Seven Decades Of Ejection Seat Development

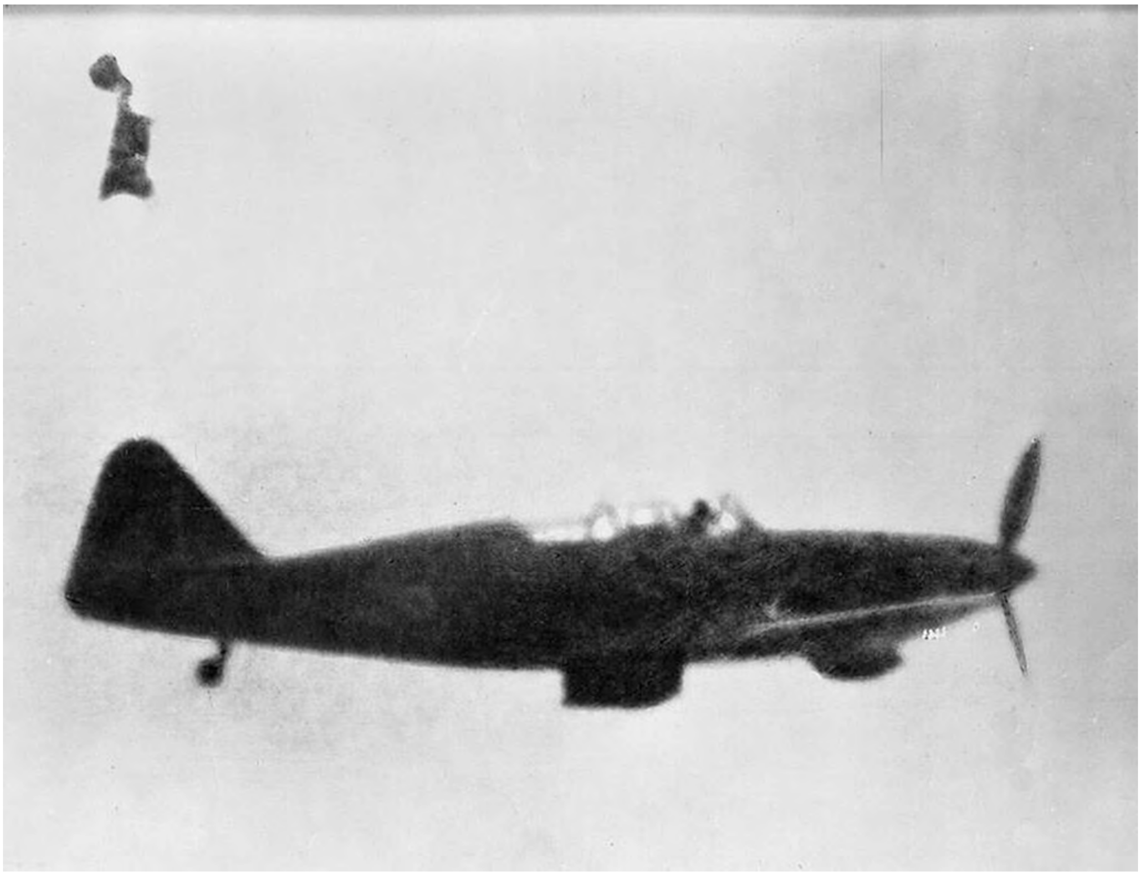
Aviation Week
Guy Norris

As the industry's largest and oldest consistent ejection seat developer, Martin-Baker has delivered more than 70,000 escape devices since first experimenting with the concept over 70 years ago. Now, with 7,514 aircrew lives saved as of February and new applications under study, Aviation Week outlines the design evolution of the British manufacturer's ejection seat through the decades.

Pilot safety became the focus for Martin-Baker Aircraft Co. founder James Martin following the death of his partner, Valentine Baker, in the crash of the manufacturer's MB3 fighter prototype in September 1942. Two years later, with the advent of the jet-powered Meteor into Royal Air Force service in 1944, the Ministry of Production asked Martin to investigate alternative means for pilots to escape a crippled aircraft.

Initial studies revealed the best means would be a forced ejection of the entire seat, with an explosive cartridge providing the acceleration. In January 1945, Martin-Baker began the first tests of a seat propelled up guide rails by a gun made up of a cartridge and two telescopic tubes. Over a series of tests, Martin concluded that spinal injury to the pilot could be avoided if the body was positioned so the vertebrae were squared to each other and that the G rate onset was held below 300g per second. In addition, tests showed peak acceleration should not exceed 21g nor 0.10 sec.

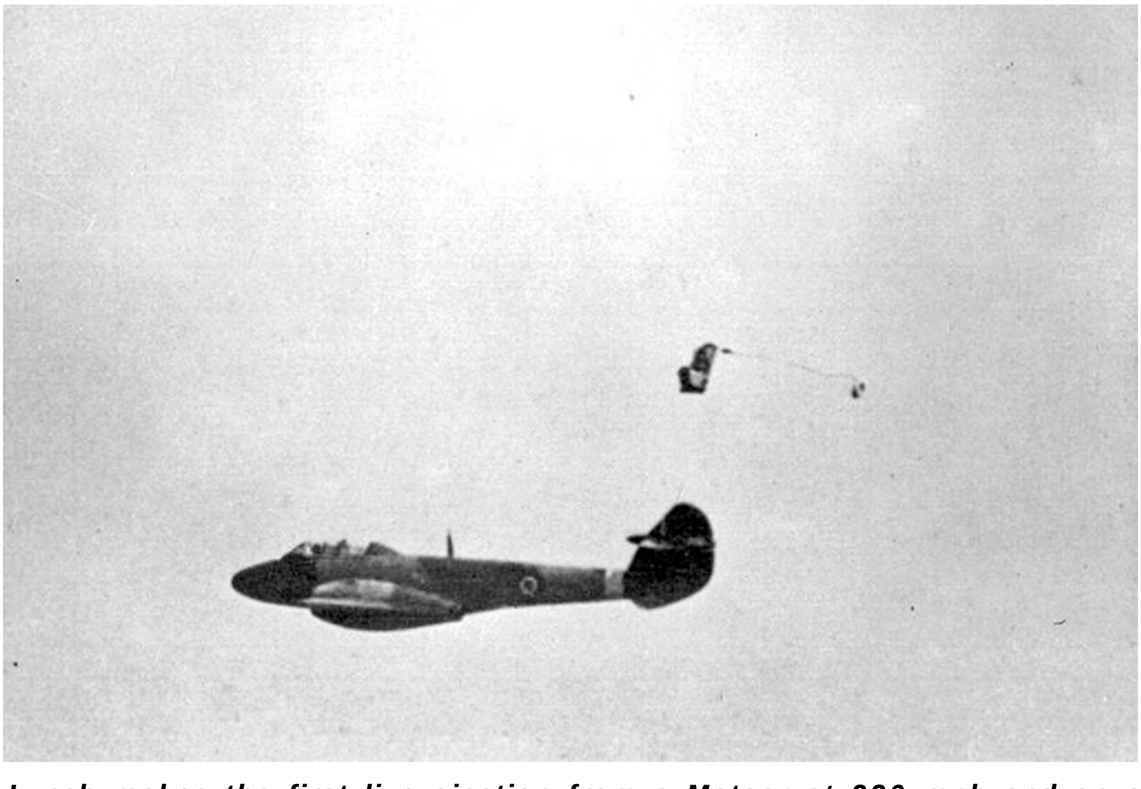
A two-cartridge gun was developed to ensure the correct G-level acceleration. In this system, the first cartridge initiated the movement of the seat while the second, firing a split second later, added further acceleration. The design also incorporated a firing handle above the pilot's head, which included a protective screen that covered the face when deployed. Together with the location of footrests, the act of reaching for the handle immediately straightened the pilot's spine into the correct posture for ejecting.



The first dummy ejection of a Martin-Baker seat in flight was from a Boulton-Paul Defiant in 1945. Credit. Martin-Baker

Another early design feature that remains in ejection seats today was the development of a device to deploy a drogue to stabilize the seat prior to parachute deployment. After various release methods proved ineffective in trials due to interaction with the vortex created by the seat, Martin-Baker settled on a drogue gun containing an explosive cartridge. The gun, which consisted of a barrel containing a piston connected to a nylon cord and the drogue, automatically fired as the seat ejected and shot the unit well clear of the vortex to enable correct opening.

Bernard Lynch, a Martin-Baker fitter, volunteered for the first live ejection test. He is shown just prior to the event, which took place in July 1946. Credit: Martin-Baker



Lynch makes the first live ejection from a Meteor at 320 mph and an altitude of 8,000 ft. on July 24, 1946. Credit: Martin-Baker

After a delay, controlled by a hydraulic release mechanism, the pull of the drogue was transferred from the seat to a large parachute that supported both the seat and pilot. In the initial seat design, the pilot had to unfasten the harness and push away to fall free from the seat, and then deploy a personal parachute.

A preproduction Mk. 1 ejection seat is on display at Martin-Baker's Denham, England, production site. Credit: Mark Wagner/Aviation-images.

From 1947, the Mk. 1 seat became standard on all new British service jet combat types and incorporated adjustable features to adapt to different body sizes; thigh guards kept the legs together against the air blast. Although many lives were saved, several pilots died because they did not have sufficient time to perform separation from the seat at low altitude or were unconscious at the time of ejection. These limitations spurred development of a fully automated sequence.

Features introduced with the Mk. 2 included housing the pilot's personal parachute in the back of the seat and a dinghy pack in the seat pan. A time-release unit, which was tripped by a static line as the seat fired, was also developed to disconnect the drogue from the seat at the correct time. Simultaneously, the mechanism unlocked the seat harness, and as the drogue pulled away from the seat its action was transferred to a canvas apron that tightened and tipped the occupant forward and out of the seat. The apron included a line that automatically deployed the parachute.

The time-release unit included a barostat to prevent the parachute opening above 10,000 ft. and enabled the pilot to ride the seat to lower altitudes with breathable air and higher temperatures. Separation from the seat, which included breathing oxygen for the occupant and a steadying drogue, became automatic below the 10,000-ft. threshold.

The Mk. 2 was the company's first automatic ejection seat. Credit: Mark Wagner/Aviation-images.com

Further improvements were introduced with the Mk. 3: the escape trajectory was increased by extending the ejection stroke to 72 in. The altered gun configuration now consisted of three tubes, two of which were telescoped inside the main outer tube, and increased velocity to 80 fps. A system using nylon cords was also developed to automatically pull the occupant's legs against the seat to prevent flailing in case of a high-speed ejection. At the same time, a duplex drogue was introduced which cut the time between ejection and main parachute deployment from 5 to 3 sec.

The increased performance of the Mk. 3 provided the basis for the development of the ground level-capable ejection seat. This was tested successfully with a time-release mechanism delay of only 1.5 sec. (from the 3-sec. standard) from a Mk. 7 Meteor by Sqdn. Ldr. John Fifield in September 1955, marking the first ever deliberate runway ejection.

The first live ejection test from the runway at Chalgrove airfield in England took place in September 1955. Credit: Martin-Baker

Although this reduced time delay was found to work safely for ground ejections, it was only effective at low speed because at higher speed the seat could not decelerate in time to safely deploy the main parachute. The solution was an automatic selector, or G switch, which was built into the time-release unit and automatically selected the correct delay to suit particular loads. Improvements were also made to the canopy ejection system, which linked it to the operation of the ejection seat firing handle and forcing the canopy clear under all conditions.

The Mk. 4 was the first-ever lightweight ejection seat. Credit: Mark Wagner/Aviation-images.com

The advent in the 1950s of a generation of smaller jet fighters drove development of a redesigned lighter-weight Mk. 4 seat. Instead of guide rails, channels were mounted on the sides of the ejection guns, while other parts of the seat structure performed double duties. The seat included an alternative firing handle on the front of the seat when high G loads prevented use of the upper handle.

The Mk. 5 seat was derived from the Mk. 4 and developed to meet U.S. Navy specifications, which called for deceleration loads up to 40g—well beyond the UK specification of 25g. The Mk. 5 became standard fit for Navy fighters and trainers and was subsequently fitted to nearly 20 U.S. aircraft types.

By the late 1950s, it became apparent that a further increase in seat trajectory height could save more aircrew in the case of emergencies at low altitude and high sink rates. Martin-Baker therefore began studying the use of rocket motors to prolong the thrust produced by the ejection gun without increasing acceleration forces.

After experimenting with a twin-tube system that combined fuel in an efflux chamber below the seat, the company opted for a rocket pack comprising multiple tubes filled with solid propellant. The pack, which could be easily retrofitted to existing seat designs, was also low maintenance and directed thrust in a near vertical line through the center of gravity. The system fired as the ejection seat neared the end of the gun stroke when a static line attached to the cockpit floor allowed a spring-loaded pin to fire the cartridge. This produced a hot flame that flashed through the tube system causing simultaneous ignition. Later designs moved to a more rugged, remote rocket-firing system that incorporated a firing unit mounted high on the seat and connected to a static line. When pulled, it fired the cartridge, which delivered gas pressure via rigid and flexible hoses to the rocket firing unit.

The rocket-powered Mk. 7 ejection seat. Credit: Mark Wagner / Aviation-images.com

Rockets were about 1 in. in size to ensure sufficient thrust to eject safely at zero altitude with a sink rate up to 30 fps. For ejections from vertical-takeoff-and-landing aircraft with higher sink rates, the company fitted a pack with 2-in.dia. combustion tubes.

Following a successful live ejection test in March 1962 at 250 kt. and 250 ft., the rocket pack was developed for the Mk. 4 and 5 seats that became the Mk. 6 and 7 seats. The latter was adapted with a powered-retraction device to pull the pilot's shoulders back into the seat for the correct ejection posture. A rocket-assisted Mk. 8 seat was developed for the TSR.2, which was later canceled.

The Mk. 9 incorporated changes to improve comfort and overall seat structure. Built with a new gas-operated seat-firing system and powered-retraction device, the seat used only the seat pan-mounted firing handle. By this time in the early 1960s, operational experience showed that it was faster to engage the seat handle than the face-screen handle; the feature was made redundant by the protection offered by modern helmets.

The follow-on Mk. 10 seat drew from development of the gas-operated firing system to further reduce the time between the start of ejection and the opening of the parachute. The firing system was extended to include the release of the drogue and to operate the harness-release system, while the drogue gun and barostatic time-release unit were redesigned for inclusion with this system as well. The seat also featured a simpler two-point harness and combined the drogue and parachute into a single assembly.

The Mk. 14 / NACES ejection seat. Credit: Mark Wagner / Aviation-images.com

Follow-on seats have become increasingly sophisticated and tailored to specific platforms. The Mk. 11, which is designed for operation at zero altitude and 60 kt., is another small, lightweight seat configured for trainers and light attack aircraft such as the PC-7/9. A follow-on seat, the Mk. 15, is bespoke for the PC-7 Mk. 2 with twin ejection guns, a cartridge-initiated time-release unit, a drogue gun time delay and gas-fired bullet-canopy fracturing system. The Mk. 12, which equips the Taiwan F-CK-1 Ching-Kuo, incorporates an airspeed sensor that adjusts operational modes accordingly from 0-625 kt.

An Mk. 16 Eurofighter Typhoon ejection seat. Credit: Mark Wagner/Aviation-images.com

The Mk. 14, also known as the SJU17A and Navy Aircrew Common Ejection Seat (NACES), is standard for the U.S. Navy fleet of F/A-18s and T-45s, as well as for F/A-18s operated in Finland, Kuwait, Malaysia and Switzerland. The zero-zero seat incorporates a gas-powered drogue deployment catapult, ejection gun and multitube rocket-pack ejection-rocket motor; it operates up to 50,000 ft.

Much of the company’s current production is focused on the Mk. 16 seat— a family of advanced ejection seats spanning several of the Western world’s major trainers and combat aircraft. With roots going back to 1988, the Mk. 16 design embodies the features of NACES, but is tailored for a new generation of lightweight fighters. Variants equip the Raytheon T-6 Texan II, Northrop Grumman T-38/F-5, Dassault Rafale, Eurofighter Typhoon and Lockheed Martin F-35.

Features differentiating the Mk. 16 from earlier seats include an auto-eject interface system, a fifth generation restraint harness, an inflatable neck-protection device and low acceleration, or “soft ride” catapult. The seat, which is fired by a twin gun system with the main gun cartridge located at the bottom rather than on top as in earlier seats, also incorporates a reefed drogue that deploys early, and a larger main parachute (24 ft. in the F-35 US16E seat). It also includes the Martin-Baker Water Activated Release System, which automatically releases the pilot from the harness and parachute assembly on submersion in water.

In this sequence, a typical ejection scenario is pictured during a ground firing of a US16E seat, designed for the F-35 at Martin-Baker’s Langford Lodge test facility in Northern Ireland. Propelled along a 6,000-ft. rail track by a solid rocket-powered pusher sled, the cockpit section is used to demonstrate the computer-controlled ejection sequence that begins with the canopy either jettisoning off or being breached by an embedded explosive cord charge. The seat is launched up a rail system by a soft-launch catapult device incorporating two telescoping tubes and a common gas generator. An underseat solid rocket motor then fires to provide sustained propulsion to carry the seat away from the aircraft. A rapid-deploying drogue chute meanwhile stabilizes the seat, and a small explosive charge deploys the main parachute for descent and landing as the seat is automatically detached. Credit: Martin-Baker

More recently Martin-Baker has developed the Mk. 17 ultra-lightweight seat for basic and primary trainers. The seat is designed to operate from 60 kt. at ground level to 250 kt. and altitudes up to 25,000 ft. Simplified for lightness, cost and lower maintenance, the Mk. 17 has no under-seat rocket motor and uses about 50% of the pyrotechnic cartridges of comparable seats.

Another seat, the Mk. 18/US18, is also in development and targeted in particular at the U.S. Air Force's T-X trainer requirement. The seat is configured with zero-zero capability, seat pitch control, full body protection and a torso harness system.