LIGHT WEIGHT ESCAPE CAPSULE FOR FIGHTER AIRCRAFT

Capt James A. Hubert
Air Force Wright Aeronautical Laboratories
AFWAL/FFER
WPAFB, OH 45433-6553
513-255-4008

ABSTRACT

Emergency crew escape capabilities have been less than adequate for fighter aircraft since before WWII. From the hover-the-side bailout of those days through the current ejection seat with a rocket catapult, escaping from a disabled aircraft has been risky at best. Current efforts are underway toward developing a high-tech, "smart" ejection seat that will give fighter pilots more room to live in the sky but, an escape capsule is needed to meet current and future fighter envelopes. Escape capsules have a bad reputation due to past examples of high weight, poor performance and great complexity. However, the advantages available demand that a capsule be developed. This capsule concept will minimize the inherent disadvantages and incorporate the benefits while integrating all aspects of crew station design. The resulting design is appropriate for a crew station of the year 2010 and includes improved combat acceleration protection, chemical or biological combat capability, improved aircraft to escape system interaction, and the highest level of escape performance achievable. The capsule is compact, which can allow a reduced aircraft size and weights only 1200 lb. The escape system weight penalty is only 120 lb higher than that for the next ejection seat and the capsule has a corresponding increase in performance.

BACKGROUND

Emergency crew escape capabilities have been less than adequate for fighter aircraft since before WWII, when over-the-side bailout was the only means of escape. The development of jet aircraft was accompanied by ejection seats that were catapulted from the cockpit. This was followed by the addition of a rocket for tail clearance and runway ejections and then a drogue parachute for stabilization and deceleration at high speeds. The current USAF ejection seat, the ACES II, includes a small gimbaled rocket that helps stabilize the escape system and airspeed sensors to vary parachute sequencing. From 1957 to 1984, the rate of major injury or fatality (M/F rate) for non-combat ejections with sufficient altitude above the ground was an average of 26 percent. The ACES II seat shows significant improvement with a M/F rate of 14 percent. When this data is filtered to isolate the effect of airspeed, the results are very interesting. In fact, only 10 percent of the non-combat ejections were over 400 KEAS (knots equivalent airspeed, 687 psf dynamic pressure). Data from combat missions in Vietnam showed that ejection speed increased dramatically, with approximately 50 percent of ejections occurring at over 400 KEAS. Due to a limited amount of combat data, the non-combat data with known airspeed and cause of injury was used for judging injury rates. The M/F rate for ejections under 400 KEAS became 73 percent and over 400 KEAS was 65 percent. (The corresponding ACES II M/F rates are 9 percent and 70 percent.) Based on these rates, the combat ejection M/F rate could exceed 45 percent due to airspeed. Technology is currently available for the development of a controllable ejection seat under the Crew Escape Technologies (CREST) program. This program will demonstrate an escape system that can remain stable at speeds up to 700 KEAS (1660 psf) and steer away from the ground during low altitude ejections. An ejection seat based on the CREST program results will improve low altitude escape performance and provide greater protection at high speed. However, it will be difficult for an open ejection seat to meet the 700 KEAS goal while fighter aircraft can already fly at 800 KEAS (2100 psf) or more. The desire for further improvements in safe escape led to an effort to develop an escape capsule that could take advantage of current and emerging technology and perhaps become available early in the next century.

Escape capsule provide protection from the elements and are a natural solution to the high-speed escape problem. However, previous capsule experiences in the USAF have led to a generally had reputation for capsule escape systems. The two operational capsules that have been flown (the F-111 and the B-1A, the B-1B has ejection seats) were based on technologies that are 20 years old or more (Figure 1). This lack of technological capability led to designs that were heavy and difficult to make feasible. The F-111 capsule now weighs 3,300 lb (crew of two), includes a large portion of the forward fuselage and contains many heavy instruments and controls. The B-1 capsule weighed nearly 10,000 lb (crew of 6) which resulted in a similar weight per crew member to that of the F-111 (about 1,700 lb). In contrast, an ejection seat with the capabilities sought by the
Figure 1. F-111 and B-1 Capsules

CREST demonstrator escape system is expected to weigh from 600 to 700 lb for one person when ejected. The comparatively higher weight of capsules leads to greater penalty to the aircraft and, because of aircraft weight limitations imposed, it is difficult to achieve the same performance levels as those possible for an ejection seat. The capsule weights are high for a number of reasons. The underlying reason is that the escape system designs were constrained by predetermined fuselage structural designs and crew stations. This led to excess volume in the capsules which allowed capsule weight increases caused by other aircraft systems. This approach also precluded the use of an insertable capsule which would reduce the amount of aircraft structure carried in the capsule and allow a minimum volume for the capsule. Lack of today’s technologies prevented solutions to the problem of crew station/capsule weight as well. The older crew stations were full of control panels with their associated boxes, control units, computers and countless wires. These combined weights added to the total that the escape rocket system had to accelerate. In addition, relatively dumb rockets and control systems were used that lacked efficiency and generally ended up oversized due to weight growth of the capsules. Another problem with the previous capsules was the method of landing them after an ejection. The most efficient approach at the time was to use inflatable airbags to absorb landing impact during parachute descent. This approach has a limited performance envelope which has led to a 15-20 percent major injury rate due to landing impact for the F-111.

A factor that added to the weight problem and created maintenance difficulties was that the F-111 and B-1 capsules were integral to their aircraft fuselage and used explosive shaped charges as the means of separating for ejection. This meant that all capsule subsystems were accessible only through the skin on the fuselage. Periodic refurbishment of the capsule involved removing much of the skin and replacing all pyrotechnic components. This scarred past for escape capsules has severely limited investment toward future capsule escape systems.

Two other areas of concern are G-induced loss of consciousness and ingress and egress in a chemically or biologically contaminated (CB) environment. Today’s fighter aircraft are designed to be able to turn at 9 G while fighter pilots can only withstand 7 to 9 G through intensive physical efforts. Also, these aircraft are capable of reaching acceleration levels of 9 G faster than pilots bodies can compensate for them. This situation has led to 7 deaths of Air Force pilots directly attributed to G loss of consciousness since 1983. Finally, there is no current method for ingressing or egressing the cockpit in a CB environment while keeping the cockpit "clean". Efforts are underway to develop ways to keep the environmental control system air free of contamination through the use of catalytic converters or a closed loop system, but the pilot must be allowed in and out of the crew station. The current approach uses a dirty cockpit and the pilot must wear cumbersome, hot protective gear while flying the mission.

DISCUSSION

The Air Force Wright Aeronautical Laboratories, Aircrew Protection Branch has engineered an approach to providing capsule escape over the last four years with encouraging results. The solution involves integration of capsule, crew station, airframe, and crew member requirements and emphasizes the need for an independent crew station and escape system design group whose requirements must be included in future aircraft development programs. The program focused on providing high speed escape capability with maximum escape system performance, protection from aircraft combat accelerations and ingress and egress in a CB environment.

The escape capsule design that emerged from our effort known as Concept Development of a Canopy Escape Module was based on the F-16 geometry as shown in Figure 2. The F-16 has a large, single-piece transparency that is convenient for attaching a crew station to form a capsule. Also, there
was recent data available on the F-16 and a prototype F-16 aircraft was at our disposal. The effort focused on providing safe escape capability up to a maximum 950 KEAS and the best combat acceleration (G) protection possible. The design really began with the G protection issue in order to define the pilot position. A capsule and escape subsystems were put around the pilot and fitted within the F-16 fuselage. This left a certain volume for the crew station which was less than optimum. The width of the F-16 at the crew station does not allow much room beside a reclined pilot. In the ideal case, the crew station requirements would have the opportunity to drive fuselage design. Following crew station design, aircraft to capsule interfaces were addressed and methods of ingress and egress in a CB environment proposed.

Reclined Seat & Minimum Weight Capsule

The approach to G protection was to recline the seat to reduce the column of blood between the head and heart. A 65 degree reclined seat was designed that could provide protection up to 9 to 12 G without requiring the pilot to perform strenuous anti-G exercises while trying to fight the enemy. (See Figure 3 below.)

Figure 3. Reclined Seat Design with 5th and 95th Percentile USAF Male Pilot Outlines

Having a reclined seat helped reduce capsule weight by minimizing the cross-sectional area. This lowered the propulsion weight requirements by reducing capsule aerodynamic drag. The capsule was made insertable into the airframe to avoid having to accelerate aircraft fuselage structures during ejection. The body of the capsule was designed to be made of composite materials and molded around the minimum volume required for the crew station. The weight of the crew station was minimized by taking advantage of predicted technologies for the year 2010. The head-up display would be projected from the helmet, and voice control, eye tracking and artificial intelligence would be used to minimize the number of instruments and controls required. The front displays would be flat panel type to eliminate all CRTs from the crew station. Finally, all display generators, control units, radios, and other avionics would be outside the capsule with data transfer through fiber optics or coaxial cable. As a result the only weights required for the capsule are structure, escape systems, display and control input devices, and the crewmember. The resulting capsule weight to meet today's aircraft performance of 800 KEAS is just over 1200 lb and the associated weight penalty to the aircraft only increased by 27 percent (117 lb) over that estimated for an ejection seat based on the CREST technologies.

Escape System Design & Performance

This Canopy Escape Module (CEM) design was able to incorporate the same controller technologies being developed for the CREST demonstrator and added a highly controllable propulsion system. The propulsion system uses gel propellants which consist of thickened liquid oxidizer and fuel. These materials ignite instantly when they meet which eliminates the need for igniters and allows pulsing of the propellant for a very simple but effective throttling method. These propellants are highly efficient and can be used more efficiently compared to solid propellants which cannot
difficult for them to do this would make this
of their enemy. Preventing them or making it
with voice control, the pilots ability
would eliminate the current dependence on control
around to compare their attitude with the attitude
system impossible to achieve unless there is an
have a pilots associate to automate many
The best solution involves the use of the Super
Cockpit as proposed by the Human Systems Division
super cockpit would also have an audio system that
targets, and assist the pilot's orientation. This
in the rearward direction where much of the danger
is
in the rearward direction where much of the danger
can greatly reduce landing impact injuries. A
system can lead to greatly improved pilot
performance by providing increased (or protection
CONCLUSIONS

Previous escape capsule experiences in the USAF
have led to a reluctance to pursue such escape
systems for future fighter aircraft. However, the
have shown that escape systems are needed to
survive air engagements. The most effective escape
system is one that is easy to use, and this means
being able to remove it from the aircraft quickly
and safely. A simple, quick-release system for an
escape capsule would be preferred. This would
allow the pilot to escape immediately in the event of
a fire or explosion. The capsule would then be
released from the aircraft and the pilot would
be able to land safely.

The propulsion system for the future fighter
aircraft would be designed for high performance and
versatility. It would be able to provide the necessary
power to achieve maximum performance, and it
would be capable of being modified for different
missions. The propulsion system would also be
able to provide the necessary thrust for takeoff,
landing, and supersonic flight.

The landing system for the future fighter
aircraft would be designed for maximum
reliability and safety. It would be able to
accommodate a wide range of landing conditions,
including high-speed landings at sea level, and it
would be able to handle unexpected situations such
as a sudden change in wind direction.

The crew station design of the future fighter
aircraft would be designed to provide the
maximum amount of information to the
pilot. This would include a computer-generated
world view, which would provide the pilot with
a clear picture of the battle environment.

The escape system for the future fighter
aircraft would be designed to provide the
maximum level of protection for the
pilot. This would include a protective
suit, which would be able to withstand high
pressures and temperatures. The suit would
also be equipped with a communications system,
which would allow the pilot to communicate
effectively with ground control.

The fuselage design of the future fighter
aircraft would be designed to provide the
maximum amount of protection for the
pilot. This would include a thick, bulletproof
shell, which would be able to withstand high
speed impacts. The fuselage would also be
equipped with a special latching mechanism,
which would allow the capsule to be
released quickly and safely in the event of
an emergency.

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Figure 4. Proposed CB Protection System

and advanced crew station technologies. The CEM has been designed to achieve these improvements while reducing maintenance problems by having a removable capsule. The serious problem of ingress and egress in a CB environment can be overcome by using the removable capsule as a transfer means. Another approach has been proposed involving a plastic curtain around the open cockpit and a large plastic suit that can be zipped to the curtain forming an airlock.

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