

IN THE CONTINUOUS PURSUIT OF EXCELLENCE IN AIRCREW SAFETY

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EARLY RESEARCH

Ever since Orville Wright first took to the sky in 1903 there has been a constant pursuit to provide aircrew with the safest possible means of survival in the event of an emergency.

The safest way down to earth from a disabled or out-of-control aircraft has always been by parachute. The Germans were the first to issue parachutes to aircraft crews and it was not until several years after the First World War, in 1926, that the Irvin parachute was introduced into the Royal Air Force. The need for assisted escape was identified in the early 1930's. As aircraft performance capability increased, conventional bale-out, either over the side of the cockpit, or escape through a hatch, became virtually impossible. In fact, as information compiled from a German study of over 2,500 emergency over-the-side bale-outs made from 1943 to 1945 showed, once aircraft speeds exceeded 200 m.p.h. the chances of making a successful escape were less than 58 per cent. In combat conditions, where injury to the pilot, aircrew disorientation and unfavourable g conditions in out-of-control aircraft were all likely to occur, escape was often impossible, a fact that was very apparent by the large number of aircrew losses sustained during the height of World War II. Commendable attempts were made to improve on the chances of successful escape by provision of escape hatches, jettison canopy hoods, and blast deflection devices, but the introduction of the first jet aircraft into service clearly

emphasised the need for a more positive means of escape. Germany led the research into assisted escape and, after various emergency escape methods were investigated, including a jettisonable cockpit for the first rocket powered Heinkel HE 176 aircraft, it soon became apparent that the only practical solution was to eject the seat, with its occupant, from the cockpit by means of a powered activated device fitted to the seat.

Junkers developed the first ejection seat installation for the test prototype of the JU-88 and a patent was lodged in 1941 for the seat design. This early seat was quite primitive, was never used in an emergency, and few details of its installation or testing are available. The Luftwaffe commissioned a number of German firms to develop ejection seats. Dornier, Heinkel and later Focke Wolf, all developed their own types of seat based on compressed air operation. The compressed air seat had severe limitations for control of acceleration performance. Dornier went on to successfully develop a more efficient cartridge-operated variant of seat, which was successfully developed following a wide range of tests using live subjects. This improved seat design eventually became the final standard, which was universally adopted in Germany for installation in seven different types of aircraft.

All new fast jet aircraft in the Luftwaffe were provided with ejection seats from 1942. Over 60 ejections were made by pilots of the Luftwaffe

during the later stages of the Second World War, although how many of these were successful is not known.

German scientists at the time claimed the ejection seat as their most important wartime contribution to flight safety.

In parallel with the work in Germany, Saab-Scania in Sweden were carrying out their own independent research into ejection seats as they had a need to provide an effective escape means for their new "pusher prop" design J-21A fighter aircraft.

The original Saab Type 21 ejection seat aroused a great deal of international interest. Teams from France and the United States visited Sweden to see this new seat and negotiate the possibility of manufacturing rights. None of the discussions resulted in any tangible proposals, although a test seat was sent to America for evaluation. A later design Type 29 ejection seat was however sold under licence to Folland Aircraft Ltd. in England. After several modifications to the seat catapult ballistic system, it was installed in the company's Gnat trainer aircraft.

Saab continued with development and went on to successfully produce six different types of ejection seat design which were fitted to all the company's military aircraft, with the exception of the latest JAS-39 Gripen, which has the Martin-Baker Mk10L.

The pioneering work carried out in Germany and Sweden was only ever revealed after the cessation of hostilities in 1945, when foreign research and development data became available. Specialist teams from the United States, Britain and Russia visited Germany to retrieve examples of ejection seat equipment and supporting scientific data for analysis and testing.

American ejection seat work began in the waning days of World War II at Wright Field (now Wright Patterson AFB) in Dayton Ohio, as a joint effort by the Army Air Force and

Aeromedical Laboratories. Much of the early work conducted in America by the Army Air Force was based on the Heinkel ejection seat equipment obtained from Germany. A comprehensive range of testing was carried out on the German design to evaluate seat performance. This was conducted by a specialist committee, which had been formed at Wright Field. Much of this Government sponsored work progressed into further development of seats by some American equipment manufacturers and several aircraft companies went on to produce ejection seats for their own aircraft.

BRITISH DEVELOPMENT

Although the feasibility of seat ejection had been under consideration in Britain, it was only in April 1944, following the tragic loss of a highly respected Gloster Meteor pilot, that the problem of assisted escape was pursued with any determination by the Ministry of Aircraft Production.

The Ministry of Aircraft Production invited R. Malcolm Limited (later known as M.L. Aviation), Vickers and Martin-Baker Aircraft Company to investigate the practicability of providing fighter aircraft with the capability of assisted escape for the pilot.

It was not entirely clear at this time whether the Ministry wanted an escape system that could be retrofitted to existing aircraft, or whether they required a system for installation in new aircraft types. This was obviously a very relevant factor on the type of escape system that would be required.

Initial studies undertaken by both Malcolm and Martin Baker favoured the idea of a spring activated swinging arm which would be recessed in the top of the fuselage with its rear end pivoted to the aircraft structure and its front end attached to the pilot's seat and parachute harness. The British authorities were aware of some of the early successful German work, so this design was very soon

abandoned in favour of an ejectable seat based on the same principle operation as the proven Dornier system. Little information is available on the Vickers work but it appears that any escape system work they considered never went beyond the drawing board. Unfortunately, M.L. Aviation's venture into assisted escape systems was both brief and traumatic, with a fatality on the first live ejection in 1947, which was attributed to an unconfirmed malfunction of the seat.

Preliminary experiments into the physiological consequences of abrupt accelerations associated with ejection began in late 1944 at the Physiological Laboratory. The research programme was later transferred to Martin-Baker who were conducting similar work into physiological acceleration tolerances of the human body.

Early physiological assessments into the tolerance of accelerations produced by ejection seats were purely subjective, so importance was placed on experimental tower testing using live subjects. Physiological assessments have become more objective over the years, with emphasis being placed on cine photography and recording accelerometers attached to strategic points on the test dummy and seat. These provide a direct measure of both the rates of onset of the acceleration and the peak value of the induced g.

The need to limit both the peak g and acceleration onset rate were known by the Germans, but they never properly understood the significance of spinal injury to the phenomena of "jolt and overshoot". Martin-Baker quickly realised from their research that these were crucial physiological factors governing injury free ejection.

Detailed studies were carried out to obtain a greater understanding of the mechanical properties of the human spine and the types of injuries that could occur. A complete spinal column was provided to Martin-Baker by the Elizabeth Garrett Anderson Hospital in South London to enable

mechanical tests to be carried out. Research showed that the greater loads are consistently experienced at the base of the spine, in the lumbar region, which is exactly where many of the all too common vertebrae compression fractures can generally occur on ejection.

From these studies Martin-Baker were able to determine the limits for human tolerance which are still universally accepted today as the definitive criteria for ejection seat design.

This was a significant breakthrough in understanding the effect of g forces on the human spine, and in allowing Martin-Baker to proceed successfully with the development of the ejection seat.

In addition to the physiological research work, the engineering problems associated with the performance of the seat and its unobstructive ejection from the aircraft were also investigated. Establishing a catapult design to control the acceleration onset rates and maximum g was a major challenge. A comprehensive programme of experimental tests with ballasted and live subject ejection tower tests was carried out to perfect a suitable catapult design. This work progressed into airborne high-speed ejection tests which demonstrated the need to provide seat stabilisation in-flight, which was again resolved following a full range of intensive testing. Many engineering problems were presented in the installation of the seat in the aircraft, all of which had cockpits that had never been designed to accommodate such an ejection system.

EVOLUTION IN SEAT DESIGN

Development of the Mark 1 Martin-Baker ejection seat rapidly followed the comprehensive range of experimental work on the ejection tower and the subsequent series of dummy and live subject airborne tests. The Mark 1 was a simple, manually operated seat, which essentially ejected the pilot from the

aircraft, leaving the occupant to unfasten the harness, release himself from the seat and deploy the parachute in the traditional "rip cord" activated manner.

A large number of ejections were made with the manually operated Mark 1. Experience had shown that a number of fatalities had occurred, due to unconsciousness after ejection, inaction due to circumstantial stress, or lack of time to carry out the necessary physical operations when ejecting at low altitudes. The limitations to this original design were quickly recognised and overcome with the development of the Mark 2, the world's first fully automatic seat, which permitted successful escape from altitudes as low as 500 feet.

The Mark 2 became the first ejection seat to be introduced into service with the RAF in 1953. Although the new automatic seat was generally successful, problems still arose at very low altitudes and very high speeds. More capable jet aircraft were being introduced at the time, some of which had high fin projections and greater operating speeds. It was therefore necessary to increase the height attained during ejection in order to avoid collision with the fin - which at the same time improved the chance of successful ejection at low altitudes. The extra height was gained in the Mark 3 seat by increasing the stroke of the catapult, giving an ejection velocity of 80 ft/sec, compared with the previous 60ft/sec. In addition, the Mark 1 and 2 seats had experienced problems with leg flail caused by air blast, so a leg restraint system was incorporated, which operated automatically on ejection to secure the legs firmly against the seat. Finally, improvements to the drogue stabilisation system reduced the delay between ejection and deployment of the main parachute. This allowed ground level ejection capability to be achieved. Following the Mark 3 came the Mark 4 design which retained the major features from the previous mark of seat but was lighter in construction and provided a fully integrated

combined restraint and parachute harness system.

THE AMERICAN SCENE

The US Navy had originally obtained their seats from American contractors, but the high fatality rate in low level ejections, particularly during take-off and landing on carriers, caused grave concern to the authorities. The US Navy were particularly interested in the unique ground level escape performance of the Martin-Baker Mark 4, but commercial interests in the USA were strongly against allowing the purchase of British seats and rumours denigrating the work of Martin-Baker were much in evidence. A successful live demonstration ejection of the Mark 4 from a Grumman Cougar taking off at the US Navy Patuxent River Air Test Centre, Maryland silenced the opposition and eventually large orders were placed by the Navy for the retrospective installation of seats in 10 different types of Naval operational aircraft.

The Mark 4 seat was adapted to meet the special requirements of the US Navy. This included the requirement for an increased crash case condition associated with the hostile carrier arrester hook landing environment and the need to have through the canopy ejection capability. These different design features created the Mark 5 variant of Martin-Baker seat, which eventually became the standard installation for more than 20 various types of US service aircraft.

NATO Air Forces also sought Martin-Baker seats at this period for their aircraft, which were obtained under the offshore procurement programme.

A whole host of different escape system methods were developed and tested in the United States by both industry and the Services. These have included a downward ejection seat, and complete jettisonable cockpit sections and capsules that were closely related to the space programme.

Because of the unusually high tail surfaces of some aircraft designs at the time, exceptionally high speeds and the possibility of multiple ejections, a downward-firing seat was considered an attractive option.

Both Stanley Aviation and Lockheed produced a downward ejection seat for the B47 and F104 aircraft. Various American authorities also believed that the future for high-altitude, high-speed escape systems lay with a completely closed capsule and not an open type seat. Many different escape schemes were investigated as new aircraft designs came off the drawing board, one of the most notable being the Stanley Aviation Corporation individual encapsulated ejection seat which was used on the B-58 Hustler.

The General Dynamics F111 is perhaps the best known example of an aircraft with a complete modular escape system, although earlier versions of the B-1B did incorporate a jettisonable front cockpit module. Subsequent versions of the aircraft were however converted back to traditional open ejection seats.

The Stanley Corporation also came up with another unique idea designed for use in aircraft where it was impossible to retrospectively fit conventional ejection seats. Known as "Yankee" this consisted of a tractor rocket attached to the pilot's torso harness. The aircraft occupant was towed out of the aircraft in the standing position by a tractor rocket on a pendant attached to the upper part of the pilot's harness. The Yankee system, although well used in Vietnam, was never really adopted on any significant scale.

Most of these American alternative methods of escape came with a number of technical problems and the use of the traditional ejection seat has always been considered to be the most efficient and cost effective means of aircrew assisted escape.

UNDERWATER ESCAPE

When fast jets were first introduced into the Royal Navy there were many appalling accidents associated with operations from aircraft carriers, because of the extremely restricted take-off and landing area. Although only some twelve per cent of major accidents involved aircraft actually entering the sea, over half of those that did were fatal. Initial concerns on these naval fatalities prompted the British Institute of Aviation Medicine to investigate the feasibility and limitations of ejection seat escape from a submerged aircraft.

Underwater ejection presented many unique problems, which were investigated by a wide-ranging series of live subject water tank trials using fully representative submerged cockpit sections. Martin-Baker were approached in the research programme to develop a fully automatic underwater ejection system which would initiate the escape sequence without any action by the crew once a specific water depth had been reached. A highly effective and safe underwater ejection seat system was produced based on the principle of compressed air operation for initial ejection to subsequent seat/occupant separation. The compressed air propulsion and inflatable bladder release system modifications to provide for underwater ejection capability in no way affected the normal ballistic operation of the seat during an airborne ejection. Whilst the system proved very effective during trials, and was subsequently introduced into Royal Navy service, it never saw emergency use, as other developments in ejection seat design soon rendered this special underwater capability unnecessary.

ROCKET PROPULSION

1962 saw the development of the rocket-powered ejection seat that provided improved escape under conditions of zero altitude and high sink rates. The introduction of VSTOL aircraft placed new demands for escape under extreme high sink rate

and adverse flight conditions, which were clearly beyond the capability of the "pure" ballistic seat which had already reached its full potential given the physiological constraints. The Americans had already started producing a rocket powered catapult propulsion system and the benefits in seat performance had been well demonstrated before the Martin-Baker work in the U.K.

Martin-Baker carried out a complete programme of rocket development. Considerable interest was created in this performance enhancement by many overseas Air Forces. Large orders for the rocket system followed and the retrospective introduction of the rocket to the range of Mark 4 and Mark 5 seats created the basic Mark 6 and 7 respectively. A highly advanced rocket seat, the Mark 8, was developed for the TSR2, and although cancellation of the aircraft meant that the seat never entered service, much valuable experience was gained, which was fully exploited in later designs of the Marks 9 and 10.

REFINEMENT IN DESIGN

The Mark 9 showed a marked advance in ejection seat design and provided the basis for further development to the following Mark 10 series of seats. The Mark 9 seats provided the "break through" in ejection seat design with the gas-operated seat firing system, re-designed parachute pack and quickly detachable seat bucket for ease of maintenance

Ejection seat development at Martin-Baker is an evolutionary process with continuous improvements and design refinements being made to meet the ever-increasing demands of new aircraft performance capability. The next major development worthy of note was the introduction of the Mark 10 seat range in the early 1970's. Initially designed for the Panavia Tornado aircraft, this single mark of seat has now been selected for more than 42 different aircraft world-wide and has been subjected to over 450 complete ejection tests. The Martin-Baker Mark 10 is undoubtedly the

most internationally used and qualified ejection seat in service to day.

A significant improvement was made to the performance of the ejection seat in 1985 with the development of the Martin-Baker Navy Aircrew Ejection Seat (NACES) which incorporated the world's first microprocessor controlled sequencer system. NACES was competitively selected by the U.S. Navy as their common seat installation for the Grumman A6 Intruder (later cancelled), Grumman F14D Tomcat, Boeing T45 Goshawk and F18C/D Hornet. The NACES was subjected to over 147 separate U.S. Government managed ejection tests as part of qualification for the 13 different aircraft cockpit installations. In addition to the introduction of advanced microprocessor seat sequencing, many other new and emerging technologies were adopted for NACES. These included a more efficient bridle controlled seat stabilisation system and highly advanced recovery parachute design, which have now become standard features for future Martin-Baker seat configurations.

ELECTRONIC SEQUENCING

The introduction of electronic sequencing provided the seat with the capability to adjust its mode of escape timing operation according to different ejection height and speed conditions. Ejection seat designs up to this point had fixed event timings which were set based on the worst ejection conditions associated with high speed escape where parachute deployment loads can be extreme. Escape performance at the lower speeds was therefore a compromise, as the fixed operating times were longer than needed for low speed, low altitude conditions, which actual ejection statistics confirm is where the majority of escapes occur. The introduction of the multi-mode electronic sequencer was therefore a significant step forward in improving the escape performance capability of the seat, especially in the low speed, low altitude envelope.

QUALIFICATION TEST

Any new escape system design requires a full and comprehensive range of qualification testing, the requirements of which can significantly vary from service-to-service or customer. Typically, the ejection seat will require independent sub-system environmental testing, seat ejection testing from ground level zero-speed, mid-speed and max-speed conditions to airborne or track testing before complete systems integration and final qualification from a fully representative aircraft cockpit.

A new seat design can be subjected to more than 30 complete full systems tests to achieve acceptable qualification and release into final service operation. All individual pyrotechnics, cartridge activated devices and seat ballistic transmission systems are subjected to an exhaustive range of tests over the entire extremes of environmental conditions.

In addition to ejection testing, the seat and its installation in the aircraft cockpit is subjected to a series of Human Factors related trials as part of the service release process. These normally consist of accommodation mapping in the cockpit, ingress and egress assessments with different size of aircrew in fully representative flight gear and post ejection survival drills over both land and water. The seat catapult, harness retraction device and recovery parachute, which are components that can directly impart potentially injurious loads into the occupant during ejection, are all subjected to detailed "Man-rating" qualification which often includes live subject tests.

Seats that incorporate on-board electronic sequencing require additional qualification to validate programming software and the electronic hardware is subject to Military-Rating, which in itself involves a full range of exhaustive reliability and environmental testing.

Martin-Baker has established an entire range of unique privately owned test facilities to support all aspects of escape system research and development. These include a specially modified Gloster Meteor MkT7.5 experimental aircraft for airborne testing and a 6,500ft long high-speed test track for dynamic full system integration testing

DIGITAL DESIGN TECHNOLOGY

Martin-Baker increasingly uses computer-based tools and digital technology as part of new escape system development and research.

Greater confidence is being gained in the use of computer based mathematical modelling and simulation as these technologies progressively mature. Good correlations between prediction and reality are now possible, which provides the necessary levels of confidence to allow a reduction in the number of tests that actually need to be carried out.

These new computer simulation techniques help to mitigate design risk and reduce the development time cycle with the underlying savings in programme cost. The use of thermal/mechanical modelling of seat pyrotechnics provides a useful tool in the design and development of seat ballistics.

Martin-Baker has a comprehensive empirical database of existing test and Human Factors documentation which can be analysed and used to validate and refine the mathematical models for improved predictions of cases which are impractical to test. Systems Engineering trade studies include extensive use of modelling seat motion and dynamics from a range of in-house produced evaluation tools, which include a highly advanced Six DOF C++ Object Orientated Code driven computer programme for accurate and rapid simulations. The model permits effective assessment of the propulsion phase, stability across the entire ejection envelope, and complete trajectory characteristic

evaluation including ground and fin clearance capabilities. A similar modelling programme is used to conduct biodynamic evaluations into the behaviour characteristics of the human body.

These tools produce extremely accurate simulations to analyse the variation of ejection seat aerodynamics, extended crew anthropomorphy, cg shift and many other performance features.

These advanced systems modelling tools are now complemented with the recent introduction of Computational Fluid Dynamics (CFD). Computational Fluid Dynamics is a relatively young discipline that has enjoyed tremendous growth and increasing acceptance over the past decade. It has attained high levels of maturity and credibility and is expected to play an important role in the future design of Martin-Baker ejection seat systems. Among its advantages is that CFD analysis mathematically replicate, as opposed to simulate, aerodynamic flow conditions about the ejection seat and occupant throughout the escape flight trajectory. Solutions are for full-sized seat and occupant as opposed to scale models, and for actual velocities and atmospheric conditions; consequently, there is no concern for matching classic simulation parameters such as Mach or Reynolds numbers, since escape flight conditions are matched exactly. CFD is a powerful design aid, which is showing tremendous benefits in aerodynamic design of the seat.

ADVANCED ESCAPE SYSTEM TECHNOLOGY

The Mark 16 range of Martin-Baker ejection seat represents the very latest in escape technology. Different variants of the Mark 16 have been developed for the French Rafale, Eurofighter, JPATS Raytheon Texan II, Korean KTX-I&II, Boeing Joint Strike Fighter, NASA T-38 and Pilatus PC-21.

The Mark 16 retains many of the best features from earlier ejection seat

designs. The Mark 16 offers additional benefits of increased aircrew accommodation capability, lightweight construction with a minimal cockpit installation "footprint" together with enhanced escape recovery capability at reduced acquisition and Life Cycle Cost; features which are now considered essential to any modern ejection seat system.

The Mark 16 provides Zero/Zero to 625Kts escape from ground level to altitudes of up to 55,000ft. Good recovery potential is also available under the extreme adverse attitude, high sink rate conditions specified by the latest U.S. operational requirements.

The Mark 16 is a self-contained, fully automatic ejection seat system that relies on no aircraft input to fulfil its escape function. Significant improvements have been achieved in seat acceleration characteristics, stability, trajectory predictability and reduced parachute deployment loads. These improvements are due to the use of a new mass/g compensating twin catapult, a faster acting and more efficient bridle drogue system and a superior personnel parachute which can be safely deployed at higher speeds without inducing high opening shock loads. Despite the rapid seat operation and quick acting deceleration and recovery subsystems, loads imparted to the aircrew member have been held well within the permitted limits for not only magnitude and direction, but also for the extreme lightweight occupant.

A ballistic transmission system is fully integrated into the Mark 16 design to provide a rapid, reliable and robust intra-seat communication network to effectively control operation of the seat under all extremes of the escape environment.

The variants of Mark 16 fitted to aircraft such as the Rafale and Eurofighter incorporate extremely sophisticated life support systems with OBOGS and chemical defence protection. The seat also has

provision to accommodate optical tracking sensors to interface with the pilot helmet mounted target sighting equipment or a fully automatic release system for night vision goggle removal on ejection.

A fundamental aspect to any aircraft escape system is providing a clear unobstructive ejection path for the seat and occupant. This is normally achieved by either rocket jettison of the entire canopy, explosively fracturing the canopy transparency or allowing direct penetration of the seat through the glass, all methods of which are well demonstrated and have proven to be very effective.

Modern combat aircraft with relaxed stability, high-speed capabilities are placing increased demands on pilot effectiveness during normal flight operations and survivability during an emergency. Aircraft with the capability to operate beyond human physiological tolerance have been in service for some time with aircraft like the Lockheed Martin F-16 Falcon, but future designs now coming to fruition have far more agile and responsive flying qualities, which are placing even greater emphasis on maintaining operating effectiveness in the cockpit.

The ejection seat acts as the principle interface platform between man and machine and will need to be able to accommodate more advanced life support systems and mission equipment in the future.

CURRENT RESEARCH

Increased incidence of escape from highly dynamic, high sink rate, adverse attitude conditions statistically account for over 90% of all ejections which occur with VSTOL aircraft, and this trend is likely to dominate the future escapes scenarios as new aircraft of the JSF class enter service. These ejection conditions have to be balanced against the considerations currently being explored to increase the upper end of the escape speed envelope for a possible future application in the F-22 Raptor.

The acceptance of female aircrew into combat flight operations by several air forces has generated the need to increase the accommodation size and weight range capability of the ejection seat. A significant amount of work has been carried out by Martin-Baker on several types of seat to provide this new capability at the request of various authorities. Increased accommodation and an associated reduction in injury risk has posed a new and quite complex set of issues which have to be addressed. Martin-Baker first worked on these issues in close consultation with both the USAF/U.S.Navy and the American aircraft prime contractors in the initial phase of the JPATS programme, as accommodation of the entire "Multi-Variant Body Case" population range of occupant was a fundamental aircraft operational requirement. The Mark 16 seat for JPATS is the only ejection seat to have this accommodation capability.

Ejection statistics over the last 50 years clearly indicate that the majority of both peace time and combat emergency escapes occur in the low speed, (100 to 300kt) low altitude, (0 to 2000ft) range. Future escape system development at Martin-Baker is therefore concentrating on these escape conditions, as this is the greatest potential improvement that exists for increasing the number of aircrew lives which can be saved.

Escape survival at the higher ejection speeds of up to 700kts has been a consideration for a number of years, although statistical evidence shows that in real terms, the probability of ejection taking place under these very extreme speed conditions accounts for an insignificant proportion of the ejection totals. As with any design, trades have to be made to meet the optimum solution which best satisfies the requirement. Emphasis at Martin-Baker has always been placed on achieving the very best level of ejection recovery capability under conditions where escape is most likely to occur and emergency profiles which match the operational performance characteristics of the aircraft.

Safe escape at these higher speeds will require some form of controllable rocket propulsion, a highly stable ejection platform, effective full limb restraint with airblast deflection devices and an efficient life support system. Research work is currently in hand both in the USA and UK to develop these emerging technologies for the potential introduction into future advanced escape system designs.

CONTINUED DEDICATION TO SAVING AIRCREW LIVES

One cannot fail to be impressed by the advances that have been made in ejection seat development since 1944. Martin-Baker alone have produced over 68,000 ejection seats for more than 147 different aircraft types world-wide. Many other makes and various types of ejection seat have been produced by several American companies, the most notable of which being the Douglas, (now Boeing) ACES II. Sweden, Russia and China all supply such equipment to aircraft of their own design origins, the delivered quantities of which are unknown without detailed research. Thousands of aircrew around the world owe their lives to the ejection seat and many interesting stories have been published on escape successes under some extreme circumstances and conditions.

As fighter aircraft performance capability increases and the weapons system delivery effectiveness improves, the "value of a pilot" in the cockpit with his inherent physiological limitations which restrict the full potential flying ability of the aircraft is a question which continues to be challenged. One thing is for sure, as long as there is a pilot in the cockpit there will always be a need for an ejection seat or some form of automated escape provision.

Who knows what the future holds?

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Ken R. Yates is currently the Programmes Manager and Security Controller at Martin-Baker Aircraft Company Limited located in the county of Buckinghamshire, England. He is responsible for the overall management of all new and development projects within Martin-Baker. Over 12 different development projects are currently being undertaken by the large department of specialist engineers under the leadership and management of Ken Yates, the most notable of these being Eurofighter, Rafale, USAF/US Navy Texan II, Joint Strike Fighter, KTX-II, NASA T-38N upgrade and CATIC Super 7. He has over 28 years of experience in the international escape system business which has provided him with an extremely broad and in-depth knowledge within this specialist field of aviation.

Ken joined Martin-Baker in 1971 and studied mechanical engineering design before being posted to the Middle East as the Company's Technical Representative supporting Martin-Baker equipped aircraft in that region for both the USAF and Imperial Iranian Air Force. Since his return from the Middle East, Ken has held various positions within the Company in both engineering and more recently in Sales and Marketing. He was promoted to the position of Programmes Manager in May 1996, is a corporate member and committee representative of SAFE Europe, a member of the American Institute of Aeronautics and Astronautics, the Institute of Sales and Marketing Management and the British Guild of Security Controllers.

Ken is married with two teenage sons, enjoys golf and music, and currently resides in Chalfont St. Peter, Buckinghamshire, England.

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