Safer ejection seats

by Keith Button

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Ejecting from a warplane has always been hazardous, but many pilots face more danger than ever. That's because their ejection seats weren't designed to accommodate modern helmets and displays. Keith Button looks at ideas for solving the problem.

A mannequin ejects from an F-35 during a test of the Martin-Baker US16E Ejection Seat at Hollman Air Force Base in New Mexico in 2010. The U.K. company is competing with UTC Aerospace Systems to upgrade ejection seats in the current U.S. Air Force fleet.

Martin-Baker

The pilot inverted and rolled his F-16 hard to the right into a 460-mile-per-hour dive toward the Adriatic Sea. He was on a training run, practicing a last-ditch maneuver to evade a simulated surface-to-air missile. Suddenly he called out, "knock it off, I'm spatial D," meaning stop the simulation because he was spatially disoriented. Seconds later, according to U.S. Air Force accident investigators, Air Force Maj. Lucas Gruenther pulled the ejection handle at the front of his seat and rocketed out of the plane.

Gruenther's helmet was torn off, and when the seat's drogue chute deployed, it jerked him with a force 40 times that of normal gravity. The Air Force medical examiner concluded he suffered head and neck injuries that were "rapidly fatal."

Gruenther's death illustrates a growing technical challenge facing ejection-seat designers. Fighter pilots now wear helmet-mounted cueing systems, or HMCSs, which are electronic visors that sense where a pilot is looking and target weapons or sensors there. Gruenther was flying at night, so he also wore night-vision goggles. The size, weight and aerodynamic drag of this modern equipment has complicated the job of ensuring that pilots can eject safely. So much so that in 2010, three years before Gruenther's accident, the Air Force recommended neck exercises for pilots who wear HMCSs. In March, the Pentagon recommended that pilots remove night vision goggles before ejecting.

None of this should be a problem for the newest warplanes in the American and British inventory, the F-35s. All three fighter variants are being equipped with seats specifically to handle ejections with modern helmets. But even if those seats work as well as hoped, that still leaves lots of F-22s, B-2 bombers, and T-38 trainers with the same kind of older ejection seat that Gruenther used, called the Advanced Concept Eject Seat 2. This product was introduced in 1978 and upgraded over the years, but not specifically for the modern helmets, although leg and arm restraints were added to the seats in some aircraft.

The Gruenther case has given fresh momentum to a proposed retrofit program for some of the ACES 2-equipped aircraft starting in late 2016, although probably not the U.S. F-16s because they could be nearing retirement. Once the request for proposals comes out, the world's top two ejection-seat makers will compete to convince the Air Force that they can do the best job of preventing more cases like Gruenther's fatal flight.

The bidding will amount to a rematch of the 2001 competition in which Lockheed Martin chose the U.K.'s Martin-Baker company as the ejection seat provider for all three versions of the F-35s, turning aside a bid from ACES-maker Goodrich, which was purchased in 2012 by United Technologies Corp. and renamed UTC Aerospace Systems.

Martin-Baker will offer to upgrade older versions of its seats and provide new US16E ejection seats, the kind going on F-35s, as replacements for ACES 2 seats.

UTC Aerospace, based in Charlotte, North Carolina, will offer kits to upgrade the ACES 2 seats with the same head, neck and leg restraints as on its newest seats, called ACES 5.

"We believe that if [Gruenther] had the benefit of an ACES 5 ejection seat design, he would have in all likelihood survived ejection," says Jim Patch, UTC's senior program manager for ACES 5 and a retired Air Force pilot who flew fighter jets for 21 years.

ACES 5 protects the head with pads that pop up during ejection to keep the pilot's head angled forward and to prevent the head and neck from snapping backward. Recessed bars on each side of the seat also pop out to keep the head from moving from side to side as the pilot encounters the wind blast. The protection pads and bars cradle the head like a softball glove, Patch says. The equipment retracts to avoid any chance of the pilot being injured by it as the pilot separates from the seat and parachutes to the ground.

Martin-Baker employs a much different approach for its US16E. Nitrogen gas is ported from the back of the seat to inflate three "air-beams," which look like oversized, hot dog-shaped pillows. An airbeam on each side of the head is inflated immediately at ejection to provide lateral support and protection.

The technology meets all "physiological requirements for head and neck load minimization across the aircrew population range," says Martin-Baker's Steve Roberts, the company's Joint Strike Fighter integrated product team lead, by email.

In the Gruenther case, Air Force acci-

U.S. Air Force Capt. Christopher Stricklin uses an ACES 2 ejection seat to escape from his F-16 Thunderbird moments before it crashes at an Idaho air show in 1982 Stricklin, who steered the plane away from the crowd, was uninjured.

dent investigators concluded that "it is reasonable to expect the HMCS helmet would fail and that this would result in potentially fatal loads on the mishap pilot's neck."

Violent event

McDonnel Douglas developed the first version of the Advanced Concept Ejection Seat in the 1970s in response to the Air Force's concern about each airplane maker making its own ejection seats, and doing so poorly in the Air Force's view.

The Air Force adopted the ACES 2 seat for every A-10 Thunderbolt; F-15, F-16 and F-22 fighter jets; and B-1 and B-2 bombers in its fleet. In all, 29 countries have equipped their aircraft with about 6,000 ACES 2 seats.

After the Gruenther acccident, Congress told the Defense Department to examine the safety implications of pairing the modern helmets with ACES 2. In March, the Inspector General's office released its findings, "Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors." The report makes clear that ejecting from an airplane is such a violent event that injuries are not uncommon. A typical ejection from an F-16 lasts two to three seconds from the point that the pilot pulls the ejection handle until the parachute is fully deployed. Pulling the ejection handle blows the canopy off the cockpit, then the pilot is rocketed up with about 4,000 pounds of thrust.

Outside the aircraft, the pilot can face extreme windblast forces — up to 1,200 pounds per square inch, at 684 miles per hour. At 0.4 seconds into the ejection sequence, a rocket fires and a drogue parachute deploys to stabilize the seat, exerting about 7,600 pounds of backward force on the pilot. Then, at 1.8 seconds in, the main parachute deploys from a container in the seat, exerting about 3,000 pounds of force on the pilot via a harness, and the ejection seat falls away. Once the chute is fully open, the pilot falls at up to 7.6 meters per second, which means hitting the ground with up to 2,938 foot-pounds of energy.

According to Air Force figures, from 1995 to 2014, there were 203 ejections using ACES 2, 93 percent of which occurred at speeds of 518 miles per hour or less, which is considered the safe envelope for ACES 2 ejections. Of the 189 ejections within the envelope, 12 percent resulted in fatalities or other injuries from windblast, ejection shock, parachute landing, hitting the ground or objects during ejection and from burns or hypothermia.

Nevetheless, the March Pentagon report concluded that the helmet-mounted cueing system and night-vision goggles don't significantly increase the risk of injury during ejection, so long as the aircrew members follow proper ejection procedures detailed in their flight manuals. They should remove night vision goggles before ejection and properly wear their helmet at all times. The Navy, according to the report, restricts air crew members who weigh 136 pound or less from wearing certain helmet-mounted devices because of the increased risk of injury.

Parachutes

As significant as the head and neck issue is, Martin-Baker and UTC are concerned about much more than that. Impact injuries from parachuting to the ground are one of the most common injuries for ejected pilots. To help solve that problem, UTC engineers designed a new chute to bring an air crew member down at a slower rate and greatly reduced oscillation, meaning the occupant won't swing at the 30-degree angles allowed by the older parachute, called the C-9. The new GR-7000 chute should reduce the chances of a crew member being in midswing when he or she hits the ground.

Martin-Baker says it too has created a larger chute, one that can inflate quickly, even with a suspended mass of 152 kilograms, and keep the descent rate at 7.3 meters per second. The company worked on the chute with Airborne Systems Ltd. of Bridgend, U.K.

Engineers must also work to keep the wind of a high-speed ejection from pulling a crew member's legs or arms away from the seat, an effect called flail.

"There have been high speed ejections that have resulted in — this is maybe a difficult analogy — but if you think of a wishbone from a turkey, and you pull it apart, you can imagine at high speed, left undeterred, if the legs were free to flail to the extreme, that can be what happens to the pilot or aircrew member," says UTC's Patch.

To attack the arm-flail problem, ACES 5 deploys a net from the sides of the seat to cradle the arms and hands. As the seat rides up and clears the cockpit rail, a cable attached to the cockpit floor activates the arm restraints.

For the leg injury risk, engineers designed the ACES 5 seat with two cable loops recessed into the walls and ceiling of the standard cockpit leg wells. As the seat goes up, loops pop out of tracks, wrapping around the pilot's legs just below the top of the flight boot, and pull the legs back against the front of the seat, so they don't flail. Only some ACES 2 seats on F-22s have arm and leg restraints.

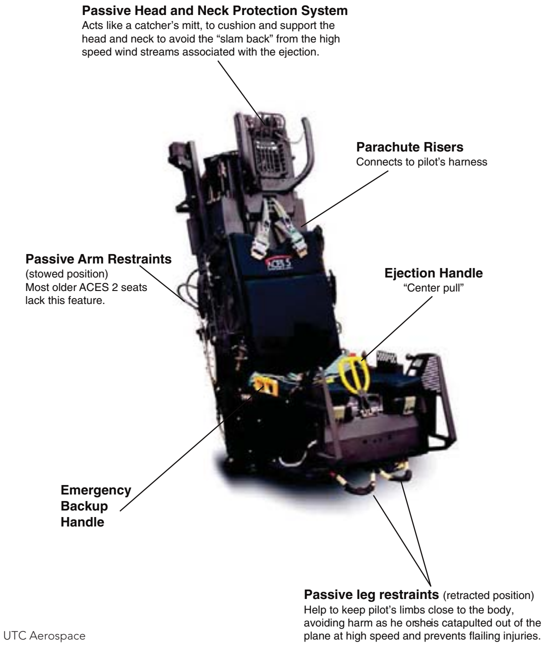
There are other improvements too. Under the ACES 2 design, two Pitot tubes were fixed at a 90-degree angle to the surface of the seat, leaving them exposed to damage if the seat were to hit the canopy during ejection. That could be disastrous, because the Pitot tubes sense the air speed pressure for a microprocessor called the sequencer, which calculates the steps necessary for a safe descent. In the ACES 5 seat, the Pitot tubes stay recessed in the seat to the sides of the headrest until the seat clears the canopy.

UTC engineers designed the ACES 2 and 5 seats to deploy the main parachute as soon as possible to maximize terrain clearance, when an ejection occurs at low altitude and low airspeed, says John Hampton, engineering manager at UTC. At high altitude, where temperatures can reach minus 60 degrees Fahrenheit and oxygen is scarce, the seat deploys the drogue but waits until it falls to 15,000 feet to deploy the parachute and release the occupant member from the seat.

To minimize injuries during the force of the ejection, the ACES 2 and 5 seats are designed to adjust their ejection force based on the mass of the occupant to give a relatively constant acceleration, regardless of the size of the aircrew member. The seat senses the load, or weight of the crew member, and compensates the rate of rocket burn depending on the weight — more burn for a heavier crew member and less for a lighter person.

Modern times, modern seat

Martin-Baker and UTC Aerospace are on a mission to make bailing out of a plane safer, even with the added weight and aerodynamic drag of modern aviator helmets. Pictured here is UTC's ACES 5, short for Advanced Concept Ejection Seat 5.



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