States.[9] By the late twenties, these government projects had produced radio ground stations, aircraft receivers, and aural and visual cockpit indicators. This equipment, which was rapidly put to commercial use, permitted reliable navigation in weather for the first time.[10]

These advances resulted from the work of many people, military and civilian. Several of the military engineering pilots who became well-known for their work were early advocates of instrument training for military pilots. Lieutenant, later General, Alfred F. Hegenberger and Lieutenant, later General, James

H. Doolittle were two training advocates among the pioneer aviation engineers.

Hegenberger worked in the Instrument Section at McCook from 1919 to 1933 except for a three year stint in Hawaii. During this period, he played a role in all the Instrument Section projects. He also designed the first standard instrument displays for the Army and built the first workable Instrument Landing System. Among Hegenberger's Firsts (Firsts were the order of the day in the twenties) were the first attempted radio-navigation flight from the US to Hawaii in June, 1927[11] (the radios failed but the crew survived) and the first solo blind flight in May, 1932. In 1934, Hegenberger was awarded the Collier Trophy, a national aviation achievement award, for his experimental work.[12] He was also one of the first, in 1923, to recommend instrument and navigation training for military pilots. Later, he designed and taught the Air Corp's first instrument training courses, but these were for specialists, not for all pilots.[13]

James H. Doolittle is one of aviation's most famous pioneers. His instrument flying experiments are only a small part of his brilliant aviation career. In 1928, The Air Corps loaned Doolittle, who was already a public figure having participated in record-setting endurance flights as well as air races, to the Guggenheim Fund for the Promotion of Aeronautics. The Fund, a privately financed research organization, had established the Full Flight Laboratory at Mitchel Field, New York, to improve safety in aviation.[14] Doolittle's job at the laboratory was to find a way to land airplanes in fog. He and his associates spent a year building

and testing instruments and radio-landing equipment. Their work culminated on 24 September 1929 when Doolittle performed the first completely blind flight. He took off, navigated his aircraft over a preplanned radio-beacon course and landed using only instruuments.[15] Doolittle's cockpit was covered with a canvas hood but there was a safety pilot in the other seat in case of an emergency. This feat was widely acclaimed as a tremendous step forward in aviation safety and demonstrated how far instrument flying technology had developed since the beginning of the decade.[16] In summing up his Guggenheim activities, Doolittle strongly recommended that the Air Corps equip its aircraft and train its airmen for instrument flight.[17] The new hardware and techniques did not stay in the laboratory, they were soon in wide commercial, but not military, use.

Civilian entrepeneurs, with Government assistance, quickly took advantage of the possibilities offered by the improved flying technology. The Air Commerce Act of 1926 was intended to spur commercial aviation development and it worked. It placed the Department of Commerce in charge of creating airways, airports, navigation facilities, and weather services for airline operations.[18] By the early thirties, there was an extensive system of published airways consisting of radio-navigation beacons, light beacons, emergency landing fields, and weather reporting stations. Later, instrument approach procedures, based on radio beacons, were developed to allow orderly traffic flow into airports obscured by clouds. Commercial passenger and mail operations at night and in the weather were becoming routine in the late twenties.[19]

Despite this rapid development in which it had participated, the Air Corps stayed in the experimental stage during the twenties. It did not offer instrument flight training or require Air Corps pilots to practice flying in the weather. There was a growing number of operational pilots, not experimental engineers, however, who believed that instruments were necessary for safe flight and military operations. They were opposed by the seat-of-the-pants community that believed instruments were a crutch for weak pilots unable to master the true "art" of flight. The most important instrument advocate was Captain, later Colonel, William C. Ocker.

Ocker did several important things. First, he developed a simple demonstration that disposed of the seat of the pants theory of instrument flying. Then, with all the fervor of a missionary, he set about convincing the Air Corps leadership that instrument flying was a necessity. Finally, he developed the first blind flying training programs for Army aviators.

Ocker became an instrument believer following World War One when, after several near-disasters caused by flying in clouds without instruments, he discovered that he could easily control an aircraft using a turn and bank indicator. From that time on, he never flew without one. He obtained his own clip-on version that he attached to the wing strut of any airplane he flew.[20] Ocker came to believe that the Air Corps was losing a significant number of aircraft and airmen to incompetence in weather flying. Army statistics from the time are suggestive but not conclusive. Since the Air Corps did not train or operate in instrument conditions, "instrument flying" was not one of the causitive categories

recognized by Air Service accident investigators. Accidents were caused by "inexperience," "poor pilotage," etc. Weather conditions were recorded, however, and "weather" was a cause category. For example, during 1921-22, 18 percent of all accidents occurred when the weather was not clear and "weather" was determined to be the cause of 5 percent of accidents. At the same time, 55 percent of the accidents were not investigated or the cause was determined to be "unknown."[21] Based on his experience, Ocker felt that a large number of the "unknown" accidents were caused by pilots losing control of their airplanes while attempting to fly in clouds without instruments or training, as he had done several times previously.[22] Interestingly, flight surgeons, who conducted investigations independent of accident boards and were presumably more familiar with vertigo and the operation of the inner ear, blamed mishaps on "weather" three times more often than the aviators.[23]

In 1926, Ocker discovered a way to prove, even to the hard-core seat-of-the-pants flyers, that instruments were a necessity, not a crutch, for blind flying. From that time forward, he became an insistent advocate for military instrument flying. His discovery happened almost by accident during his annual flight physical. For one of the eye tests, pilots were spun in a rotating chair called a Barany Chair,[24] then stopped suddenly to determine how quickly their eyes recovered and focused. Ocker's flight surgeon, Dr David A. Myers, had added a demonstration to the Barany test. He spun the pilots while they were blindfolded. This was intended to show that, without vision, the sense of balance could

be easily confused. Blindfolded, the pilots quickly lost track of their direction of rotation, could not sense changes in acceleration, and could not even tell when the chair had stopped turning.[25] Ocker took the balance test, became disoriented like the other pilots and decided to try his own experiment. He enclosed his turn and bank indicator in a box with a viewing aperture and tried the test again, this time watching the turn needle. He found that the flight instrument kept him oriented at all times. Here was solid proof that seat-of-the-pants flying was a myth. The human body cannot "feel" where it is going without visual references. Pilots need help, in the form of instruments, to fly when they cannot see outside the cockpit.[26]

Armed with his beliefs and his instrument box to demonstrate them, Ocker became a crusader. He and Dr Myers reported their findings to the War Department, then Ocker began offering Barany Chair rides to any pilots who were interested, civil and military alike.[27] He also published articles, made speeches, and developed additional evidence. In testing pilots between 1929 and 1932, Ocker found that fewer than 3 percent could maintain control of an aircraft for more than twenty minutes while flying in the weather. One airline, after reviewing Ocker's evidence, adopted instrument training and reduced its weather cancellation rate to less than 1 percent on some routes.[28]

Ocker's intent was not merely to demonstrate that instruments were necessary for weather operations. He wanted the Air Corps to provide instrument training programs. Ocker knew that training and practice were necessary because without them, even pilots who

understood that the instruments were accurate and their sense of balance false, could revert to their instincts and be overwhelmed by vertigo.[29] While he was stationed at March Field, California, and Brooks Field, Texas, Ocker designed a program and trained a cadre of instrument flyers. In 1932, Ocker and one of his converts, Capt Carl Crane, published one of the first books on instrument flying. To complement his training course, Ocker also designed and built training aids. Among these were an improved version of his turn needle demonstration device, which he patented and which won a $1,000 prize from the National Advisory Committee for Aeronautics, and the first instrument flying hood. The hood was a canvas device which enclosed the aircraft cockpit allowing the pilot to simulate flying in clouds. Ocker also tried, but failed, to build a machine that could simulate instrument flying without leaving the ground.[30] (He was unaware that a mechanical genius named Edwin Link was putting the finishing touches on a workable simulator that would later revolutionize instrument training). In the late twenties, Ocker petitioned the Air Corps several times to adopt his training program and equipment but was turned down.[31]

Interest in instrument flying had grown by 1930. Ocker had won many converts in the Air Corps and the aviation community and had generated considerable publicity. The Chief of the Air Corps, General Lahm, aware of Ocker's activities, and also aware that the Navy, the airlines and foreign services were training instrument flyers, instituted Air Corps instrument training in mid-1930.[32]

The program was short and limited to Advanced[33] students, but it was a start.

The 1930 training program was significant because the Air Corps had formally recognized the need for instrument flying, but it would be a long time before a true all-weather capability became reality. William Ocker remained in the Air Corps. During his crusade for instrument flying, he was court-martialed once and subjected to two sanity board hearings, all of which he survived with his career intact. He was still teaching flying and designing training equipment until shortly before his death, from natural causes, in 1942.[34]

CHAPTER THREE

THE THIRTIES

The 1930 instrument program was more of an introduction to instrument flying than a comprehensive course of instruction. It consisted of approximately ten hours of flight (5 percent of the total hours in pilot training) and two hours of ground instruction. Students began with straight and level flight and shallow turns, then progressed to more demanding maneuvers such as steep turns, climbing and descending turns, and changes of airspeed in turns. The latter phase of the course covered turns to precise headings, compass navigation, and a solo instrument flight. In addition, students practiced aerobatic maneuvers and spins on instruments. Implementation was difficult because few training aircraft were equipped for instrument flying and there were no training manuals. Also, there was a shortage of qualified instructors because instrument flying was new to the Air Corps.[1]

The instrument technique the Air Corps employed was based on the turn and bank indicator. It was called the "1,2,3"; "A,B,C"; or "X,Y,Z" method depending on slight variations. Collectively, these procedures were referred to as "needle-ball and airspeed" flying. Basically, students were taught that each aircraft control surface (rudder, aileron, and elevator) commanded an individual instrument indication. For example, with the A,B,C method, the

rudder controlled the turn needle, the ailerons controlled the bank (ball) indicator, and the elevator controlled the vertical velocity indicator. Each was changed or corrected in turn in an endlessly repeated cycle. Student pilots were cautioned not to try to visualize the position (referred to as "attitude") of the aircraft because that introduced an additional mental step and slowed the process.[2] Needle-ball and airspeed flying, with practice, was effective. It was the best option until the introduction of artificial horizons (now called attitude indicators) which were in existance but not widely available in the early Thirties.[3]

Needle-ball and airspeed flying seems mechanical to pilots trained to fly instruments on attitude indicators. The attitude indicator, by replicating the natural horizon, makes instrument flying essentially the same as flying in the clear.

In addition to introducing an instrument course into the Advanced training course in 1930, the Air Corps ordered all pilots to accomplish a minimum amount of instrument flying annually.[4] However, compliance was difficult because instrument-equipped aircraft and instructors were as scarce in operational units as they were in training units. There was also little motivation for pilots to master instrument flight because there were no check flights or certification procedures to ensure they were competent. In sum, the Air Corps, as events were to demonstrate, did not take instrument flying seriously at this time. It remained a daytime, clear-weather service.[5] Instrument flying was an annoyance imposed by headquarters. Air Corps pilots concentrated on traditional

flying skills like gunnery and formation and parked their airplanes at the end of the day or when clouds rolled in.

Clouds and darkness were not barriers to the civilian operators. They surged far ahead of the Army in instrument capability.[6] By 1932, all commercial pilots had to undergo an extensive instrument training program and pass a rigid check flight before they were licensed.[7] While the civilians were mastering twenty-four hour a day schedules, few fliers in the Army squadrons could even conceive of an actual operation that would require flying in the weather.

Just such an operation materialized abruptly in early 1934 when President Roosevelt fired all of the Government's civilian Air Mail contractors and offered the job of carrying the mail to the Air Corps. The Chief of the Air Corps, General Benjamin Foulois, accepted the mission immediately. He was aware of the Army's limited instrument capability but was anxious to restore the Air Corps budget which had been cut repeatedly. He also saw the assignment as an operational test for the aviators and a chance to demonstrate to the public what they could accomplish.[8] Regardless of General Foulois' reasons for accepting it, the mission was a challenge. For the first time, the Air Corps would have to operate around the clock in all weather conditions.

The Presidential Directive gave the Air Corps only ten days to prepare. The requirements were enormous. Airplanes, pilots, and technicians had to be relocated and prepared. Part of the preparation included frantic efforts to install instruments in the aircraft and provide weather and Air Mail route training for the

aircrews.[9] To add to the difficulties, the country was in the midst of the worst winter weather in memory.

In spite of the short notice and the logistics problems, the first Army Air Mail mission launched on time on 19 February 1934 in an intense glare of publicity. The attention was unavoidable. Because the Air Mail contract dispute involved politics and large amounts of money, the press was following the operation closely.[10] From the first flight, every maintenance problem, delay and disruption was widely reported, especially the crashes.

There were many crashes. After one week of flying, losses from Air Mail delivery and support missions totaled eight aircraft destroyed, five airmen killed and six critically injured.[11] A storm of criticism erupted over the Air Corps, the Post Office Department, and the Roosevelt administration. The Army imposed increasingly severe safety restrictions on the operation which reduced mail service to a fraction of what the airlines had delivered and ultimately had to suspend operations so that instrument-trained reserve airline pilots could be recalled to active duty to help fly the mail. Fifty-two airline pilots eventually flew Air Mail missions in Army aircraft.[12] By the end of the project in June, there had been sixty-six accidents, twelve fatalities, and fifteen serious injuries.[13]

A War Department committee investigated the Air Mail project and the Army's entire aviation program. The fact that many of the Air Mail losses were caused by weather and darkness played a prominent role in the committee's findings. The investigators recommended that Air Corps pilots receive more flying time and

training to include "much night, blind, cross-country, and bad-weather flying." The Air Corps was also ordered to equip its aircraft with all of the instruments used by the airlines.[14]

The Air Corps didn't wait for the committee's findings, however. In May, while Air Mail operations were ongoing, it doubled instrument training for student pilots by adding a ten-hour course of instruction to the Basic course. The syllabus was essentially the same one used in Advanced training. Students practiced basic maneuvers, advanced maneuvers,and navigation, including radio-navigation if the facilities were available.[15] Instrument flying now made up ten percent of the Air Corps' pilot training program.

Another consequence of the Air Mail episode was increased funding for the Air Corps. In the improved budget environment, the Army was able to purchase more and better instruments, equipment, and radios for its aircraft.[16] In April, 1935, the Army ordered all observation, basic training, and attack aircraft to be equipped for instrument flying.[17] In 1936, it installed radio equipment in all tactical aircraft.[18] In 1937, all Air Corps aircraft except single seat fighters and primary trainers were outfitted with instrument hoods.[19] The instrument hood purchase reflected the changed attitude toward instrument flying that resulted from the Air Mail scandal.

Following the events of 1934, the Air Corps decided to monitor the instrument flying proficiency of all pilots, not just students. In early 1935, the annual instrument flying requirement for all aviators was fixed at ten hours.[20] Later that year, the

Air Corps initiated instrument check flights for all pilots. Every six months, every Air Corps pilot had to take an instrument flying examination.[21] In addition, commanders were told to monitor their pilots to determine the minimum hours of practice required to maintain "continuous proficiency" in weather flying.[22] These procedures were the Army's first system for managing instrument flying. They illustrate the dramatic change in official attitude which took place in 1934. Far from being an annoyance, instrument flying was now seen as a primary skill. All pilots were expected to be competent instrument flyers. The Air Corps was on its way to becoming an all-weather service.

The increased emphasis on all-weather operations in the mid-thirties was not caused by the Air Mail fiasco alone; there were other factors at work, most notably changes in air doctrine. Strategic bombing was becoming an important part of the Air Corps' plans for the next war. With its requirement for protracted, long-range missions, strategic bombing implied a requirement for flying in clouds since the weather could hardly be expected to be clear over huge expanses of territory. By 1935, the Air Corps Tactical School was stressing blind flying, along with navigation and formation, as necessary for bombers to reach their objectives. Weather was seen as helpful for concealment; clouds were now an aid, not a hindrance, to military operations.[23] A Tactical School study from the period noted that while both ground and sea forces were immobilized by stormy weather, aircraft, if properly equipped, could operate in zero ceiling and visibility, icing conditions, high winds, and precipitation. The equipment required included

flight instruments, radio-navigation and communications gear, and an automatic pilot for maintaining an accurate course.[23] In light of later experiences in combat, this was a hopeful forecast, but it illustrates that instrument flying was well established in Air Corps thinking. Operations limited to daylight and clear weather were becoming a thing of the past, at least on paper.

In spite of the new equipment, regulations, and doctrines, the Air Corps did not completely transform itself into an all-weather fighting force during the thirties. There were still plenty of old-school flyers around who considered weather flying to be an inconvenience. Enforcement of the regulations was lax, procedures were not standardized, and proficiency levels among the pilots were erratic.[24] Training continued, however, and there was steady progress.

By the end of the decade, the Air Corps had become the Army Air Forces (AAF) and instrument flying was fairly well established. Annual instrument flying requirements were up to twenty hours per year[25] (when World War Two began, requirements were dropped for the duration),[26] and instrument training was a routine part of flying training for cadets. The pilot training curriculum had expanded to three phases: Primary, Basic, and Advanced. Every phase included instrument flying. Primary students received six hours of hooded flight training, Basic students received six hours, and Advanced students received fifteen. Primary and Basic students learned aircraft control and instrument maneuvers while Advanced students learned radio-navigation.[27] The twenty-seven hours of instrument

flying represented 11 percent of the total flying time in the syllabus.

There was some additional instrument training. Basic and Advanced students flew a device called a Link Trainer (fifteen hours total) which was just becoming available. In the Link, they could practice instrument maneuvers and perfect their technique without leaving the ground. All pilots from this time forward would become intimately familiar with the Link and its descendants. The simulator had arrived; it quickly became a fixture in pilot training and permitted expanded instrument work that was much less expensive and much safer than training in aircraft.

CHAPTER FOUR

THE LINK TRAINER

The Link Trainer was named after its inventor, Edwin Link. Mr. Link was uniquely qualified to construct the first workable aircraft simulator. He was an expert practical mechanical engineer, having worked in his father's piano and organ factory, and an aviator who had learned to fly in the barnstorming era in his spare time with whatever money he could scrape up. It was the high cost of flying training that originally led Link to build a device that could substitute for some of the expensive flying hours required to learn the basics.[1]

Link built his first trainer in 1929. It consisted of a small aircraft replica (including stubby wings and tail section) mounted on a universal joint. The stick and rudder pedals in the cockpit actuated a set of air bellows (doubtlessly inspired by Link's earlier career as an organ builder) which caused the entire assembly to rotate and tilt like an aircraft in flight. Link was operating his own flying school at Binghampton, New York, at this time and he used the trainer to teach his students basic aircraft control without leaving the ground. This reduced the amount of flying time required to gain a license and lowered the cost.[2] In 1930, using the trainer, Link could solo a student pilot with two

hours of flying time compared to fifteen hours for his competitors.[3]

In addition to teaching, Link's business encompassed any and all types of air services such as sign towing and aircraft delivery. To expand his capabilities, he obtained an instrument rating. Once Link was an instrument pilot, it wasn't long before he installed a hood and flight instruments on the trainer and set out to market the first instrument simulator. This was in 1931 and the aviation industry was not quite ready for such a revolutionary concept. As a result, the Link Trainer spent several years as a coin-operated amusement park device before anyone took it seriously.[4]

Word eventually got around and in 1934 the Air Corps, very interested in instrument training after flying the Air Mail, initially had Link train a group of pilots then ordered six Link Trainers.[5] At first, Air Corps orders were slow due to lack of funds but other agencies and governments, realizing that the device offered effective instrument experience at a fraction of the cost and none of the risk of flying training, steadily ordered trainers throughout the Thirties. The U.S. Navy, the Civil Aeronautics Administration, the airlines, and the Air Forces of Germany, Japan, England, Russia, France, and Canada all purchased Link Trainers before World War Two. The savings were considerable, the Link used only electricity at a cost of five cents an hour compared to ten dollars an hour for training aircraft fuel.[6] The Air Corps, firmly committed to instrument training by the mid-Thirties, made the Link standard for pilot training in 1936 and continued to purchase them

as funds became available. By 1939, the Army owned forty Links (by comparison, the Royal Air Force had two hundred Links in 1939).[7]

The AAF found that training with simulators could be economical in more ways than one. In 1939, the AAF opened its first training course for enlisted Link instructors. Using enlisted instructors to teach instrument procedures (the Link was used mainly for procedural training and practice) was less expensive than using pilots and made better use of the flight instructors. During the war, thousands of Link Trainer instructors were used to teach the huge classes of pilots going through training.[8]

With the start of the World War Two, all Link production was reserved for the U.S. Armed Forces. Between them, the Navy and the AAF purchased 7,316 Links by 1945.[9] The investment was worthwhile. The AAF estimated after the war that it had saved 243 lives, $78,839,441, and 15,142,953 man hours per year by using the Link to train its wartime airmen.[10]

The trainers used in the war were far different from the crude 1934 device. Edwin Link constantly updated the trainer adding more capabilities and more fidelity to actual flight. The 1934 "A Model" gave the student only the basics. It had a compass, airspeed indicator; vertical velocity indicator, turn and bank indicator, and headphones for receiving aural radio signals for navigation.[11] Neither the A Model's instrument panel nor its flying characteristics resembled any actual aircraft. It was strictly a procedural trainer used for memorization and practice; actual flying was taught in real airplanes.

Edwin Link was convinced that more realistic trainers offered better training. During the thirties, he produced the "C," "D," and "E" Models each of which improved on the preceeding machine. The 1940 version, called the ANT-18 by the Army, illustrates the improvements. The instrument panel had all of the A Model features plus an altimeter, directional gyrocompass, and artificial horizon. Navigation equipment consisted of all of the advanced devices becoming available. These included Marker Beacons, an Instrument Landing System, Automatic Direction Finding equipment, and multiple Radio Beacon pointers. Detail was minute; even the magnetic compass had turning and dip errors.[12] The ANT-18 instructor had a separate station with a duplicate set of instruments to monitor the student's performance. The instructor's station included a recording device that plotted the student's mission on an aeronautical chart for later review. In addition, the instructor could act as an air traffic controller, passing directions and weather information to the student in the trainer. The instructor could also create problems by altering the direction and velocity of the winds affecting the student's flight. The ANT-18 was an effective trainer, but it was still a generic cockpit used for procedural training. The first trainer that replicated a real airplane was the Model 45 which Link began delivering to the Army and Navy in 1942. In appearance and performance, the Model 45 duplicated the T-6 training airplane. Refinements included a realistic "feel" to the flight controls and an operational fuel system. Control pressures in the Model 45 varied with airspeed and the trainer had to be kept in trim. The fuel guage indications

decreased as the student flew a mission and those who got lost and ran out of gas, crashed.[14] The fuel and variable wind features permitted realistic navigation training in the Link. Students could plan and fly entire missions. The Model 45 also had a full suite of engine controls including starter, carburetor, and propeller pitch. All the engine and instrument indications were integrated and the trainer reacted to flight conditions and control inputs like the real aircraft. In short, Link was approaching true flight simulation.[13]

During the war, Link Trainer sections were organized as separate units in the flying wings with their own administrative, maintenance, and instructor divisions. Students were put through a complete instrument training course. They started with basic aircraft control, just as they would in the flying program, then took up complex maneuvers and navigation using the aural radio range and other navigation equipment. The course also included holding patterns and instrument approaches in addition to extensive instruction in radio communications. The course was complete, covering every phase of instrument flying.[14] The simulator had evolved from a simple, introductory training aid into a complex and complete training system. Naturally, the possibilities of this simulation technology were not limited to instrument training for student pilots.

Edwin Link built a variety of training devices for the military during the war. There were gunnery trainers, bombing trainers, navigation (including celestial) trainers, and even a bomber crew trainer in which pilot, co-pilot, navigator, and

bombadier could simulate an entire mission.[15] Simulators were coming of age.

After the war, both airplanes and simulators changed. Aircraft became jet powered and simulators went from pneumatic-mechanical actuation to electronics, which were easier to maintain. The first electronic Link trainer was the C-11, introduced in 1950. The C-11 duplicated the Air Force's first jet trainer, the T-33. In addition to instrument and navigation training, this device taught students to operate complex aircraft systems and handle emergency procedures. The instructor could program in a variety of malfunctions and mishaps which were much too dangerous to practice in the air.[16] This was still another area of training opened up by simulator technology. The cost savings were even more dramatic in the jet age. One hour of T-33 time cost $500, one hour of C-11 time cost fifteen dollars.[17]

By the fifties, simulators were a standard feature of all types of flying training. The Link Company was producing combat simulators on which aircrews could practice intercepting and destroying enemy aircraft.[18] There were also jet bomber simulators and transport simulators.[19] Every new aircraft had a simulator designed concurrently with it.

Training aircraft development also continued. The Air Force introduced its first Primary jet trainer, the T-37, in the late fifties. The T-37 had a Link simulator designed to complement it. The evaluation report on this trainer illustrates how much a part of flying training simulators had become by this time. The evaluators suggested that students should fly fifteen to twenty

hours of simulator time before flying the aircraft, then accomplish one hour of simulated instrument time for every hour of instrument training in the air. This was in addition to simulated emergency procedures training.[20]

Visual systems, added in the seventies, expanded training possibilities even more. Student pilots today, in addition to learning instrument flying, navigation, emergency procedures, and systems operations, practice takeoffs, landings, and basic visual flight before they ever go near a real airplane.[21]

The simulator has become a key tool in all flying training. It also played an important role in the development of instrument training, largely because it appeared at precisely the right time. The Link Trainer arrived in the late thirties and made instrument training convenient, safe, and inexpensive shortly before the buildup for World War Two put unprecedented demands on the AAF Training Command. The timing couldn't have been better.

CHAPTER FIVE

THE FORTIES

For the Army Air Forces Training Command, World War Two began in 1939 when the War Department ordered the first of many increases in the rate of pilot production. Production had averaged fewer than three hundred per year during the thirties. The first increase was large, 4,500 per year. As war loomed closer, successive increases took the training rate to 7,000, then 12,000, then 30,000 in a short time. New training plans were scrapped before they could even be implemented. This explosive growth continued until 1943 when the pilot training rate peaked at 102,000 per year.[1]

The AAF needed new facilities and management arrangements to accomodate the much larger wartime operations and training programs. The AAF as a whole went from 17 bases in 1939 to 114 by December 1941, and eventually operated 783 bases at peak wartime strength. Training Command expanded from a single headquarters into three sub-commands: Southeast, Gulf Coast, and West Coast Training Commands.[2]

Pilot training also changed dramatically. The course remained in three phases but phase lengths were compressed to increase production. The AAF eventually reduced total training time from one year to seven months. Civilian contractors took over

Primary training entirely, while the military continued to conduct Basic and Advanced.[3]

In the 1942 training program, students flew approximately 205 hours during the three phases. During Basic and Advanced, thirty hours were devoted to instrument flying (there was no instrument work in Primary). Thus, instrument training now totaled 15 percent of the flying time in the course. There were an additional thirty hours of Link Trainer instruction bringing the total hours of instrument training to sixty.[4] This was a significant increase in both percent of the flying program and total training hours over the 1939 course (11 percent of flight time and 42 hours total). Graduates received additional instrument instruction when they transitioned to combat aircraft. For example, bomber pilots flew an additional twenty hours of instruments and fifteen hours of Link time during transition training.[5] The increased emphasis on instruments was necessary.

Pre-war predictions about the requirement for weather flying in combat proved to be accurate. Operations requiring extensive instrument flying occurred in all theaters with all types of aircraft throughout the war. Two major operations, Allied bombing in Europe and the air resupply of China, were especially dependent on instrument flying. In Europe, 28,000 Allied planes flew 1.4 million bombing sorties during the war.[6] Of these, approximately 50 percent required instrument flying at some point in the mission.[7] This was precisely what the Air Corps Tactical School had predicted back in the thirties. In China, the Tenth Air Force kept the Chinese Army operating by flying supplies from India

during the period 1942 to 1945. At its peak, the operation involved 650 aircraft flying round trip missions daily. The route, over the Himalayas, required instrument flight nine months out of the year.[8] The capability to undertake these large-scale missions did not come easily to the AAF; the instrument flying program had to be adjusted frequently.

Almost from the beginning of the war, there were complaints about the AAF pilots' instrument flying. In late 1942, an Army investigation determined that instrument training was lax, instrument instructors were unqualified, and newly-graduated pilots were not confident in their ability and did not like to fly instruments. The report also criticized AAF for teaching an outmoded flying technique, needle-ball and airspeed, when there were better alternatives available with gyroscopic instruments.[9] In mid-1943, a Training Command conference on instrument flying blamed the problems on a lack of qualified instructors and poor supervision. The keynote speaker at the conference, Col Joe Duckworth, whose role in modernizing AAF instrument training is discussed below, complained that AAF was "...treating instrument flying training as an uninteresting and unessential phase."[10] The 1943 pilot training syllabus reflects the attitudes and problems that AAF was trying to overcome. It directs squadron commanders to ensure that all instructors and students are aware of the importance of instrument flying and goes on to state: "All efforts must be made to popularize instrument flying in an effort to obtain better results."[11] Better results required changes.

In 1943 AAF initiated a series of corrective actions to improve the instrument flying situation. These included: a standardized method of instrument flying based on the attitude indicator; instrument instructor schools; and a completely revamped system for managing instrument flying.

One problem had been AAF's failure to adjust its flying methods to the gyroscopic attitude indicators which were standard aircraft equipment by the early forties. In August, 1942, the Chief of Training Command, General Yount, complained that pilots were jeopardizing lives and airplanes because they did not know how to use gyroscopic instruments. He also noted that maintenance personnel and pilots were damaging the equipment because they were not familiar with operating limitations and repair procedures. General Yount ordered all aircrew members and mechanics to familiarize themselves with the new instruments.[12] This was a start but not a training program.

The AAF was still teaching needle-ball and airspeed flying. This method, described in Chapter Two, had several disadvantages: it was mechanical (and rough) because students were attempting to control each instrument individually with a separate input on the stick or rudder;[13] it was unnatural and difficult to learn because students were initially taught to use the natural horizon for orientation then had to shift gears instantly to mental calculations upon entering the clouds. In sum, needle-ball and airspeed flying may have been acceptable in the biplane era, but it was a hindrance in wartime operations with high-performance aircraft.[14]

A new system called "full panel" or "attitude" instrument flying[15] was much easier to master. Students learned to visualize the attitude of the aircraft using all of the instruments but especially the artificial horizon. Control movements were presented in terms of changing the position of the airplane, not just changing the instrument indications "...instead of saying 'center the ball,' the instructor should say 'raise the left (right) wing.' In this way the student learns to associate attitude with instrument indications."[16] Attitude instrument flying was a much more natural way to learn.

The airlines and the Navy were teaching full panel flying before the AAF. Col Joe Duckworth, a recalled airline pilot who was Director of Training at the AAF Advanced Twin Engine school at Columbus Air Force Base, Mississippi, was familiar with the technique and adapted the Navy training program for his students in 1942. The training was so successful that full panel flying was standardized AAF-wide in June, 1943.[17]

The AAF took several additional steps to introduce full panel flying and improve instrument training generally. In 1943, it published a revised set of instrument flying Technical Orders, the 30-100 Series.[18] These were professionally produced and covered every phase of instrument work from basic maneuvers through instrument approaches and landings in aircraft and the Link Trainer. The new manuals stressed full panel flying. In addition, AAF established instrument instructor schools in 1943 to qualify full panel teachers and spread the technique among training and operational units. Col Duckworth commanded the first instrument

instructor school at Bryan Air Force Base, Texas. Later there was an instructor school in each of the training sub-commands.[19] These evolved into the USAF Instrument Pilot Instructor School which remained in operation until the mid-seventies.

In addition to revising training for student pilots, the AAF drastically changed training and qualification procedures for operational pilots. Beginning in 1943, every flying unit was required to establish a permanent Board of instrument qualified officers to oversee training and check the proficiency of all assigned pilots. Every pilot had to be certified instrument qualified once per year. The certification process was more complex than the simple check rides required previously. It included a twelve-hour flying training course; a written examination; and a check flight covering basic maneuvers, navigation procedures, and instrument approaches. There were two types, or levels, of instrument certification: Form 8[20] (White) for less experienced flyers and Form 8 (Green) for the more experienced. "Green card" pilots had fewer restrictions and could fly in worse weather than "white card" pilots.[21] In order to qualify for a green card, pilots had to have a minimum of one hundred hours of actual (not hooded) instrument time. Green card holders also had to take a more demanding check ride than white card holders.[22] The two-tier certification was probably necessary because of the wide diversity of instrument experience among AAF pilots.

These requirements were much more stringent than those in effect previously and the adjustment was difficult. Changes to the

program in 1944 indicate that there were problems with standards, enforcement, and implementation, not surprising in the middle of a war. Language was added to the regulation requiring all pilots to be certified "as soon as practicable" after arrival at a unit. In addition, AAF revoked all exisiting green instrument certificates and required the holders to recertify. The prerequisites for a green card were amended to include a minimum of fifteen hundred hours total flying time in addition to the one hundred hours of instrument time. Another change replaced the written examination with an oral exam administered by the unit Instrument Board. Finally, commanders were made directly responsible for the validity of instrument certificates issued within their units.[23] The increasingly stringent requirements imposed during the war show that the AAF was determined to achieve a higher standard of performance. The training for student pilots also continued the wartime trend toward increased emphasis on instrument flying.

The amount of instrument training in the 1945 syllabus, thirty-seven flying hours (14 percent of the total hours) and twenty-five Link hours,[24] was approximately the same as the 1942 syllabus, but there were several additional features designed to improve the quality of the training. Instrument instructors were required to be graduates of one of the AAF instrument instructor pilot courses or to take a local course consisting of fifteen flying hours, ten Link hours, and twenty-five classroom hours. Ground school instrument training was formalized and made a regular part of the academic curriculum. The 1945 course included thirteen hours of this training. Another change was the rate at which

students received instrument training. Training was concentrated; once they started instrument work, students had to complete one hour of instruments per day until they were proficient, after which they had to fly instruments at least one day per week.[25] This practice of concentrating training and managing continuity remained a feature of post-war pilot training.

Post-war training and management of operational pilots showed AAF's increased confidence in their ability. The twelve hour annual training program for all pilots was dropped[26] and the twenty hour annual flying requirement was reinstated.[27] Pilots were once again responsible for their own proficiency; they did not have to be retrained every year. Instrument certification required only a written test and a check ride. Command pilots were exempted from certification altogether.[28] Training procedures in the flying units changed also. The Instrument Board was deleted and a single pilot, who had to be a green card holder and a graduate of the instrument instructor's course was responsible for all unit training and certification. This Officer in Charge of Instrument Flying appointed flight examiners, at a ratio of one for every fourteen assigned aviators, who performed the training and certification. The minimum hours required to apply for a green card were also increased to twenty-five hundred.[29] The fact that the AAF continued after the war to refine its management procedures, train instrument instructors, and demand high standards of performance demonstrates that it was permanently committed to being instrument capable. There would be no regression to previous attitudes where instruments were approached half-heartedly and

regarded as an intrusion and a burden. In 1946, the AAF Chief of Staff, General Ira Eaker, confirmed the new thinking by announcing that one of the Air Force's chief post-war goals was to become an all-weather service.[30] Again, pilot training quickly reflected the attitudes of the leaders.

In 1947, pilot training was much longer (two hundred and seventy hours total) and less chaotic than the wartime courses. There were once again only two phases, Basic and Advanced. Twenty percent of the flying time (fifty-five hours) was devoted to instrument flight along with an additional forty hours of Link Trainer instruction.[31] The ninety-five hours of training required in 1947 was the highest total yet. Comparison with earlier programs clearly shows the steadily increasing emphasis on instruments. Comparison with today's flying shows that the evolutionalry process described in Chapter One was essentially complete by this time.

The details are different, but the key elements were all in place. In 1947: (1) Instrument flying was a basic skill that all pilots had to learn and maintain. (2) Instrument training was extensive (even more extensive than the current program). (3) Simulators were an important element of the training. (4) The technique of instrument flying was based on the attitude indicator. Events quickly showed how well this system served the Air Force.

The Soviet Union put the newly independent Air Force's mastery of instrument flying to the test in 1948. The blockade of Berlin brought about one of the most intense operations in the history of aviation. Over a period of thirteen months, the USAF

and the Royal Air Force airlifted 2,231,600 tons of supplies into the besieged city. This effort took 533,288 aircraft sorties,[32] many flown in typically poor European weather. In the planning stages of the airlift, weather was seen as the greatest single obstacle to success, but events proved these fears groundless. During the busiest period of the operation, there was a takeoff or landing at Templehoff airport every ninety seconds, good weather or bad. There were only minor shutdowns for weather during the worst months when ceiling and visibility approached zero.[33] Safety was not compromised to achieve these results; the Air Force could operate safely in this severe environment. The overall accident rate for the Berlin operation was half that of the rest of the Air Force during the same period. In its final report, the Airlift Force was able to state: "...weather is definately not a factor in the accident rate of an operation of this type."[34]

The Berlin Airlift demonstrated several things. It showed that instrument flying is a key military capability. In the Berlin crisis, it functioned like a weapon and inflicted a defeat on the Soviets. The Soviets were shocked and amazed by the Air Force's success. Their own air arm had a negligible instrument capability and they could not conceive of an operation of the magnitude of the Airlift continuing day in and day out in all kinds of weather.[35] The Airlift also showed that the instrument flying techniques and systems the Army had evolved over the previous thirty years were effective and mature. Although there was some special training for Berlin Airlift pilots, it was temporary and mainly for orienta-

or scramble to match the capability with the mission. There were no massive revisions of training programs or regulations; the system and the pilots functioned as planned. The Air Force was truly an all-weather weapon.

Since the end of World War One, the Army had been accumulating the capability that made the Berlin Airlift possible. The process of incorporating instrument flying was complex and no single factor was decisive. In general, technological advances, forward-looking people, and operational requirements pushed the Army forward, while complacency and lack of funds held it back.

Instrument flying required machine and human technology. Developing instruments, radios, aircraft lighting, airfields, and approaches was no more complex than developing the necessary organizational, managerial, flying, and teaching skills. The two technologies advanced at different rates, usually with the machines ready but the Army unwilling to exploit them, because of attitudes (inertia and complacency) and lack of funds. Before instrument flying was completely integrated into Army aviation, it took an operational emergency to force progress, although individuals like Ocker did cause incremental advances. The larger the emergency, the larger the effect. The Air Mail project caused a ripple, World War Two was a watershed.

Combat requirements in World War Two forced the Army to develop intensly the human technology required to use the machines that were available (it also forced new instrument technology such as radar and ground controlled approaches). The best example of human and machine technology intertwined and progressing at the

same rate is the rapid development of the Army's Link Trainer sections.

World War Two operations not only forced development of instrument flying technology but revealed that it was a permanent feature of aerial warfare just as the airplane itself became a permanent feature in World War One. The Army never considered returning to pre-war operational standards. Thus, instrument flying and its training and management establishments became the norm.

With the current emphasis on technological solutions to military problems, it is unlikely that the military will ever again spend thirty years perfecting an indispensable combat capability (today's problem is discerning which technologies are indispensable). What has not changed are the influences (operations, attitudes, funding, people) that determine how quickly and how well technology is perfected. These influences are unavoidable and should be understood in any military program. The Army's evolution of instrument flying illustrates that there is much more to technical proficiency than simply recognizing a good idea, buying a machine, and turning it on. The process takes time, ingenuity, and much effort.

NOTES

CHAPTER ONE

1. The term "instrument flying" refers to flight when the natural horizon and other visual cues are not available. The definition also includes radio-navigation because this type of navigation uses instruments in the cockpit and is performed in conjunction with instrument flying. Radio-navigation and instrument flying have always been taught together.

2. The organization underwent several name changes during the period covered by this study. Before 1927 it was the U.S. Army Air Service, called the Air Service here. Between 1927 and 1941 it was the U.S. Army Air Corps, referrd to as the Air corps. After 1941 it was The U.S. Army Air Forces, the AAF. In 1947 it became the U.S. Air Force, or USAF.

3. Department of the Air Force, Headquarters US Air Force, AF Regulation 60-1, Flight Management (Washington: 1985), 36-38.

4. Department of the Air Force, Headquarters Air Training Command, Syllabus of Instruction for Undergraduate Pilot Training (T-37/T-38) (San Antonio: 1987), 1-2.

5. Department of the Air Force, Headquarters US Air Force, AFM 51-37, Instrument Flying(Washington: 1986), 9-12.

CHAPTER TWO

1. William C. Ocker, Blind Flight in Theory and Practice(San Antonio: Naylor Press, 1932), 12.

2. Maurer, Maurer, Aviation in the US Army 1919-1939(Washington: USGPO, 1987), 45.; Monte Duane Wright, Most Probable Position: A History of Aerial Navigation to 1941(Lawrence: University Press of Kansas, 1972), 172.

3. Herbert N. Eaton and others, Aircraft Instruments (New York: Ronald Press, 1926), 3-4.

4. Mortimer F. Bates, "Filling Up the Instrument Panel," Aviation, August 1941, 192.

5. Edward O. Purtee, "Development and Adaptation of Aircraft Instruments for Military Use," February 1946, File 201.16, USAF Historical Research Center, Maxwell AFB, AL., 4-7.

6. Eldon W. Downs, "Contributions of US Army Aviation to Uses and Operation of Aircraft" (Ph.D. diss, University of Wisconsin, 1959), 326-331.

7. Ibid., 338.

8. Norris B. Harbold, The Log of Air Navigation (San Antonio: Naylor, 1970), 4.

9. Maurer, Aviation in the US Army, 149-152.

10. Downs, Contributions, 312-318.

11. Ibid., 324-340.

12. Maurer, Aviation in the US Army, 279.

13. Harbold, Log, 12.

14. Lowell Thomas and Edward Jablonski, Doolittle, A Biography (New York: Da Capo, 1976), 194.

15. The Guggenheim Fund, The Final Report of the Daniel Guggenheim Fund for the Promotion of Aeronautics, 1929 (n.p.: 1930), Collection, USAF Historical Research Center, Maxwell AFB, AL., 18. Doolittle's and Hegenberger's blind flights, which included covered-cockpit takeoffs and landings, were ambitious undertakings even by today's standards. Currently, safety regulations preclude routine takeoffs and landings in "zero-zero" ceiling and visibility conditions.

16. Thomas, Doolittle, 102-103.

17. Downs, Contributions, 349.

18. John H. Fredrick, Commercial Air Transportation (Chicago: D. Irwin, 1942), 137-141.

19. W.B. Courtney, "They're Coming Through the Ceiling," Collier's, 16 September 1933.

20. Ben Pearse, "Now You Can Fly With Your Head in the Clouds," in The Wild Blue, ed. John F. Loosbrock and Richard M. Skinner, (New York: Putnam, 1961), 184.

21. U.S. Army Air Service, Medical Section, Air Service Information Circular, vol. IV, no. 340 (Washington: 1922), Collection, USAF Historical Research Center, Maxwell AFB, AL.

22. Ocker, Blind Flight, 12.

23. Army Air Service, Information Circular, 6,9.

24. The Barany Chair is still in use today but no longer for physical examinations. Now it is used to demonstrate vertigo to student piots.

25. Ocker, Blind Flight, 13-14; J.H. Doolittle, "Early Blind Flying (An Historical Review of Early Experiments in Instrument Flying)," The Third Lester Gardner Lecture given at the Massachusetts Institute of Technology on 28 April 1961, [transcript] File 168.3, USAF Historical Research Center, Maxwell AFB, AL.

26. Maurer, US Army Aviation, 276-277.

27. Pearse, Wild Blue, 185.

28. Ocker, Blind Flight, 7,17.

29. William C. Ocker, "Instrument Flying to Combat Fog," Scientific American, December 1930, 430.

30. Pearse, Wild Blue, 184-187.

31. Downs, Contributions, 344-345.

32. Pearse, Wild Blue, 185.

33. At that time, pilot training was divided into two courses: Basic, at Brooks Field, and Advanced, at Kelly Field. Both bases are at San Antonio, TX.

34. Pearse, Wild Blue, 181.; Ben H. Pearse, "The Pre-flight Reflex Trainer," U.S. Air Services, August 1941, 16.

CHAPTER THREE

1. Harbold, Log, 52.; Ocker, Blind Flight, 16, 130. Aerobatics and spins are no longer a part of instrument training. This is much too dangerous in high-performance aircraft.

2. Elmer J. Rogers, "Blind Flying," U.S. Air Services, April 1934, 12.

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