In 1934, the Army Air Corps wanted what would today be termed a "fifth generation" bomber to fulfill Billy Mitchell's ideas.

On July 18, 1934, the Corps released US Army No. 98-201 specification, which called for a multiengine, four-to-six place land airplane with high performance.

The bomber was to have a 250 mph top speed, 220 mph cruise, and 10 hours' endurance at cruise. The mandatory service ceiling was a lofty 25,000 feet with an initial climb rate of 2,000 feet per minute. One "killer spec" was the requirement to maintain a 7,000-foot altitude with "any one engine cut out."

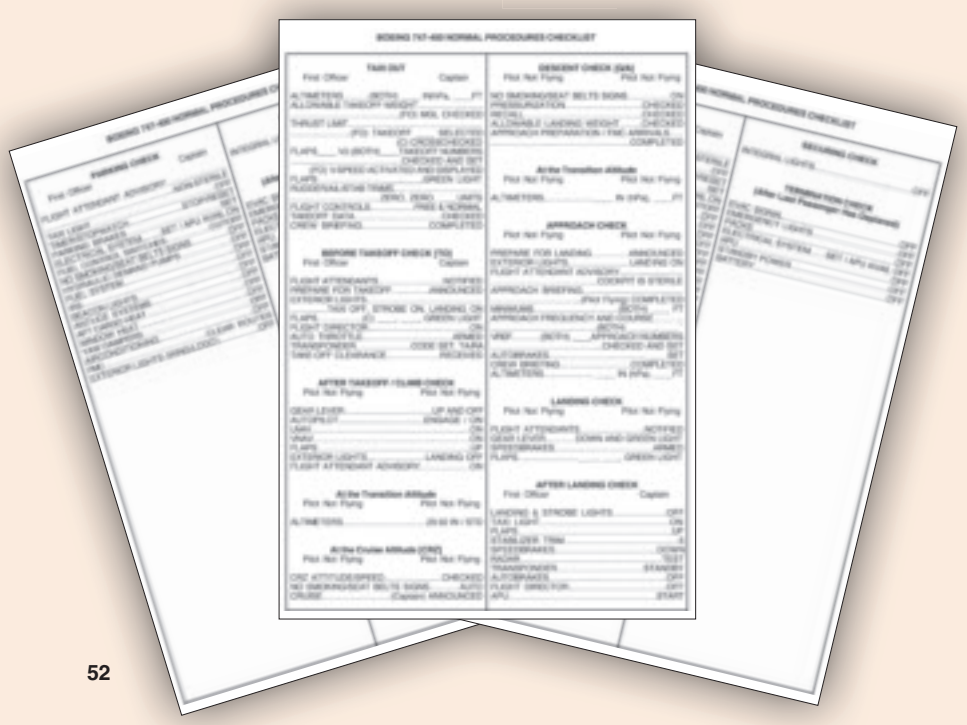
The specification called only for a "multiengine" aircraft, but Boeing Airplane Co. asked if a four-engine aircraft was acceptable, and the Army said yes. Boeing assembled a great team for the project including its president, Clairmont L. Egtvedt, and engineers Charles N. Monteith, Robert J. Minshall, and Edward C. Wells.

From that point on, Boeing played its cards close to its chest as it literally bet the existence of the company on the success of the program. The Model 299 made its first flight on July 28, 1935, flown by Boeing's chief test pilot Leslie R. Tower.

The huge 103-foot wingspan Model 299 was an aviation bombshell, stunning the flying world with its four big engines, controllable pitch propellers, retractable landing gear, flaps, and provision for five .30-caliber machine guns. Dubbed the "Flying Fortress" by

Boeing's Model 299 on the ramp.

THE



Seattle reporter Richard L. Williams, the Model 299 was the prototype for 12,730 B-17s which followed.

The Model 299 next made headlines when Tower flew it from Seattle to Dayton, Ohio, in nine hours and three minutes. The 2,100-mile nonstop flight caught the immediate attention of the Air Corps, for the 232 mph average cruise speed matched the Boeing P-26 pursuit's 234 mph top speed.

At the fly-off competition at Wright Field, Ohio, the Flying Fortress seemed to be a sure winner, although it was almost twice as expensive as its competitors. The Army wanted the Model 299 because of its superior performance and obvious growth potential. Although there were cautious naysayers in Congress who regarded the airplane

USAF photo

CHECKLIST

By Walter J. Boyne

A 1935 crash almost killed the B-17 program. The accident led to the modern checklist, and the B-17 survived.

as too costly to buy and too difficult to fly, the Air Corps pressed on.

Then on Oct. 30, 1935, with the suddenness that characterizes experimental test flights, Boeing's great gamble seemed to fail when the beautiful silver Model 299 crashed on takeoff from Wright Field. The tragic event seemed certain to lead to the cancellation of the program and an immediate change in Army Air Corps planning.

No one then could have guessed that with a little clever management and a dose of politics, the program not only would be salvaged, but the accident would bring a long overdue idea into existence: the checklist.

The checklist ultimately would alter the way aircraft were tested and flown around the world.

The Crash of 299

At about 9:30 a.m. on that October day, the Model 299 was manned by a very experienced crew, including Maj. Ployer P. Hill, Wright Field's Flying Branch chief, and his copilot, 1st Lt. Donald L. Putt. Also on board were John B. Cutting, a flight-test observer; Mark H. Koogler, also from the Flying Branch; and Tower. Hill was an experienced test pilot, having flown the earliest versions of the Martin B-10. It was his first flight in the Model 299. Tower was positioned behind the two pilots, ready to give advice.

Observers described the initial run of the Model 299's takeoff as normal, even though it broke ground at about 74 mph in a "tail low" attitude. As its speed increased, the bomber's nose went up much higher than normal. Two men, 1st Lt. Robert K. Giovannoli and 1st Lt. Leonard F. Harman, sensed it was in trouble and ran forward as the airplane reached an altitude of about 300 feet.

The Model 299 stalled, turned 180 degrees, and fell back onto a field. It landed on its left wing, cushioning the impact, which probably saved the lives of several crew. Lying flat on the field, the bomber burst into flames. Amazingly, four crew members were able to crawl from the blazing wreckage.

Putt and Tower emerged from the cockpit area, while Cutting and Koogler got out from the rear. Giovannoli rushed into the fire to find Hill jammed behind the controls. Harman crawled in and cut Hill's shoe off, freeing him from the rud-

USAF photos

The cockpit of Model 299. The controls were not ergonomically designed. Right: Boeing's bombardment airplane in pieces at Wright Field, Ohio, in 1935. The crash killed two crew members and destroyed the airplane.

der pedal. Giovannoli handed Hill out of the cockpit into the arms of Barney Miller, an employee of the Martin Co., but Hill died later from his injuries.

Tower, also grievously injured, gave testimony about the accident and apparently blamed himself for the crash. He, too, died not long afterward from the injuries sustained in the accident.

A board of officers convened at Wright Field to investigate the crash. The presiding officer was Lt. Col. Frank D. Lackland, for whom Lackland AFB, Tex., was later named. The board determined the accident was "not caused by": structural failure; malfunction of flight controls, engines, or propellers; the automatic pilot; or any faulty structural or aerodynamic design. Instead, it ascribed the direct cause to the elevator control being locked.

This is, by implication, a "pilot error" verdict—but the board did not say that directly. The board's determination was based on a detailed analysis of the flight-control mechanism and the testimony of Tower and Putt on how the aircraft behaved in the air. This assessment was corroborated by eyewitnesses on the ground, many of whom were experienced airmen who watched the flight from takeoff to impact.

The tail section of the aircraft was virtually all that survived the fire, but it contained the cause of the accident: an internal control lock that controlled both the elevator and rudder. There were three positions for the elevator on this lock. Two of these were "up"; one was "down."

Enter the Checklist

The board concluded that the elevator control could not have been in the extreme up position, because at that position the control yokes would have been inclined back at an angle of 12.5 degrees, and the pilots would not have been able to climb into their seats without releasing the controls. They also deduced that it could not have been in the down position because the aircraft would not have been able to take off.

Further, the Pratt & Whitney representative, Henry Igo, had conducted the engine run-up with the controls locked in the first up position. This meant the pilots could have initiated takeoff without realizing the controls were locked. The flight would have seemed normal until they increased the speed, which would have affected the locked control surface, forcing the aircraft's nose up into a stall.

Both Tower and Putt believed the control was locked.

The investigators concluded that when the pilot pushed forward on the control yoke, the small elevator trim tabs moved to the up position, contributing to the nose-up attitude. Tower said he made an attempt to unlock the controls when he realized the situation, but could not reach them.

The board stated that—due to the size of the airplane and the inherent design of the control system—it was improbable that any pilot, taking off under the same conditions, would discover the locked controls until it was too late to prevent a crash. Ordinarily, pilots make checks of their movement as a precaution, but apparently this did not occur.

In the aftermath of the Boeing Model 299's crash, the Air Corps declared Douglas Aircraft Co. to be the winner of the multiengine bomber competition. Douglas' DB-1 was redesignated the B-18 and later given the name Bolo. Some 350 were built, and they gave excellent service—but not in the long-range bomber role.

The Air Corps still wanted B-17s, and Boeing received a consolation prize, a contract for 13 aircraft designated Y1B-17. Still, the Air Corps faced arguments that the aircraft was too big to handle.

The Air Corps, however, properly recognized that the limiting factor here

was human memory, not the aircraft's size or complexity.

To avoid another accident, Air Corps personnel developed checklists the crew would follow for takeoff, flight, before landing, and after landing.

The idea was so simple, and so effective, that the checklist was to become the future norm for aircraft operations. The basic concept had already been around for decades, and was in scattered use in aviation worldwide, but it took the Model 299 crash to institutionalize its use.

According to the Merriam-Webster dictionary, the term "checklist" first appeared in 1853. There is no mention of its specific use, but the need for it in operating heavy machinery or railroad equipment is obvious. Some similar types of reminders probably have been in use for centuries for complex tasks.

One current formal definition has special meaning for anyone who has made a wheels-up landing. It says that a checklist is an "informational job aid used to reduce failure by compensating for potential limits of human memory and attention."

Checklists are intended to be used precisely. Every certified aircraft has to have an approved cockpit checklist easily accessible. The checklist must have all the necessary items from engine start to engine shutdown, including emergency procedures. But it is impossible to remove the human element—errors still occur.

Forget Memory

Today the checklist can take several forms, including paper, a scroll giving line by line actions, and various mechanical types, some involving a voice presentation. Modern glass cockpits use different methods, including a computer-based text on the display screens and even electronic checklists that sense the state of a system.

The paper checklist has been the most common.

Aircrews can either "run a checklist," where each item is called out and the action or status is reported in reply, or they can configure the aircraft from memory then use a checklist to verify that all the steps have been taken.

There are great improvements over the earlier mnemonic checklists. These varied from the familiar "GUMP" check for the gear, undercarriage, mixture, and propeller to the Royal Air Forces' wartime "TMP and Flaps," i.e., trimming: neutral; mixture: rich; pitch: fine; and flaps. This was used to preflight everything from a Tiger Moth to a Lancaster.

The creation of the checklist was delayed by an unrealistic reliance on the memory of pilots. This dated all the way back to 1903, with the Wright brothers' intimate knowledge of airplanes. The precise care and organization of their preflight techniques often was commented upon at the time, particularly in the demonstrations Wilbur Wright conducted in Europe. Audiences for his flights sometimes became restive with his deliberate, unhurried, and comprehensive checks of the aircraft, catapult system, weather, and everything else.

Wilbur knew well that if something could go wrong it would, and he took his time to be sure to prevent a mishap.

This same philosophy has endured through the years, both before and after checklists became commonplace. It was the pilot's responsibility to ensure the aircraft is ready for flight.

Still, this approach does not result in uniform success. Aircraft accident reports are replete with findings that the failure to use a checklist properly resulted in an accident.

Capt. Benjamin Foulois at the controls of a Wright military biplane in 1911. Foulois advised preflight actions that resemble today's checklist procedures.

Like the Wrights, Glenn H. Curtiss began a pilot training program to enhance the sale of his aircraft. In 1911, he established a flying school at North Island, Calif., where Lt. Theodore G. Ellyson, the Navy's first aviator, was among his students. Although articles on the school mention that Curtiss demanded a checklist be made for his students, there is no hard evidence of such a checklist.

During the same year in San Antonio, a young Benjamin D. Foulois wrote the "Provisional Aeroplane Regulations for the Signal Corps." In it he wrote, "Immediately preceding every flight, an aeroplane will be carefully inspected by the pilot and mechanic. Each inspection is to be made independently of the other. Upon completion of both inspections the mechanic will report the result of his inspection to the pilot; the pilot will then report the result of both inspections to the senior officer present on aeronautical duty."

While not a checklist in the modern sense, Foulois' instructions have the challenge-response element of today's procedures.

Other training schools recognized the need for systematic care in operating aircraft. Sometime in 1915, engineer George E. A. Hallett developed a checklist-like procedure for the Army at North Island. Hallett went into much greater detail than Foulois. The document, "Inspection of Aeroplanes Before Flight," included extremely precise instructions on the inspection of every element of the aircraft, from the correct tension of wires to the proper inflation of tires.

Hubris, then Accidents

By 1918, with vastly expanded pilot training in the United States, a special handbook was created by Curtiss for the JN-4 "Jenny." One section was titled "Hints on Flying" and provided a list of 18 items, each with considerable detail. Five items were devoted to actions to take before takeoff, nine covered in-flight procedures and safety precautions, two advised on landings, and two discussed ways to avoid stalls and spins.

While not a handheld checklist that was carried in the cockpit, it was a manual that contained all the advice necessary for the operation of the aircraft. It also set a pattern for the future around the world—most air forces would depend on the appropriate flight manual to be an adequate source of knowledge.

As was the case with all of these checklist predecessors, pilots were expected to know the manual by rote. Sometimes this led to hubris, which led to accidents.

Given its wild expansion from a handful of aircraft in 1912 to the largest air force in the world in 1918, it is not surprising that the Royal Flying Corps—and its successor, the Royal Air Force—created the closest ancestors to the modern checklist.

The nearest relative to a post-1935 checklist is found in "Hints on the Bristol Fighter," dated March 30, 1918, and written by the officer commanding No. 39 Squadron. The section headings are similar to modern checklist, including specific sections designed to ensure pilots see that the pressure is holding, the ignition is fully advanced, the temperature is at least 65 degrees and not over 85 degrees, the oil pressure is OK, the blinds are open, and the tail lever is forward.

In 1919, the Director of Air Service published "General Rules to be Observed at all US Flying Fields." This order listed 33 items vital to the safe operation of aircraft. In the same year, the Royal Air Force Air Publication 129 stated that a pilot should always carry out his preflight walk-around "systematically in order that no part may escape notice."

Even by 1937, two years after the Model 299 crash, RAF instructions still depended on memorization for their execution. They were much more precise, offering checks that had to be accomplished before each stage of flight, but pilots were "required to learn the drill" rather than have something written in hand.

It should be remembered that cockpit ergonomics were not a big consideration anywhere at this time, and the placement of even such basic controls as throttle, mixture, and propeller varied from type to type.

The general attitude within the US Army Air Forces continued to be, "If it has a stick and a throttle, go fly it," but increasingly after 1935 paper checklists were more available, particularly on multiengine aircraft.

The success of aviation checklists led to their adoption by many other disciplines, including the quality assurance for software engineering, in civil litigation, and even in tracking and evaluating sports card collections.

So as tragic as the Model 299 Wright Field crash was, it almost unquestionably has saved thousands of lives over the ensuing decades. ■

Walter J. Boyne, former director of the National Air and Space Museum in Washington, D.C., is a retired Air Force colonel and author. He has written more than 600 articles about aviation topics and 40 books, the most recent of which is How the Helicopter Changed Modern Warfare. *His most recent article for* Air Force *Magazine, "C-124 and the Tragedy at Tachikawa," appeared in the July issue.*