National Security Assessment of the Emergency Aircraft Ejection Seat Sector

A Report for the
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National Security Assessment of the Emergency Aircraft Ejection Seat Sector

Prepared by

U.S. Department of Commerce
Bureau of Export Administration
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Table of Contents

Executive Summary

The U.S. Department of Commerce, Bureau of Export Administration (BXA) conducted this national security assessment of the emergency aircraft ejection seat sector at the request of the U.S. Department of the Air Force, Crew Systems Directorate of the Armstrong Laboratory at Wright-Patterson Air Force Base in Ohio. The request was in response to Congressional language in H.R. 1530, FY 1996 Defense Authorization Bill, Air Force RDT&E on Aircraft Ejection Seats which stated, "The committee is also concerned about the sustainment of the U.S. (Ejection seat) industrial base during this period of virtually no aircraft production."

BXA is delegated the authority under Section 705 of the Defense Production Act of 1950, as amended, and Executive Order 12656 to gather basic economic and industrial information from the private sector. These provisions enable BXA to perform industry analyses to assess the capabilities of the industrial base to support the national defense and develop policy alternatives to improve the international competitiveness of specific domestic industries and their abilities to meet defense program needs. Ejection seats enhance the national security by preserving the lives and operational experience of war fighters.

Major reductions in U.S. defense procurement of new combat aircraft in the last decade have severely eroded the market for new ejection seats. The smaller market was attended by a sharp drop in employment and in the specialized expertise required to design and produce ejection seats. The United States is down to one currently active producer (McDonnell Douglas). Based on current projections, the prospects for an expanded market over the next five years are not encouraging. It appears likely that, without cooperative industry-government action, the future market will be forfeited to major foreign concerns.

The rest of the world has also experienced major defense reductions. Revenues and employment declined by about a third for the two major foreign ejection seat producers, the Zvezda Design Bureau in Russia and the Martin-Baker Aircraft Company in the United Kingdom. However, each company is aggressively targeting the U.S. market. For example, Martin-Baker, who by every economic measure is the world's strongest competitor, recently captured the 1,400 ejection seat Joint Primary Aircraft Training System (JPATS) contract. This is the only significant new U.S. ejection seat procurement until forecasted production of the Joint Strike Fighter (JSF) begins around 2008.

However, according to various industry sources Martin-Baker may also be the front-runner for the production JSF ejection seat; although indications are that one of the JSF competitors may use a U.S. made seat in their concept demonstrator aircraft. Reportedly, no current U.S. producer has an ejection seat in contention for the production JSF, although the U.S. Air Force and Navy are sponsoring an American-Russian joint venture to examine the possible adaptation of Zvezda's K-36D seat to American cockpits. This potentially puts Zvezda's technology in contention for the JSF seat competition. However, no commitment has been made by the JSF Program Office or either of the two contractors now competing to build the aircraft. The JSF will be the major U.S. market for ejection seats, with expected procurement of over 3,000 seats, in the first quarter of the next century.

Historical circumstances greatly influenced the development of a highly fragmented ejection seat industry in the United States, composed of dozens of firms that supply various component parts for the final product. None of the companies has a very large financial stake in ejection seats in relation to their total corporate revenues; the highest is less than 4 percent.

The fragmentation in the U.S. industry, added to the relatively small size of total ejection seat revenues worldwide, leaves the U.S. ejection seat industry poorly structured to compete in world markets. The structure fails to provide the necessary incentives and focus needed for product innovation and improvement. It also levies an added administrative and regulatory burden on the Government, which must periodically inspect, certify, procure from, and coordinate with many more firms.

As part of the assessment process, BXA conducted a survey of firms in the ejection seat sector. Several subcontractors reported that Government regulations impose additional inefficiencies on the industry, such as outdated and difficult to change testing procedures. The Defense Federal Acquisition Regulations contain non-defense related policies that burden the ejection seat industrial base. These programs include the small and minority business set-asides, the Buy American provisions, and the Competitiveness in Contracting Act.

In sharp contrast to the American situation, Martin-Baker is integrated into most areas related to ejection seats, actively seeks to improve the product, and invests in the latest technologies. Ejection seats constitute more than 95 percent of corporate revenues. The firm aggressively markets ejection seats worldwide, has a 75 percent share of the world market, excluding former communist countries, and provides lifetime service for seats in world inventories.

U.S. research and development and qualification testing (RD&T) funding is left largely to the Government. This relates back to the fragmentation of the industry and to a poor economic return (or value) for ejection seats that have discouraged private support for RD&T programs. Moreover, during the course of this study numerous industry and government sources expressed their opinion that ejection seats have a lower priority among the various other combat aircraft subsystems (avionics, weapons, engines, etc.), which creates a desire to minimize ejection seat costs. Also, there are no commercial markets for ejection seats that could promote greater private efforts.

The major driving forces behind the current RD&T effort are the push toward fourth-generation seat technologies and the increased range of weights and sizes to accommodate female aircrew. Another thrust is for improved stability at higher speeds and improvement in lower-altitude adverse attitude ejections. Currently, portions of the U.S. RD&T funding for this work are directed overseas to Zvezda and Martin-Baker.

The Department of State's export controls on military equipment encompass ejection seats and seat components, and thereby limit the competitiveness of U.S. products on the international market. The U.S. ejection seat industry argued that ejection seats are not weapons and do not belong on the munitions list. The British have established a two-tier control system that makes it easier to export non-lethal military items such as ejection seats. The U.S. State Department controls everything on its munitions list as a weapon system, which makes the licensing process more difficult and time consuming for American firms.

The Boeing takeover of Rockwell and merger with McDonnell Douglas, combined with contractual relationships with the Universal Propulsion Company in Arizona and Zvezda, are positive developments in a move toward consolidation of industry assets. This could present both the U.S. Department of Defense (Air Force and Navy) and industry with an opportunity to revitalize the domestic sector. Such revitalization would strengthen the national security by maintaining U.S. control over leading-edge technology and promote a manufacturing base capable of deploying these advances. Many in industry believe an integral part of this revitalization could be the successful development of fourth generation ejection seat technologies and female weight and size accommodation in cooperation with a unified, rationalized, and forward-looking U.S. ejection seat sector.

Recommendations

- o Facilitate greater rationalization (elimination of redundancy) and consolidation in the U.S. ejection seat industry with procurement and RD&T policies, and discussions with industry.

- o Where appropriate and possible, support U.S. teaming/licensing agreements with foreign manufacturers for production sharing and technology exchange on a worldwide basis.

- o Additional steps to stimulate the competitiveness of U.S. ejection seat industrial base:

  - Establish multi-year contracting for all levels of the ejection seat sector to increase economic efficiencies and industry-funded investment.

  - For this sector, establish a temporary waiver from the provisions of the small-business set-asides and other non-defense related regulations so as not to further subdivide procurement and decrease economic efficiencies.

  - Support the joint U.S.-Japanese initiative, proposed by the Japanese, to share in the development of technology for improvements in ACES II performance to handle the expanded aircrew weight/size distribution.

  - Open discussions between the U.S. Departments of Defense, State, and industry to examine possibilities of modifying the munitions export controls to mirror the United Kingdom's simplified two-tier system for non-lethal items such as ejection seats. The objective of these discussions would be to enhance U.S. companies' ability to compete in world markets, while maintaining the integrity of the munitions export control system.

1. INTRODUCTION

1.1 Background

This national security assessment of the aircraft ejection seat industrial base was initiated in August 1996, at the request of the U.S. Department of the Air Force, Crew Systems Directorate of Armstrong Laboratory (AL/CF) at Wright-Patterson Air Force Base in Ohio. The request was in response to Congressional language in H.R. 1530, FY 1996 Defense Authorization Bill, Air Force RDT&E on Aircraft Ejection Seats which stated, "The committee is also concerned about the sustainment of the U.S. (Ejection seat) industrial base during this period of virtually no aircraft production."

The Air Force noted that only one company was active in the design and manufacture of ejection seats in the United States, and that this company was dependent on U.S. military and foreign military sales (FMS). Should foreign ejection seat companies win the few available future contracts for ejection seat production (U.S. and foreign), it was speculated that American companies could be forced out of the business, leaving the United States with no domestic source.

The U.S. Department of Commerce, Bureau of Export Administration (BXA) is delegated the authority under Section 705 of the Defense Production Act of 1950, as amended, and Executive Order 12656 to gather basic economic and industrial information from the private sector. These provisions enable BXA to perform industry analyses to assess the capabilities of the industrial base to support the national defense and develop policy alternatives to improve the international competitiveness of specific domestic industries and their abilities to meet defense program needs. The Office of Strategic Industries and Economic Security (SIES) is the operating unit within BXA with the responsibility for this data collection and analysis. The Strategic Analysis Division of SIES performed this assessment with technical support from the Air Force's Aeronautical Systems Center's Engineering Crew Systems Branch (ASC/ENFC).

The Air Force and other services have an established history of cooperative study efforts with BXA that resulted in about two dozen national security assessments in the past decade. These assessments were generally of subcontractor industries of major importance to the military because of the products produced. Past assessments included optical components, ball and roller bearings, forgings, electronic components, and robotics. A recent assessment completed for the

Naval Surface Weapons Center at Indian Head, Maryland, covered cartridge actuated and propellent actuated devices - the CAD/PAD - industry. Generically called "pyro", these energetic devices are essential components used in ejection seats. The Crew Systems Branch (ASC/ENFC) at Wright-Patterson AFB appreciated the CAD/PAD assessment, and requested the ejection seat assessment as a follow-on to it. (See Appendix A)

1.2 Methodology

A survey was prepared by the Strategic Analysis Division to gather economic and other data relevant to the ejection seat business for the assessment. Comments and guidance were solicited and received from Air Force officials at the Crew Systems Branch (ASC/ENFC) and Wright Laboratory, and the Naval Air Systems Command. In addition, two companies in the industry were asked to comment on the survey's content and the difficulty or reservations they might have in responding to any of the questions. The survey was designed as a top-down document, to be completed primarily by ejection seat producers, and to elicit information from them about conditions in the subcontractor base. However, other companies that showed an interest in entering the ejection seat sector were also invited to complete a survey at the Air Force's direction. A copy of the survey document is contained in Appendix B.

The survey questionnaire was sent to a total of eight domestic firms. One firm returned the survey uncompleted. Also, only two firms, McDonnell Douglas Corp. in Titusville, Florida, and Universal Propulsion, Inc. in Phoenix, Arizona, actually produced ejection seats during the reporting period (i.e., 1993, 1994, 1995, 1996, and estimates for 1997 and 1998). The remainder sold major seat components or participated in important research and development projects. Altered versions of the survey were also sent to three foreign firms: Martin-Baker Aircraft Company, Ltd., located in Higher Denham, United Kingdom, Zvezda Design Bureau in Tomilio, Russia, and Daicel Chemical Company of Japan. Daicel chose not to respond. The firm produces a small number of ejection seats in Japan under a license agreement with McDonnell Douglas. These are for the Japanese co-produced F-15 and FSX fighter aircrafts. Daicel also produces Universal Propulsion seats under a separate license agreement.

Site visits were made to each of the seven responsive domestic firms, and to Martin-Baker and Zvezda. The domestic site visits consisted of question and answer sessions with the top management of the firms. The purpose of these sessions was to clarify any questions the firms had about the survey, hear their concerns about the ejection seat sector, and tour their operations.

A three-day visit was arranged to review the operations of Martin-Baker in England, Northern Ireland, and on the Isle of Man, as well as to discuss numerous issues and concerns with the firm's management. A two-day visit with Zvezda was arranged at our request through the company's agent, IBP International. IBP, located in England, provided translation services and liaison between the Russian Government, Zvezda, and our representatives. One or two Commerce officials, and usually an Air Force technical advisor, were in attendance at each of these sessions. In addition, Commerce officials visited the ejection seat test tracks at Holloman AFB in New Mexico and China Lake Naval Weapons Center in California to discuss the testing process with Defense officials who operated the tracks.

A great deal of critical information was provided by the U.S. Air Force and U.S. Navy in response to written questions sent from the Commerce Department that dealt with various aspects of the ejection seat business. Supplementary information was gathered from various publications such as Jane's All the World's Aircraft, *Air Force Magazine*, *Flight International*, and the Aerospace Industry Association's Facts and Figures. Several Government Accounting Office reports relevant to the ejection seat sector were reviewed. Searches were conducted through Lexis/Nexis and other databases. Finally, a great deal of information was obtained in telephone conversations with industry historians, various government officials and retirees, other experts, and in additional conversations with officials of the surveyed companies.

The scope of this assessment is outlined in the Table of Contents on page ii. The assessment is organized into five major sections and has five appendixes. Following this introductory material, in the second section is a description of the industry and review of seats currently in use. To orient the reader, the industry's organization is outlined, followed by a discussion of the historic evolution of ejection seats which is needed to understand the present situation.

The third section is a summation of the industry survey responses, supplemented by site visits. The section begins with the general effects of the shrinking business base on the ejection seat sector. Then, the industry responses are summarized with respect to the adverse impacts of defense budget cuts, trends in shipments, reductions in and concerns about employment, investment, the industry's profitability and competitive concerns, and finally, information about conditions in the subcontractor base.

The second subsection of part three covers research and development. It starts with major initiatives by the U.S. Government. Then, respondents' involvement in R&D and their suggestions for additional research are chronicled. The next subsection discusses government

regulatory impacts on the industry. It begins with the State Department's export controls procedures on ejection seats. This is followed by an in-depth review of the Leader-Follower programs instituted by the Air Force and the Navy. Finally, other regulatory issues such as the small business set-asides, Buy American provisions, and the Competitiveness in Contracting Act of 1984 are reviewed for their effects on the ejection seat sector.

The fourth section reviews recent and future market opportunities. This includes reviews of two trainers and three fighter aircraft that offer business potential over the next two decades. The trainers are the Joint Primary Aircraft Training System and the T-38 Talon Upgrade programs. The fighters include the potential for upgrading the ejection seats for some of the world's large inventory of F-5s, the F-22, and the Joint Strike Fighter.

The fifth and final section of the assessment reviews the findings developed in the previous sections, and makes recommendations to help rectify various problems identified in the report.

1.3 National Security Issues

Are ejection seats critical to the national security? Ejection seats are manufactured as a purely military product, whose purpose is to save the lives of pilots and aircrew in emergency situations. Pilot and aircrew safety is a high priority in the United States, as well as other countries. The ejection seat provides the war fighter with a means of survival if his aircraft is severely damaged while conducting a mission in a high threat environment, or if the aircraft undergoes a catastrophic failure on a peacetime mission. On a cost-benefit basis, ejection seats are a cost effective means of amortizing aircrew training expenditures, which can run from $1-2 million for a newly qualified aircrew member. However, the seats also preserve the non-quantifiable attributes embodied in the war fighter's experience and maturity gained through years of training beyond initial qualification. Thus, each successful ejection preserves a valuable war fighting asset, the aircrew member.

Further guidance in determining the national security significance of ejection seats is provided in U.S. Department of Defense Directive (DODD) 5000.60, "Defense Industrial Capabilities Assessments," dated April 25, 1996. To determine a product's national security standing, the Directive asks: 1) is the product needed to supply and equip the existing or future force structure of the armed forces? or 2) will the product's absence affect the ability to support defense systems over their life cycle? or 3) would its loss limit our ability to develop or field new systems? It is

evident that ejection seats meet all three criteria.

<u>Is it necessary to preserve a domestic source for ejection seats</u>? The domestic industry is at risk. Based on the low level of projected near term requirements, the possibility of losing domestic ejection seat production capabilities is high as we enter the twenty-first century.

Normal market forces do not apply in this situation. The U.S. ejection seat industry is almost *totally dependent* on U.S. military requirements and export sales of U.S. aircraft for its existence. The industry would be healthy and stronger if today's military requirements were greater. The industry would also be stronger if it were less fragmented and structured more like its foreign competition, which could have enabled it to compete more effectively in international markets. Because there are no commercial opportunities, and the domestic producers are not competitive in international markets, the industry currently has no options but to decline in proportion with U.S. defense requirements.

1.3.1 Reasons to Preserve Domestic Industry

1. **Ejection seat technology is unique and difficult to replicate** - Ejection seats are technology intensive. They are difficult to produce, modify, and maintain over a long life. In a Leader-Follower program implemented for the Air Force's ACES II ejection seat, it took four years to fully certify the *follower* as a defense supplier, and that applied only to the seat structure and proper assembly of purchased components onto the seat. The numerous and complex components and explosive devices that go on the seat also require custom production. Unique skills and experience are needed to oversee this process.

2. **U.S. ejection seat industrial base is very limited, despite the U.S. having the world's largest market** - Without a domestic capability, U.S. Government-funded leading-edge R&D will be transferred overseas. Only one U.S. company currently produces the ejection seat structure compared with more than half a dozen companies 30 years ago. The number of seat component subcontractors has also diminished, yet components are critical to supporting the existing inventory of seats. The components and other items in the production chain require specialized facilities and know-how. There are no alternative technologies available to produce ejection seats without significantly compromising quality.

3. **Foreign firms are not subject to U.S. authority** - In a national security crisis, the U.S. Air Force or Navy cannot legally control foreign production schedules, lead times, emergency

production, or gain access to technical drawings. Moreover, the Europeans and Russians are not compelled to support U.S. emergency requirements. The Defense Priorities and Allocation System, which gives priority to Defense contracts in the United States (and Canada *by Treaty*), is not applicable to foreign firms.

4. **Economic advantages of a domestic capability** - Aside from the obvious tax and employment advantages, a domestic capability also protects the United States from exchange rate risk, supply interruption, and monopoly pricing by a single foreign supplier. The U.S. Navy is paying about 30 percent more than initially contracted for the NACES seat from the United Kingdom because of the dollar/pound fluctuations. In the opinion of various U.S. contractors, if properly structured, an American ejection seat company could produce an ejection seat at a lower cost than currently available from other countries. Also, if present trends continue, the world may become dependent on only one or at most two (non-U.S.) firms. Historically, monopolies have tended to slow down innovative behavior, erode efficiency, and reduce responsiveness to the customer. The presence of a viable U.S. competitor could ease these concerns.

1.3.2 Reasons not to Preserve a Domestic Capability

1. **Foreign sources are politically reliable** - NATO countries may be the sources of choice and are politically reliable. Deliveries of needed ejection seats could be made under most emergency situations. U.S.-funded R&D could be incorporated into foreign manufactured seats.

2. **Mobilization highly unlikely** - The Cold War is over and the need for a general mobilization of production to meet surging defense requirements is unlikely. A domestic ejection seat capability would not be needed under these circumstances.

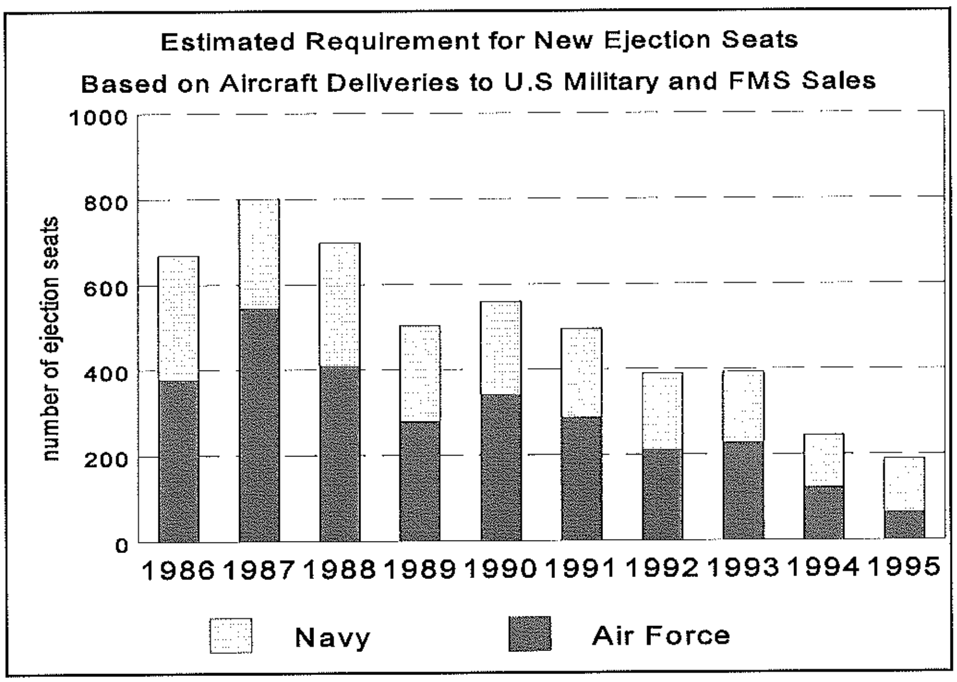
3. **Foreign sourcing of ejection seats may promote exports of other U.S. defense products and strengthen cooperation among U.S. allies** - Declining defense budgets worldwide make it logical to cooperate on defense programs internationally. Procuring ejection seats from foreign sources may open export markets for other U.S. products.

4. **Economic disadvantages of domestic sourcing** - While most defense products are made more efficiently in the United States by virtue of sheer volume, it is evident that ejection seats are currently produced with greater economic efficiency by a foreign producer. The global ejection seat market appears too small to support multiple major companies. The implication is that average production costs would rise and economic efficiency would decline if production were

spread across several competitors. This would waste scarce resources, and cause Defense to pay more.

1.4 Overview

1.4.1 Market Trends and Technology - The problem is clear. Estimated shipments of new ejection seats to the U.S. military and foreign military (FMS) customers have declined sharply in the last decade, from a high of more than 800 seats in 1987 to less than 200 in 1995. This shrinkage in the market more than any other single factor has weakened the domestic industrial base. The following chart presents this trend.



Source: Aerospace Industries Association, "Aerospace Facts and Figures"

Ejection seat requirements for the U.S. Air Force and Navy dropped by nearly 80 percent between the 1987 high and 1995. Current projections call for a further decline over the next few years. The Navy's portion of the shipments is mostly imported from Martin-Baker. In recent years, imports of Martin-Baker's Navy Aircrew Common Ejection Seat (NACES) contain about

30 percent American content in each seat.

While the industrial base is in serious decline, we stand on the verge of demonstrating fourth generation ejection seat technology. A major driving force behind the pursuit of this technology is the need for improved escape capability for all aircrew and accommodation of the lighter weight female aviator. Congressional approval of female pilots in 1993 expanded the weight limits of pilots and aircrew. Subsequently, the range of weights to be accommodated was increased from 140-211 pounds to 103-245 pounds.

This creates its own set of challenges. An ejection seat is designed to extricate aircrew members from aircraft in emergency situations using the explosive force of a rocket catapult. However, the human body can only tolerate the application of a limited force before serious injuries ensue. Ejection seat catapults are designed to remain within tolerable human limits while applying enough force to hurl the crewmember a safe distance from the aircraft. The catapult force needed to safely eject a large person could seriously injure a smaller one and the force needed for a smaller person might be inadequate for a larger one. Various promising technologies are being examined and tested to accommodate this expanded crew member range.

1.4.2 Changing Face of the Aerospace Industry - With the shrinking of the U.S. military budget, there has been a corresponding shrinkage in the number of major aerospace companies. Mergers, consolidations, and other actions have greatly changed the landscape of the U.S. aerospace industry. Recent actions by the Boeing Corporation could potentially have a major impact on the U.S. ejection seat industry.

As of January 1, 1997, Boeing owns Rockwell Aerospace and as of August 1, 1997, merged with McDonnell Douglas. The lion's share of outstanding ejection seat R&D projects are now under Boeing's purview. Rockwell is the American partner of Zvezda, the Russian ejection seat maker, on the $9.2 million K-36D project, which is an effort to adapt the Russian seat attributes to American cockpits. McDonnell Douglas is finishing up on the $20.5 million fourth Generation demonstration project. Boeing is also heavily involved in ejection seat research on several fronts.

Boeing, which completed a survey for this assessment, has an experienced team of aircrew systems researchers, and has an interest in seeing new ejection seat technologies become a reality. This interest is reinforced by the company's being one of the two finalists in the Joint Strike Fighter program. McDonnell Douglas will bring with it over 40 years of experience in developing and building ejection seats and is currently the U.S. Air Force's primary seat builder.

In addition, Rockwell has a subcontracting agreement with Universal Propulsion Company, the only other U.S. seat maker (currently inactive), with regard to the Russian K-36D project. The merger of all these elements appears to be a unique opportunity to re-energize the U.S. industrial base and renew the industry's international competitive standing.

2. Ejection Seat Industry

2.1 Ejection Seat Industry

2.1.1 Industry Description - The U.S. ejection seat industry is made up of dozens of companies that feed parts into the final product, and provide spares for seats in service. Two companies make the most costly part, the seat structure itself, which is a complex assembly of mostly aluminum parts held together by as many as 1,500 rivets and other fasteners. McDonnell Douglas Corporation (MDC) assembles the seat structure for the Advanced Concept Ejection Seat (ACES II) in Titusville, Florida. The ACES II was selected as the common ejection seat for the U.S. Air Force in 1976. Over 8,000 ACES II seats have been produced in the last 20 years. They are installed in the Air Force's A-10, F-15, F-16, F-22, F-117, B-1B, and B-2 aircraft. The seat was also chosen for the T-46 trainer, but this program was canceled.

Universal Propulsion Company (UPCO), a subsidiary of Talley Corporation, although currently inactive, makes the S-IIIS seat in Phoenix, Arizona. The S-IIIS is used on the U.S. Marine Corp's AV-8B Harriers. It is also on the Alpha Jet used by the German and Nigerian Air Forces, the T-4 in Japan, and the Argentine 1A-63. Aircraft production under these programs is now completed, and there is no requirement for S-IIIS seats at his time. About 500 S-IIIS seats are active in U.S. inventories, and many more internationally.

The U.S. Navy has long relied on a lone British firm, the Martin-Baker Aircraft Company, Ltd., to supply most of the ejection seats for its aircraft. Martin-Baker is the world's largest ejection seat manufacturer with about 75 percent of the world's market (excluding former communist countries). In May 1985, Martin-Baker was selected to produce the Navy Aircrew Common Ejection Seat (NACES). The NACES is found in the F/A-18C/D, T-45A, and F-14D. About 1,000 NACES seats have been produced. Martin-Baker was directed to subcontract several high-valued seat components from U.S. suppliers, which account for about 30 percent of each seat's value. This is done to satisfy Congressional concerns about foreign dependency raised in the early phase of the program.

The Zvezda Design Bureau (Zvezda), located about 35 miles southwest of Moscow in Tomilio, Russia, is the only other important player in the world. Zvezda (translated "star") was founded in 1952, and makes ejection seats for modern combat aircraft in Russia and many former Soviet countries and satellite nations. Of special interest is Zvezda's K-36D ejection seat, which is in

the MiG-29 and other aircraft. The seat surpasses the capabilities of any western manufactured seat in very high velocity ejections, although these rarely occur. The seat was successfully tested at 755 KEAS (knots equivalent airspeed). The U.S. Air Force and Navy are jointly sponsoring a two-year, $9.2 million research project partnering Rockwell Aerospace (now owned by Boeing) with Zvezda to see if the Russian seat, or a derivative thereof, can be adapted to American cockpits. Zvezda ejection seats are also being marketed to countries that currently own Russian manufactured or licensed aircraft. However, at this time, Zvezda must obtain authority from the Russian State Corporation for Export and Import (Rosvoorouzhenie) to sell military equipment to foreign buyers.

The Swedish Aircraft Company (Saab) made ejection seats until recently, but closed its operation because its own ejection seat was too large and heavy for the new JAS39 Gripen aircraft. The company recognized that developing a new seat, combined with a lack of reasonable volumes, would be prohibitively expensive. Saab selected Martin-Baker seats after a competition with UPCO. The contract includes a technology transfer agreement for Martin-Baker to assist Saab in maintaining capabilities to support earlier seat designs.

The People's Republic of China has at least one seat maker, the Chendu Aircraft Company. Chendu principally builds aircraft. Some of the ejection seats built by the firm were reportedly reverse engineered from vintage Russian seats. Chendu exported aircraft with these seats to Pakistan. The Pakistani Government ordered the seats replaced with Martin-Baker models. Chendu Aircraft is going to co-produce the Zvezda ejection seat for Chinese manufactured versions of the Russian SU-27 aircraft.

Other minor instances of ejection seat or parts production take place in certain countries, often at the direction of national governments. These arrangements are called co-production or "offset" agreements, in which a government requires a percentage of local production to "offset" the higher priced import. This almost always adds significantly to the total cost of the ejection seat in the purchasing country, unless a large enough volume justifies the investment. It also disrupts the efficient operation of the original ejection seat maker by building redundant capacity into the system.

For example, MDC licenses the ACES II seat to Daicel Chemical Corporation in Japan as part of the much larger F-15 and FSX co-production agreements. Daicel has assembled about 200 ACES II seats, initially from kits supplied by MDC. These reportedly are assembled one at a time, craftsman style, for more than twice the cost of making the seat in Titusville, Florida. In a

separate agreement, UPCO licenses the S-IIIS seat to Daicel for installation in the T-4 aircraft.

Martin-Baker must share production to varying degrees or source parts locally when doing business in many countries. Major agreements of this nature exist with France, Italy, Germany, India, and the United States. France, despite a large cost penalty, has nearly a full-up seat producer, set up as a subsidiary to Martin-Baker. The arrangement in France may change somewhat when Dassault's Rafael aircraft comes into production. The Rafael will have an advanced Martin-Baker ejection seat. Because of small volumes, the expense of supporting two production lines would be even greater. It is likely the new seats will be produced in Martin-Baker's UK facilities. The existing production base in France may phase down slowly as existing plane inventories are retired or replaced.

As an interesting sidelight, during the Falklands War in 1982, Martin-Baker was embargoed from shipping ejection seats or spares from the United Kingdom to its Argentine customers. To bridge the gap, the Argentine Mirage seats were serviced and supplied spares by Martin-Baker's French subsidiary. Martin-Baker also lost the Argentine 1A-63 (the German Dornier 63 aircraft) seat account to the Stencel Aero Engineering Company (now part of UPCO) of the United States.

2.1.2 Industrial Organization - The industrial organization of the U.S. ejection seat industry is very different from that of Martin-Baker or Zvezda. For historical reasons, the United States developed an ejection seat industry that includes numerous firms. The structure of the U.S. industry can be described as fragmented. Most of the firms sell product or services into only one or two sub-areas of the ejection seat business, with minimal direct exposure to the market and a small corporate stake in the business.

As the largest manufacturer of ejection seats, Martin-Baker constitutes much of the rest of the global industry (excluding former communist countries). Martin-Baker has brought most of the business together under the management of one firm that is almost totally focused on ejection seats. The firm on average produces about 85 percent of a seat's value, out-sourcing items such as recovery parachutes or fasteners where the specialized items needed are readily available from reliable outside sources at a lower cost. This structure requires a high volume of business to operate efficiently and attain the lowest per unit cost production level. The business volume comes from a global market that includes sales of both new ejection seats and activity in a large aftermarket for spares and engineering services. Currently, about 18,000 Martin-Baker seats are in global military inventories, although this is down from nearly 30,000 in the mid-1980s.

The global market for ejection seats may not be large enough to support multiple integrated private companies. The world market dollar value for ejection seats would not come close to making the Fortune 500 list. We see only one such integrated company in the world at the moment, Martin-Baker, and another potentially emerging on the horizon in Zvezda. Zvezda, formerly a state-run monopoly, apparently is hoping to challenge Martin-Baker. However, a lingering problem of over capacity in the ejection seat business could mean stiffer competition.

Ejection seats are an especially risky business. The market is very demanding and subject to wide swings. Also, for practical purposes, no commercial markets exist for the product that might otherwise supplement defense revenues. Efforts by firms to lower or minimize this risk vary. In the United States the risk is spread across many firms. Companies tend to focus on specialized parts that are brought together and assembled to make the ejection seat. Specialization in one or two areas helps manage the complexity and product liability, and limits a firm's risk exposure to the vagaries of the market.

Importantly, virtually all U.S. companies active in the ejection seat market also produce other products of greater importance to their bottom line. Very few hold a particularly high financial stake in the ejection seat business relative to other product lines, although ejection seats and their

Ejection Seat Share of Corporate Revenues for Selected Companies (1995 Data)

Company	Company Revenues ($000)		% Ejection Seats of Total	Ejection Seat Activity
	Corporate	Ejection Seat*		
McDonnell Douglas	$14,332,000	$25,000	less than 0.2%	Design & Engr., Seats
Teledyne	$2,567,800	$10,000	less than 0.4%	Sequencers, Pyro
Talley Industries, Inc. (UPCO)	$301,296	$10,000	less than 4.0%	Design & Engr., Testing, Seats
Pacific Scientific	$284,812	$6,000	less than 3.0%	Inertia Reels, Pyro
OEA, Inc.	$129,211	$4,000	less than 4.0%	Pyro
Martin-Baker**	$105,102	$100,000	over 95.0%	D&E, Seats, Testing, Comps., Pyro

Source: Dun and Bradstreet's "Moody's Industrial Manual, 1996" and "United Kingdom's Top 1,000 Companies"
* Ejection seat revenues are rough approximations to protect company proprietary information.
**Martin-Baker's corporate revenues were reported at 65,689,000 British pounds. A dollar conversion factor of 1.6 was used to convert this number to U.S. dollars.

other products frequently complement one another. Further, little direct investment in ejection seats is required. Most capital outlays are recaptured across several product lines. The table above shows the exposure (and stake) that five key U.S. companies have in the ejection seat

business. Martin-Baker is shown for comparative purposes.

As structured, the U.S. ejection seat industry has low fixed costs, and can operate at relatively low production rates without losing money. The downside is that this structure dilutes the knowledge base, lengthens response time to domestic and foreign demands, and adds to administrative and transactions costs (i.e., transfer pricing between firms). Ejection seats are technically complex, and quality is imperative. Producing an ejection seat involves putting together several thousand precision parts. The assembled seat structure has more than two dozen dimensions controlled to .015 inches. It must be able to withstand 40 G's (40 times occupant's weight), weigh less than 200 pounds, and perform 100 percent of the time. A high degree of design and engineering know-how is essential for success. Above all, ejection seats also require a skilled and experienced workforce working as a team to manufacture the product. One company described this as "tribal knowledge," which can only be obtained on the job. The complexity and quality imperative are cost drivers. At $100,000 per ACES II seat, the price is over $500 per pound.

Both MDC and UPCO rely upon metal working job shops to supply metal parts (or details) for their ejection seat structures. According to one company official, U.S. firms have the largest pool of reliable job shops in the world from which to choose. Rather than buy the most advanced machinery, which may become obsolete with next year's model, why not contract with the most up-to-date machine shops? This philosophy is currently the "low cost" scenario applicable to the ejection seat industry in the United States. As things stand, MDC and UPCO have low investment requirements and reduce their risk exposure by relying on the machine shops.

As another option, Weber Aircraft Company produced the seat structure for about 1400 ACES II seats over a 12 year period under the defunct Leader-Follower program using in-house machines to make the metal details. The firm was already a producer of commercial aviation products, and owned machinery at the time the ACES II contract was awarded. The machines were multi-purpose and made parts for aircraft ladders, galleys, and regular aircrew seats. The ejection seat details "piggy-backed" on the machines. Investment and risk were spread across several product lines. MDC operated in a similar fashion when located in Long Beach prior to 1986, and initially at Titusville, piggy-backing on machinery used on the Dragon and Tomahawk missile programs.

Aside from metal details, the major components affixed to ejection seats are also made separately by specialized companies and shipped to Titusville or Phoenix. These components include sequencers, parachutes, harnesses, inertia reels, survival kits, oxygen containers, environmental

sensing devices, and lap belts. Each seat also uses more than a dozen pyro devices, such as the catapult (or ejection gun) that shoots the seat and pilot out of the cockpit. Another pyro device is the rocket motor that propels the seat away from the aircraft or in low level ejections to an altitude high enough to fully deploy a parachute. Other pyro devices include gas generators, reefing line cutters, power supply actuators, and time-delay actuators.

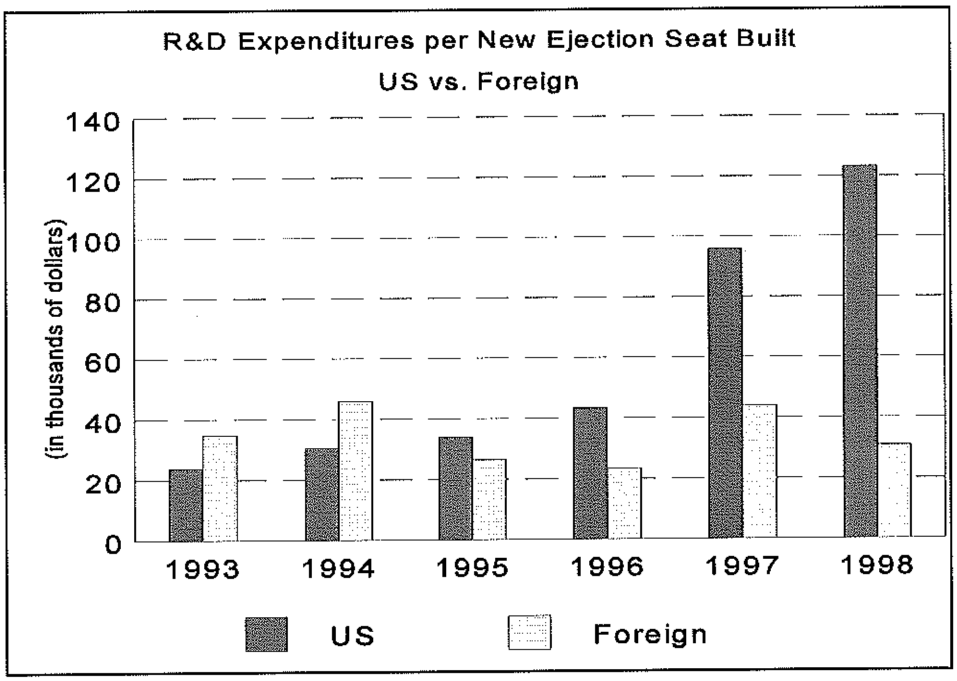
Companies that supply parts and components to the U.S. market are presented on the following table.

Ejection Seat Components and Manufacturers		
Ejection Seat Component	**Component Manufacturers**	
	Domestic	**Foreign**
Seat Structure	McDonnell Douglas, UPCO, East-West (seat bucket)	Martin-Baker (UK)
Propulsion Units	UPCO, Talley, Naval Surface Weapons Ctr, Indian Head Division	Martin-Baker (UK), Royal Ordnance (UK)
Stabilizers	EMCO (gyro), Talley, Aerojet (maxpac- in testing stage)	Martin-Baker (UK)
Inertia Reels	Pacific Scientific	Martin-Baker (UK)
Harnesses	Conrad Co., Aero Products, Air-Lock, UPCO, Frost	Martin-Baker (UK)
Drogue Parachutes	Pioneer, Guardian, Mills Mfg.	Martin-Baker (UK), Irvin G.B. (UK)
Recovery Parachutes	Pioneer, Guardian, Mills Mfg.	Irvin Aerospace (Canada & UK)
Sequencers	Teledyne, Pacific Scientific, Air Research, Hi-Shear, Quantic	Litef Gmbh (Germany)
Survival Kits	Conrad Co., Aero Products, American Safety Flight Systems, East-West	
Emergency Oxygen	R.E. Darling, East-West, American Safety Flight Systems, Litton Life Support	Normal Air Garrett (UK) L.Adams (UK)
Other CAD/PAD Items	Roberts Research, UPCO, Talley, Pacific Scientific, Teledyne, Scot, OEA	Martin-Baker (UK), Royal Ordinance (UK), Haley Weller (UK)
Other Components	Eagle Picher (thermal batteries) Vickers (electric motor) L.H. Black (parachute metal gun frame) FXC Corp (environmental sensor), Barber Coleman, Metropolitan A/C, Hydraflow, Frost (connectors), Koch (connectors), Conax (Uwars)	RFD (Northern Ireland) MSA (thermal batteries - Scotland)

Source: U.S. Dept. of Commerce, BXA/SIES Industry Survey, Hill AFB, Kelly AFB, NSWC at Indian Head, MD
Note: Zvezda does not currently sell ejection seat related products in the U.S. market, and therefore does not appear on table.

The research and development and qualification testing required for ejection seats is far greater than the ability of any commercial company to undertake independently and see a profitable return on the investment. These high costs are mostly financed directly by the military, and therefore are not reflected in the seat manufacturer's selling price of the ejection seat. Otherwise, these non-recurring costs would be amortized over a relatively small volume of seats.

Based on survey information, in prior years the average ejection seat (globally) contains about $40,000 of R&D and testing cost ($200 per pound). This number was lower 10 years ago when three or four times as many seats were produced. However, in the future the amount is projected to grow, as both R&D requirements increase and ejection seat production declines. As the chart below displays, the average R&D per ejection seat sold into the United States is likely to exceed



Source: U.S. Department. of Commerce, BXA/SIES Survey

$120,000 in 1998. More ejection seats are built and used outside of the United States, which moderates the foreign R&D ratio.

2.1.3 Government Role in Industry - The U.S. military is pervasive throughout the ejection seat sector. The military defines the market, finances most technology development, and administers programs to assure that quality and performance standards are met. The acquisition of new ejection seats and the day-to-day management of thousands of ejection seats in military inventories requires many people with specialized skills. Of necessity, there are probably more people in the U.S. Government performing various ejection seat-related tasks than currently populate the private portion of the ejection seat industrial base. However, in recent years the Government, like the industry, has downsized and consolidated operations.

The U.S. Air Force maintains ejection seat operations at Wright-Patterson AFB in Ohio (specifications and R&D), Kelly and Brooks AFBs in Texas (program management, procurement and R&D), Langley AFB in Virginia (end-user requirements), Hill AFB in Utah (pyro spares), Holloman AFB in New Mexico (sled testing track and analysis), and Kirtland AFB in New Mexico (safety analysis). The Navy has similar units at Naval Air Systems Command (Navair) in Arlington, Virginia (program management and R&D), the Patuxent River Naval Air Station in Maryland (R&D and testing), the Naval Surface Weapons Center at Indian Head, Maryland (pyro procurement, spares, and inter-service management), the Naval Weapons Center at China Lake in California (sled testing and analysis), and the Safety Center at Norfolk Naval Base in Virginia (safety analysis). The Navy vacated its facility in Warminster, Pennsylvania, in 1996, consolidating those operations mostly at the Patuxent River site and Navair. The China Lake test track may also be closed shortly.

Ejection seats in the field require regular inspections, maintenance, and spares for the periodic replacement of parts. An ejection seat normally has a service life that lasts over 20 years, although the seats in B-52s are nearing the 40 year mark. The military interface with industry continues throughout the seat's life cycle for product improvements and upgrades, as well as provision for spares. Field inspection and maintenance units (egress shops) are located at various Air Force bases, Marine and Naval air stations, and on aircraft carriers to service the ejection seats.

2.1.4 Historic Evolution - The beginning date in the history of ejection seats is often listed as 1910. In that year Professor J.S. Zerbe of Los Angeles designed and installed an ejection seat, complete with parachute pack, in the "multi-plane" (many wings) he invented. The plane was not a particular success. However, the ejection seat was successfully tested with a dummy. It used a powder-charged "gun" to catapult the dummy and parachute clear of the aircraft.

As aviation technology advanced, some form of assisted bail-out became necessary. An ejection seat was installed on the German Dornier Do-23 bomber aircraft in 1934. The aircraft was falsely listed as a cargo plane to comply with provisions of the 1919 Treaty of Versailles restricting German combat aircraft. The position of the engines and the arc of the propellers made it extremely hazardous for the pilot to escape without assistance.

By 1939, German scientists had determined that the maximum acceleration a human could withstand without serious injury was about 20 Gs for a duration of 0.1 second. In 1941, the Junkers JU-87 Stuka and JU-88 dive bombers were used as ejection seat test beds. Heinkel Aircraft Company made compressed-air ("Pressluft") and explosive cartridge ("Kartusche") type ejection seats, and emerged as the principal supplier of ejection seats. By war's end in May 1945, ejection seats had been designed for and tested in the Messerschmitt Me-163 and Me-262, the Heinkel He-162, He-219, He-229, He 280, the Dornier Do-335, and others. About 60 successful ejections were made from operational aircraft.

Except for spotty and incomplete intelligence reports, little was known during the war about the German ejection seat program. A fact gathering team was dispatched to Germany from Wright Field (now part of Wright-Patterson AFB) shortly after the war ended. This team was led by Colonel W. Randolph Lovelace, Chief of the Aero Medical Lab, and included Dr. Edward J. Baldes from the Mayo Clinic as special consultant, and Lt. Werner J. Wulff as translator.

The Heinkel He-162 People's Fighter ("Volksjager") was of most interest to the team. The seat used an explosive cartridge to catapult the pilot from the aircraft. It was considered the most successful method of escape at the time and strongly influenced postwar American designs. The Lovelace team sent a He-162 seat back to Wright Field for evaluation. Another was sent to England, and a third to the U.S. Navy's Bureau of Aeronautics. Explosively propelled seats were also captured intact and later copied by both the French and the Soviets in their development of ejection seats after the war. After Germany, Lovelace visited Sweden, where Saab had been conducting research since 1939, and then went to England before returning to the United States.

In 1944, Allied military authorities met in Britain with representatives from Martin-Baker, Vickers, and Mobbs-Lobelle Aviation to discuss how to match the enemy in this technology. The design concept of James Martin, the founder of Martin-Baker Aircraft Company (1934), ultimately prevailed. After first designing a swinging arm to lift the pilot clear of an aircraft, Martin concluded that an explosive charge would have to be used. In this approach, he was duplicating earlier work done by German engineers. He also developed an inclined test fixture

to investigate ejection accelerations and how to control the onset of G forces. He independently came to the same conclusions the Germans had in 1939. He visited Germany after the war and gained additional insights.

In the two decades after the war, the American industry grew outward, with the military at its core. The British industry, largely because of the determination of James Martin, grew with Martin-Baker at its core. In America, the first operational ejection seats were built during the 1950s by about a dozen different airframe companies for their own unique needs. The ejection seat was an important, but minor, adjunct to their main focus of building airplanes. Most airframe builders had no ambitions to push the technology, or integrate into other aspects of the industry, or to pursue markets other than that provided by their own airframes. In sharp contrast, ejection seats were the focal point of Martin-Baker, and were handled like a business.

Time Frame	Evolution of Ejection Seat Technology	Performance
up to 1953	Catapult ejection seat	assisted bailout
1953	Automatic lap belt and parachute	seat man separation and parachute automated
1958	Rocket catapult ejection seat	sustained propulsion, safer low altitude ejections
1962	Powered inertia reel	automated positioning of aircrew in seat
1964	Drogue chute stabilizer	seat stabilization in wind stream
1966	Mortared main parachute/seat-man separation	quicker parachute, parachute separates aircrew from seat, safer low altitude ejections
1968	Stapac - Vernier rocket	seat stabilizer during first second
1968-1975	ACES II Seat	integrated latest technologies, 3 mode operation
1985-1988	NACES Seat	digital sequencer, 5 mode operation, modularity
1990s and on	Variable thrust rocket, controllable catapult	4th generation, expanded crew weight range, 3-D stabilization

Source: "USAF Crew Escape State-of-the-Art Requirements for Technology Advancement" Report #AFWAL-TR-82-3089 (December, 1982), by B.J. White, Crew Escape and Subsystems Branch, Vehicle Equipment Division, Wright-Patterson AFB. More recent information developed with assistance from Crew Systems Branch of the Engineering Directorate at WPAFB.

The early seats were little more than catapults (or ejection guns) attached to the seat structure. The pilot had his own parachute. An ejection was an "assisted bailout" that got the pilot out of the plane. He would have to remove his lap belt, push away from the seat, and pull the rip-cord. The second generation seat added a rocket propulsion system, and automated the seat-man

separation. Douglas Aircraft developed the Escapac in the early 1960s, one of the more successful second generation seats. The Escapac is still in use in the Navy's TA-4s and S-3s. There may be about 4-5,000 others in foreign aircraft.

In the mid-1960s, qualification testing was formalized (Mil-Std-846) by the Air Force. This required a series of 22 ejection seat tests, from stand-still ejections up to 600 KEAS sled tests. Sled tests were conducted at Edwards AFB in California and Hurricane Mesa in Utah (now owned by UPCO) until about 1963; the Navy conducted their sled tests at China Lake. The Air Force transferred its testing to Holloman AFB in New Mexico, where the world's longest sled track (almost ten miles) was installed. Testing is expensive, but essential to identify deficiencies in ejection seat design and performance, and qualify the seat for operational service. Holloman conducted tests on dozens of seats in the past 30 years.

As the product improved, the number of aircraft companies making seats declined. By the third generation, the number of producers dropped to only two in the United States, Stencel and MDC. With Navy funding, Stencel Aero Engineering Company developed the S-III ejection seat starting in 1968; it was the first of the third generation seats. From 1968 to 1975, the Air Force financed the McDonnell Douglas ACES II seat. The ACES II incorporated a controlled force catapult, a gyro-stabilized vernier rocket, and a sustainer rocket, all of which ensured safe ejection over a broader spectrum of speed and altitude. This new design prevented tumbling and minimized parachute opening shock. The ACES II integrated the latest available technologies.

The ACES II was selected by the Air Force as its common seat in 1976. This occurred after 30 years of product cycle evolution established a basic model. The selection would save a great deal of money by forcing the common use of as many ejection seat parts and components as reasonable across cockpits. A possible downside is that the selection of one model closed the Air Force market to competitor seats for the next 20 years and may have constrained innovation. In the years following selection of the ACES II, the Air Force initiated the Crew Escape Technology (CREST) program to design fourth generation ejection seat technologies.

Boeing was named the prime contractor on the $27 million CREST program, while Martin-Baker was not permitted to participate; the program precluded foreign participation because of the use of very high speed integrated circuit (VHSIC) technology. The program explored the possibility of using rocket nozzles that swivel to control the rocket motor and stabilize the ejection seat. This did not prove workable and was abandoned. However, the program later succeeded in developing a more capable dummy, the Advanced Dynamic Androphomorphic Manikin

(ADAM), to record test ejections more accurately. CREST also developed the multi-axis seat ejection (MASE) test sled, which both saves money on sled set-ups and expands testing capabilities with respect to pitch, yaw, and rolling ejections.

Ejection Seats Tested at Holloman AFB (mid-1960s to 1996)			
ACES II	**Northrop**	**Lockheed**	**UPCO/Stencel**
F-105	T-38	F-104	A-10
F-106	A-9A (AX)	CF-104	F-15
A-10	F-5	T-33	F-16
B-1B		Space Shuttle	YF-17
B-2	**North American**		F-20
F-15	F-100	**Weber**	
F-16A		A-37	**Escapac Seat**
F-16B	**Martin-Baker**	T-37	A-10
YF-22A	F-5E	B-52	F-15
YF-23A		CT-114	YF-16
	Stanley/Yankee Seat	F-101	F-16
Republic	RSRA	F-105	A-7D
F-105		F-106	A-7K
	Zvezda K-36D Seat		
Fairchild	F-16 (MASE)	**Convair**	**Saab (Swedish) Seat**
A-10A(AX)		F-102	J-35
	McDonnell		J-37
Talley	F-101		
F-102			

Source: Holloman AFB, New Mexico

Note: The seat name or maker is in bold and underlined. The airframe in which the seat was tested is listed underneath.

The second CREST program (called the "fourth Generation") cost $20.5 million. This began in 1992 and is now completed. It incorporated the valved nozzle approach in which small valves directed by a microprocessor control the rocket motor. This approach is promising. Also, in 1990, the first interaction between U.S. laboratory personnel and Russian scientists took place. Through the Comparative Foreign Technology program, the contact led to joint testing of the K-36D ejection seat, and then to the Joint Venture between Rockwell Aerospace and Zvezda paid for by the Air Force and Navy.

Martin-Baker

In the 1950s, the U.S. Navy was losing many pilots in low altitude ejections, which were frequent in take-offs or landings on aircraft carrier decks. The survival rate on ejections under 1,000 feet was an abysmal four percent. Martin-Baker developed a more automated seat, designated the Mark 5 series, that would fully deploy the parachute canopy and safely separate the pilot from the seat structure at low altitude ejections. This was the solution the Navy needed. In August 1957, the Martin-Baker ejection seat was successfully demonstrated in a runway take-off at about 100 knots in front of top Naval officials at the Patuxent River Naval Air Station in Maryland. The order soon came to retrofit all Navy jet fighters and trainers with the Martin-Baker seat.

Martin-Baker suddenly became very busy retrofitting 11 types of Navy aircraft. Several circumstances then came together to propel the company to the dominant position it continues to enjoy today. McDonnell Corporation (prior to merger with Douglas in 1967) developed what many consider the best all-round fighter plane of the postwar era, the F-4 Phantom. Initially, the two-seater Phantom was sold to the Navy. However, in 1962 Defense Secretary McNamara called for commonality between the services, so the Air Force, at first reluctantly, procured the F-4 too.

The Air Force wanted to replace the Martin-Baker seats with North American's HS-1 ejection seat. Commonality ruled that out. When the Air Force realized the F-4 aircraft could outperform its more specialized planes at their own missions, their attitude changed. Then, the Vietnam conflict led to far greater and accelerated procurement of the F-4s and other aircraft than had been anticipated.

With Vietnam operations demanding increasing numbers of combat aircraft, Martin-Baker had more than enough work to "tool-up" and bring what was previously outsourced into a specialized factory. In the 12-year period ending in 1975, the company averaged production of about 260 seats a month. This came to more than 37,000 seats, or about 55 percent of the total the company built in its 50 year history (about 68,000).

The F-4 Phantom was the workhorse in Vietnam. It also was a company maker with respect to ejection seats. Over a production life that extended to 1979, a total of 5,068 F-4s were built by McDonnell Douglas in St. Louis. The two-seater Phantoms required over 10,000 ejection seats. Ironically, in its development stage the F-4 was equipped with ejection seats made by Stanley Aircraft Company (Denver, CO). However, in 1958 the Navy's Bureau of Aeronautics ordered

(as it had for the other 10 aircraft) the seat replaced with Martin-Baker's model. Robert Stanley, the company's founder, is remembered for his pioneering work in ejection seat technology, particularly on escape modules. Had this switch not occurred, Stanley may have become the world leader in ejection seats. The remnants of Stanley's ejection seat product line were sold to Talley Corporation/UPCO in the early 1980s.

<u>Stencel Aero Engineering Company</u>

Stencel Aero Engineering Company was the only pure ejection seat company America produced. Fred Stencel founded the company in Asheville, North Carolina in the mid-1960s. He invented the "spreader gun" (used to rapidly deploy parachutes) while employed with the Stanley Company in the late 1950s. In creating the S-IIIS ejection seat, Stencel can be credited with stimulating both MDC and Martin-Baker to create more advanced products. Had MDC and Martin-Baker not done so, Stencel could have won both the Air Force and Navy common ejection seat competitions. By not winning, the market was closed to Stencel. These competitions are discussed later in the report. The company's short life ended on the first day of 1987, after a jury found certain of the firm's top management guilty of defrauding the Government.

Stencel: The British Harrier

In the 1960s, imported British Harriers (AV-8A/TAV-8A) contained off-the-shelf Martin-Baker ejection seats. The Navy's Board of Inspection and Survey report on the aircraft cited 31 major deficiencies in the Martin-Baker seat. Stencel came forward in 1968 with a seat design to correct these problems, which the Navy funded. The funds to develop the improved seat came from a surplus in the Navy's Harrier import budget, created by a favorable shift in the dollar/pound exchange rate. By 1972, Stencel had developed the S-IIIS ejection seat at a cost of about $11 million. After extensive testing, considered the most stringent in the history of ejection seat programs to date, the Stencel seat met or exceeded all performance requirements. The Navy replaced the Martin-Baker seats with the S-IIIS, and ordered it placed in the American made Harriers co-produced by McDonnell Douglas.

The F/A-18 Switch

In 1976, McDonnell Douglas switched from Stencel's S-III ejection seat to Martin-Baker's Mark 10 ejection seat for the Navy F-18 aircraft then in development. As contractor furnished

equipment, McDonnell Douglas was responsible for seat selection, and free to make such a switch. However, an investigative report (April 11, 1977) published by the U.S. General Accounting Office (GAO) raised a number of questions about the change. The GAO report cited a possible conflict of interest relating to the Harpoon missile. GAO noted that McDonnell Douglas had contracts with the United Kingdom at the time to design a British version of the Navy's Harpoon missile. The British Ministry of Defense could have used this as leverage to influence McDonnell Douglas's decision. However, GAO also stated that no evidence was available to support this hypothesis.

The GAO report recommended that the Secretary of Defense direct the Navy to reexamine this procurement decision, and that the Navy conduct a technical evaluation of the award. The report also recommended that, if warranted, the Secretary of the Navy should direct McDonnell Douglas to terminate the Martin-Baker contract. In support of these recommendations, the GAO identified several waivers in performance requirements that the Martin-Baker seat was granted, notably in seat stability requirements and weight. GAO also reported that the Stencel seat was considered to be technically superior by both McDonnell Douglas and U.S. Navy technical personnel. GAO reported that since Martin-Baker was an offshore manufacturer, the U.S. Government had no effective means of audit and cost control. The Secretaries of Defense and Navy elected not to implement the GAO's recommendations.

In 1978, compatibility testing was conducted by the Navy at the China Lake test track in California. The results confirmed the findings of the above referenced GAO report. The Martin-Baker seat was unstable in flight, demonstrated excessive parachute descent rates, and proved to be 50 pounds over the weight limit. In operational use, the first three Americans to eject with this seat suffered major injuries.

In 1982, an independent cost comparison contracted by the Navy showed a potential cost savings in favor of the Stencel seat of $89 million. Stencel cost comparison studies, using the Air Force ejection seat life cycle cost model, showed a cost savings of almost $100 million. These potential cost savings were made available to the U.S. Navy by Stencel. Stencel submitted a proposal to the U.S. Navy for replacement of the British seat with the American-made Stencel seat in the F-18 aircraft. This was not implemented.

Stencel's legal problems

On December 20, 1984, based on documentation an employee passed to the Defense Contracts Audit Agency, the Defense Criminal Investigative Service seized the company's files. In early March 1985, Stencel's President, the Vice President for Manufacturing, the Comptroller, and the Company were indicted. Stencel's President had been hired around 1980, to replace Fred Stencel, who was ousted from the company in a stock buy out. Stencel's President was sales manager for Martin-Baker prior to joining the company. In a plea bargain, Stencel's President accepted responsibility for defrauding the U.S. Government. He was fined $10,000 and forbidden to have further contact with the company.

Following a trial in the fall of 1985, the Vice President for Manufacturing was sentenced to jail for six months, and the Comptroller was sentenced to serve 18 months. The Company was found guilty on 10 counts of misuse of public funds, was fined $100,000 and put under "suspension," which called for Stencel to honor all existing contracts with the U.S. Government, but blocked the company from entering into new ones. While under suspension, Stencel was not paid by the government.

In late 1985, the U.S. Department of Justice brought a civil action against Stencel on behalf of U.S. Navy. The investigators selected the 18-month period from the second half of 1983 to the end of 1984 for audit to calculate damages. Damages calculated for those 18 months were assessed in equal increments for six years as allowed by the pertinent statute of limitations. Under the relevant law, damages in this type of case were doubled and a penalty was assessed. The damages and penalty came to $2.6 million.

As a result, Stencel was destroyed as a viable concern. Before the initial investigation the firm's annual revenues were close to $20 million. About 200 people were employed by Stencel, and a cadre of local vendors were given business opportunities to supply parts for Stencel ejection seats. In addition to more than $2.6 million in damages and penalties, the company also incurred nearly $2 million in legal fees. It also was forced into debt to pay employees and suppliers and to make interest payments while under suspension. The company was dissolved on January 1, 1987. About 30 people were absorbed into UPCO.

2.2 Ejection Seats in Use

The ACES II ejection seat, deployed initially in 1978, was the last new ejection seat to be developed in the United States. Since that time Martin-Baker has developed and deployed two new seats. Although technologies were developed to upgrade the ACES II in the last 20 years, they were for the most part not deployed. Both the high success rate of the ACES II as originally designed and budget constraints were deterrents to the upgrades. Procurement dollars for egress systems overall have historically had a lower priority in competition with other combat aircraft subsystems (e.g., engines, weapons, avionics, etc.) for funding. An unintended result of this circumstance has contributed to a decline in U.S. industrial competitiveness in ejection seats.

2.2.1 ACES II - The Advanced Concept Ejection Seat, the ACES II, was developed following nearly eight years of intense research and development effort. The subsystems on the seat were designed, tested and qualified in the first ACES program in the late 1960s. In 1971, a study revised the seat's design, reducing weight by 30 percent and projecting lower production costs. At that time the program was redesignated "ACES II". Seat qualification was completed in June 1973.

The ACES II included several advanced features. It had three operating modes: mode 1 - immediate parachute deployment below 250 KEAS; mode 2 - deployment in 1.0 second above 250 KEAS (at sea level); and, mode 3 - parachute deployment delayed until seat descends or decelerates to a mode 2 boundary. Airspeed and altitude sensing devices determined mode selection. A gyro-controlled vernier rocket provided stabilization at lower speeds, and a drogue parachute at higher speeds. It used electronic sequencing with precision timing. And, it used a high performance mortar-deployed recovery parachute, which also separated the crew member from the seat.

In 1975, MDC's ACES II and Stencel's S-IIIS were in competition to become the Air Force's common ejection seat. MDC won the competition. However, Stencel filed a protest that could have delayed the selection process in legal proceedings for years. This was not in the interest of the Air Force. The Commander of Aeronautical Systems Division, Air Force Systems Command, General Stewart, ordered a "fair and impartial" run-off competition of 16 sled tests to decide the matter, and allocated $2 million to each company to prepare. The companies provided seats and assembled them on-site at Holloman AFB's test track. The Air Force provided the sleds. Eight runs were made on an A-10 fuselage, and four on a TF-15 (two seater).

The Air Force rated the ACES II as *correctable* (yellow coded), while the S-IIIS was rated *difficult* (red coded). (Blue was excellent; green acceptable.) In certain tests, a tube on the Stencel seat ripped the parachute; also the spreader gun that deployed the parachute did not fire. While MDC's seat used an electronic (analog) sequencer, Stencel used a mechanical sequencer, which reportedly may have been a strategic mistake. Also, while MDC's proposal included an agreement to fix deficiencies, Stencel's did not; Stencel lacked the financial strength and engineering depth. Based on these results, it was determined MDC's proposal lowered the risk and cost to the Air Force.

The ACES II ejection seat was selected by the Air Force as its common ejection seat and MDC was awarded the contract in November 1976. The Air Force included a Leader-Follower clause in the contract, which was a program to create a second source and lower procurement costs. The clause required MDC to establish a second source (the *follower*) to compete for ACES II contracts. More will be said about the Leader-Follower program in later sections.

The first operational ACES II was installed as government furnished equipment in an A-10 in 1978, replacing the Douglas Escapac seat. The Escapacs were also replaced in the F-15s. Initially, the ACES II cost about $45,000 per seat. High inflation rates in the 1978-1981 period drove the ACES II price up to about $70,000. However, starting in 1981, competitive bids for contracts between MDC and Weber, initiated under the Leader-Follower program, led to successive drops in prices during the 1980s. MDC's move to Titusville to cut costs enabled the company to continue getting the lion's share of the contracts, and most of the F-16 work. In the 1990s the price has remained between $70-80,000. Lately, it has climbed to near $100,000 because of minimal production quantities.

The ACES II is configured somewhat differently for each cockpit, although most parts and components, including pyro, are shared across cockpits. For example, the F-15 and F-117 have side "pull handles" to initiate ejection. The F-16 has a center handle. The F-16 is painted gray. The F-15 and F-117 are black. The timing on the A-10's sequencer is set to respond more quickly. The B-2 uses a thin layered explosive (TLX) ballistic train. And the B-1B has arm rests, and arm and leg restraints. The F-22 will have a fast acting drogue, arm restraints, and a larger oxygen container.

The ACES II increased the survival rate on ejections to over 90 percent. Ejections inside the performance envelope of the seat were over 95 percent. The seat's performance was a significant improvement over its predecessors. However, a great deal of research has gone into improving

the performance still more, and expanding the performance envelope to accommodate the newest combat aircraft. As with other seats in use, seat stability problems are encountered at higher ejection speeds (over 300-400 KEAS). Also, low altitude ejections can cause problems if the aircraft has a high sink rate or adverse attitude ejections.

As of January 1997, there have been about 425 ejections worldwide using the ACES II. About 40 were fatal. More than 380 survived, and most walked away. The single engine F-16 has recorded the most ejections at over 300. It is also the most numerous aircraft. Aircraft engine failure is the most common malfunction in which ejection seats are used in peace time, followed by pilot error. The following table lists ACES II saves from the first ejection in 1978 to early August 1996.

Lives Saved by ACES II Ejection Seat, Worldwide (1978 to August 3, 1996)

Year	A-10	F-15	F-16	B-1	B-2	F-117	Year Totals
1978	2						2
1979	1	1	2				4
1980	2		7				9
1981	1		9				10
1982	3	3	16				22
1983	5	6	12				23
1984	2	4	6				12
1985	2	3	11				16
1986	2	4	17				23
1987	1	3	13	3			20
1988	3		19	8			30
1989		3	18				21
1990		3	13				16
1991	5	6	28				39
1992	2	4	27			1	34
1993		3	28				31
1994	3	3	23				29
1995	2	3	22				27
1996		1	7				8
Totals	36	50	278	11	-	1	376

Source: McDonnell Douglas

Pyro is the muscle of the ejection seat. It must work in the proper sequence for the seat to perform properly. The pyro in the ACES II is periodically replaced under a closely managed program at Hill AFB in Ogden, Utah. A total of 3,738 ACES II seats were in U.S. inventory at the end of 1996. The A-10s, F-15A/Cs, and the F-117s have 15 pyro components. The F-16s, B-1Bs, and B-2s have 16 pyro components. The added component in the latter group is a trajectory divergence rocket used to avoid seat collisions in two seater aircraft.

PYRO REPLACEMENT REQUIREMENTS FOR THE ACES II EJECTION SEAT

Item	F-16 A/C (1 seats)	F-16 B/D (2 seats)	A-10 (1 seat)	F-15 A/C (1 seat)	F-15 B/D/E 2 seats)	F-117 (1 seat)	B-1B* (4 seats)	B-2 (2 seats)	Item Cost	Item Life (years) Shelf	Item Life (years) Use
CKU-5	1	2	1	1	2	1	4	2	$6,698	8	8
Vernier Rocket	1	2	1	1	2	1	4	2	$1,567	11	11
Harness Release Cartridge	1	2	1	1	2	1	4	2	$159	7	7
Drogue Cartridge	1	2	1	1	2	1	4	2	$187	10	10
Mortar Cartridge	2	4	2	2	4	2	8	4	$208	9.5	9.5
Gyro Gas Generator	1	2	1	1	2	1	4	2	$182	7	7
Trajectory Divergence Rocket P/N 1143-1	1	2			2		2	2	$558	13	12
Trajectory Divergence Rocket P/N 1163-1							2	2	$1,558	17	15
Reef Line Cutter (1.15 sec. delay)	2	4	2	2	4	2	8	4	$57	10	8
Reef Line Cutter (4.0 sec. delay)	1	2	1	1	2	1	4	2	$57	9	9
Drogue Cutter	2	4	2	2	4	2	8	4	$199	7.5	7.5
I.R. Gas Generator	1	2	1	1	2	1	4	2	$188	7	7
JAU-8	2	4	2	2	4	2	8		$157	10.5	10.5
Machined Initiators								2	$1,019	5	3
Pyro Items per aircraft	16	32	15	15	32	15	64	32			
Pyro Cost for new seat(s)	$10,835	$21,670	$10,277	$10,277	$21,670	$10,277	$45,295	$25,036			
Pyro Cost, 20-year service	$25,981	$51,962	$25,051	$25,051	$51,962	$25,051	$181,180	$67,613			
Pyro Cost, annual average	$1,299	$2,598	$1,253	$1,253	$2,598	$1,253	$9,059	$3,381	**Total**		
Number of aircraft in service	1,595	103	375	480	305	54	95	19	3,026		
Number of seats in service	1,595	206	375	480	610	54	380	38	3,738		
Pyro Cost, annual, all seats in service (in $000s)	$2,072	$535	$470	$601	$1,585	$68	$3,442	$128	$8,901		

Source: Hill AFB, Ogden, Utah

* B-1B is on a depot maintenance cycle of five years. Pyro is changed each cycle.

Based on recent prices, the cost of all pyro in a new ACES II averaged about $10-11,000. The B-2's two seats cost more (slightly over $12,500) because of a more expensive mechanized initiator. This is used with very light weight TLX line to transmit the ejection sequence and replaces the JAU-8 initiator (first pyro to fire) used on the other seats. The hypothetical 20-year service cost of pyro averaged about $25,000, except for the B-1B and B-2. The B-1B pyro is changed every

five years as part of the aircraft's depot maintenance cycle. This may change with surveillance testing, which may establish a longer life cycle if warranted. The 20-year cost for four seats, therefore, comes to more than $181,000. The B-2 mechanized initiator is changed three times as frequently as the JAU-8 unit, which drives its 20-year cost to about $34,000. However, like the B-1B, this may change with surveillance testing. The average annual cost of pyro replacement for all ACES II seats in inventory is slightly more than $8.9 million. Note the shelf life and use (installed) life on the previous table are predominantly the same. This evolved over a number of years from "surveillance" testing.

Many other components and subassemblies on the ACES II are also regularly inspected and replaced as necessary. Some of these items and their latest prices are listed on the table.

ACES II Component or Subassembly	Recent Cost
Government Furnished Equipment (total 1-4, + 5b)	$9,102.20
1. CKU - 5 (Catapult)	$6,698.00
2. JAU - 8 Initiator	$157.00
3. Seawars/Uwars	$900.00
4. Lap Belts	$944.84
5a. Parachute Connectors (for F-16)	$116.64
5b. Parachute Connectors (for all others)	$402.36
Contractor Furnished Equipment (total for items shown)	$22,619.69
Mortar Disconnect Assembly	$2,516.00
Backrest Cushion	$207.99
Seat Cushion	$139.91
Inertia Reel	$5,478.54
Survival Kit	$1,371.95
Environmental Sensor	$903.96
Velocity Sensor	$1,421.59
Emergency Power Supply	$578.00
Recovery Sequencer	$5,404.34
Recovery Parachute	$1,200.00
Pitch Stabilization Control Assembly	$3,397.41

Source: Kelly AFB

2.2.2 NACES - The Navy Aircrew Common Ejection Seat (NACES) had a rocky beginning. The problems with the F/A-18 seat lingered into the early 1980s. Stencel submitted a plan to replace Martin-Baker's Mark 10 seat and got help from the U.S. Congress. The National Defense Authorization Act for FY 1983 (Public Law 97-377) contained a provision that withheld funding for the F/A-18 program and the T-45A (a.k.a. Navy's Undergraduate Flight Training System-VTXTS) until the Secretary of the Navy submitted a plan to the Committees on Appropriations in the House and Senate to install an American-manufactured ejection seat in the aircraft. The Navy plan (submitted in December 1982) advised the Committees that due to procurement, manufacturing, and qualification testing lead time, a new ejection seat system would not be available during Fiscal Year 1983. In December 1983, the FY 1984 DOD Appropriations Act modified the provision to say that ejection seats could not be purchased in any foreign nation that does not permit U.S. manufacturers to compete for ejection seat procurement in that foreign nation. This provision applied to ejection seat appropriations through FY 1989.

In September 1983, reacting in part to outside sources and to Government Accounting Office criticism regarding the Navy's lack of standardization in ejection seats and other areas, the Secretary of the Navy John F. Lehman, Jr. called for an open competition for a Navy common ejection seat for installation into the two contested aircraft and the F-14D. In March 1984, a Request for Proposal was issued and responded to by Stencel, MDC, and Martin-Baker. Stencel proposed the S-IVS design ejection seat; McDonnell Douglas proposed a modified ACES II; and, Martin-Baker proposed to develop a seat and submitted a technical package closely related to the Mark 10 (SJU-5A) seat in the F/A-18. The competition was based on technical and price factors.

The Navy found all three proposals met the stated technical and performance requirements. All three seats proposed a microprocessor digital sequencer and multi-mode sequencing based on air speed and altitude conditions. The Stencel proposal was found deficient in two areas. There was a lack of redundancy for the divergence rockets and an unclear parachute development program. MDC's proposal was also weak in the parachute area, and in life support and maintenance. Also, MDC could not substantiate claims about stability and performance with the data submitted in support of the proposal. Martin-Baker's proposal incorporated several new concepts and components, including a three-point drogue for stability and deceleration. The company also presented a very sound test program to validate the new concepts and components.

In the down selection to two finalists, MDC's submittal was rejected based on the higher costs required to correct the seat's deficiencies. The Stencel seat was judged the easier seat to

maintain, and to have more parts in common with existing seats. Also, the Stencel seat was initially the lower priced. The Martin-Baker seat was technically equal to Stencel's in most respects, and superior in several. In a best and final offer (BOFO) competition, an additional element (company management capabilities) was added as a factor, in which Martin-Baker was judged the more capable.

In February 1985, the British pound fell to a new low at under $1.10/pound. This pushed Martin-Baker's price slightly below Stencel's BOFO offer. Martin-Baker was selected at $1.07/pound, and three months later awarded the NACES contract. The pound has never been as low since that time. Also, Stencel was under investigation at the time of the selection, which may have influenced the final choice.

The contract for the NACES was awarded to Martin-Baker on May 3, 1985. The Navy financed development and testing of the seat as originally proposed for about $20.4 million. A Leader-Follower program was initiated with East-West Industries of Long Island, New York, but abandoned in 1992, when projected aircraft procurement dropped below levels to support two production lines. Martin-Baker was directed to purchase the firing handles and snubbers for the NACES from East-West. East-West also supplied the survival kit for the NACES as part of Martin-Baker's original bid in 1984. Martin-Baker selected Teledyne to supply the electronic sequencer following a solicitation of bids from several candidates. The catapult and other pyro were also competed. In total, U.S. sourcing represented about 30 percent of the value of the seat.

The first NACES seat was delivered in October 1988 for installation into an F-14D. Since then almost a thousand have been delivered, including about 150 for FMS sales. The NACES is the first ejection seat to use a microprocessor digital sequencer to control the seat's operation. The NACES is built in five modules: the catapult, main beam assembly, seat bucket, survival kit, and parachute assembly. It's configured with a wide version for the F-14D, and a narrower version for the T-45A and F/A-18C/D. As of January 1997, 20 successful ejections have taken place with the NACES seat with no injuries.

The price of a fully configured NACES seat ($200,000) is higher than a fully configured ACES II ($110,000) seat by about 80-90 percent. Care must be taken in how this is interpreted. The NACES seat weighs about 40 pounds more. The digital sequencer costs about $25-30,000, or roughly five times the cost of the ACES II sequencer. The NACES has more built-in redundancy than the ACES II seat. It also has five modules that can be removed/replaced separately. The pyro is more expensive due to added costs relating to special corrosion, vibration, and thermal

properties required for use in the aircraft carrier environment. Also, Martin-Baker makes its own tooling, the cost of which is recovered in the sales price. The U.S. Government finances most of the tooling costs for the ACES II. The NACES price includes a 5-year warranty on all parts and a 5 percent mark-up for product liability insurance. Martin-Baker maintains customer service technicians on both coasts to service the NACES (and other seats) in the fleet.

Other considerations also affect price. More than 8,000 ACES II seats have now been constructed. NACES seats were originally to total more than 3,000, but projections were cut back by about two-thirds in the early 1990s. Economies of scale never took hold in the NACES program. A minimum economic production lot is about 25 seats. More would reduce unit costs further. The dollar/pound exchange rate was near an all time low (about $1.07) when the first contract was negotiated. The increase to $1.60 or higher (40-50 percent) was an exchange rate risk taken by the Navy.

Martin-Baker is also at risk from exchange rate fluctuations. NACES contracts are denominated in U.S. currency, but may be deliverable over the next 12 months or longer. To hedge against exchange rate risk, Martin-Baker sells the contract to a bank at the current exchange rate in return for British pounds. This transfers the risk to the bank.

Twelve contracts were awarded for the NACES from 1985 to 1997. The largest (Lot 4) was for 188 seats, signed May 3, 1985. The 1997 contract will be for only 36 seats. In addition to being sensitive to both quantities and exchange rates, the unit price of the NACES is also sensitive to inflation rates in the UK. The price index in the UK for all manufacturing output (1990=100) rose from 82.7 in 1985 to 120.7 in 1995 (International Monetary Fund). This averages slightly more than a three percent increase per year, not significantly different from that of the United States.

NACES Contract History U.S. Navy Procurement						
Date of Contract	$1/Pound Exchange Rate*	# of Seats Ordered	Total Value (in $000)	Average Ejection Seat Price**		
				F/A-18C/D	F-14D	T-45
May 3, 1985	$1.207	8	$622			$77,789
May 3, 1985	$1.207	9	$710		$78,920	$79,630
May 3, 1985	$1.207	48	$2,669		$86,443	$60,766
May 3, 1985	$1.207	188	$26,220	$149,850	$153,020	$144,353
Apr 17, 1991	$1.783	123	$19,998	$152,028	$179,087	$151,113
Mar 19, 1992	$1.711	84	$14,539	$170,690	$179,087	$164,316
Jun 26, 1992	$1.891	117	$19,587	$167,057		$168,558
May 28, 1993	$1.561	72	$13,625	$180,811		$204,174
May 3, 1994	$1.513	42	$7,253	$167,267		$178,668
Apr 26, 1995	$1.611	44	$7,686	$171,708		$177,175
Apr 17, 1996	$1.507	50	$8,772	$174,619		$176,362
January 1997	$1.60-1.70	36	$6,607	$180,391		$185,100
Totals		821	$128,288			

Source: Navair, NACES Program Office, Federal Reserve Board, "Exchange Rate Statistics"
* Exchange rates are noon buying rates in New York for cable transfers payable in UK Pounds Sterling, and certified by the Federal Reserve Bank of New York for customs purposes.
** Average prices exclude pyro and thermal batteries. Also excluded are oxygen hoses and regulators, which are actually pilot equipment that plugs into the seat. These items would add about $20,000 to the 1996 prices.

As mentioned, the pyro items for the NACES seat are more expensive than the ACES II pyro. In part, surveillance testing for the NACES has not progressed as far as the ACES II. However, the philosophy in the Navy establishes a shorter shelf life and installed life to start with because of the harsher operating environment. Regular maintenance is another factor. It is usually more frequent because the Navy environment is generally harsher - flight deck operations, jerky starts and stops, salt spray, and other factors. Under some circumstances, such as complete overhaul of an aircraft, all the pyro in an ejection seat may be routinely changed also, regardless of its age. Over time, the installed life and shelf life may still approach parity.

PYRO REPLACEMENT REQUIREMENTS FOR THE NACES EJECTION SEAT							
Item	F/A-18C (1 seat)	F/A-18D (2 seats)	F-14D (2 seats)	T-45A (2 seats)	Item Cost	Item Life (yrs.)	
						Shelf	In Use
Thermal Battery	1	2	2	2	$2,870	6.5	4.5
Ejection Gun Initiator (JAU-5)	1	2	2	2	$585	6	4
Impulse Cartridge (Multi-Purpose Initiator)	2	4	4	4	$280	6	4
Explosive Actuated Initiator		3	4	3	$487	5	3
Cartridge Actuated Initiator (1.0 sec. delay)			1		$827	5	2
Cartridge Actuated Initiator (1.5 sec. delay)			1		$827	5	2
Impulse Cartridge (Drogue Release)	1	2	2	2	$411	6	4
Impulse Cartridge (Drogue Gun)	1	2	2	2	$394	6	4
Impulse Cartridge (Secondary Cartridge)	1	2	2	2	$101	6	4
Impulse Cartridge (Seat Initiator)	3	6	6	6	$106	6	4
Impulse Cartridge (Power Reel)	1	2	2	2	$291	6	4
Impulse Cartridge (Barometric Release)	1	2	2	2	$752	5	3
Cartridge Actuated Initiator (0.3 sec. delay)	2	2			$287	5	1.5
Cartridge Actuated Initiator (0.5 sec. delay)				1	$425	5	1.5
Cartridge Actuated Initiator (0.75 sec. delay)		1			$140	7	3
Cartridge Actuated Initiator				1	$461	10.5	7
Parachute Deployment Rocket Motor	1	2	2	2	$2,828	7	7
Underseat Rocket Motor (MK 123)		1	1	1	$8,071	9	9
Underseat Rocket Motor (MK 124)	1	1	1	1	$8,071	9	9
Pyro Items per aircraft	16	34	34	33			
Pyro Cost for new seat(s)	$17,756	$36,541	$37,968	$36,712			
Pyro Cost, 20-year service	$64,745	$132,521	$143,720	$130,908			
Pyro Cost, annual average	$3,237	$6,626	$7,193	$6,545	**Total**		
Number of aircraft in service	228	78	47	75	**428**		
Number of seats in service	228	156	94	150	**629**		
Pyro Cost, annual, all seats in service (in $000s)	$738	$517	$338	$491	**$2,084**		

Source: Naval Surface Weapons Center, Indian Head, Maryland

2.2.3 Current U.S. Military Inventories - Over 9,300 ejection seats were in Air Force and Navy inventories at the end of 1996, installed in about 5,900 aircraft. There are perhaps 30-35,000 ejection seats in world inventories. U.S. inventories are down approximately 50 percent from the late 1980s, and continue declining. Various component and pyro manufacturers rely on the replacement market for a substantial part of their ejection seat-related sales.

U.S. Air Force Aircraft Inventory with Ejection Seats (1996)				
Aircraft	**# of Aircraft**	**Ejection Seat Maker**	**Ejection Seat Designation**	**# of Seats**
B-52	94	Weber	Weber -1	564
T-37	454	Weber	Weber -2	908
T-38	432	Northrop	Northrop Seat	864
F-4	19	Martin-Baker	H-7	38
EF-111	39	McDonnell	Escape Module	39
U-2A	30	Lockheed	Lockheed Seat	30
U-2B	5	Lockheed	Lockheed Seat	10
A-10	375	McDonnell Douglas/Weber	ACES II	375
B-1B	95	Weber (McDonnell Douglas)	ACES II	380
B-2	19	McDonnell Douglas	ACES II	38
F-15A/C	480	McDonnell Douglas/Weber	ACES II	480
F-15B/D/E	305	McDonnell Douglas/Weber	ACES II	610
F-16A/C	1,595	McDonnell Douglas	ACES II	1,595
F-16B/D	103	McDonnell Douglas	ACES II	206
F-117	54	McDonnell Douglas	ACES II	54
Total Aircraft:	4,099		Total Ejection Seats:	6,191

Source: Kirtland AFB, New Mexico and Hill AFB, Utah

The inventories are a snap-shot of aircraft inventories at the end of 1996. The Air Force had 6,191 ejection seats in 4,099 aircraft (average of 1.51 per aircraft). The numbers include aircraft used by the Air National Guard and the Air Force Reserve. The numbers change frequently as aircraft are retired and new ones added. The F-4s have now almost all been retired. Desert Storm saw their last major missions in anti-radar sorties ("Wild Weasels") and as escorts for the anti-tank A-10 Thunderbolts ("Wart Hogs"). The A-10s were also being retired, but after their distinguished Desert Storm service, that decision was reconsidered. They may be transferred to the Army in the future.

The total number of ACES II seats in Air Force inventories is 3,738, or about 60 percent of the seats in the current inventory. More than 1,500 additional ACES II seats are in foreign fleets,

mostly in F-16s and F-15s exported from the United States. The F-16As, which were first delivered for service in August 1978, combined with the F-16C upgrade contained the greatest number of ejection seats in the Air Force fleet at 1,595 at the end of 1996. The much older T-37 trainer, which initially entered the fleet in the 1950s, has a Weber Aircraft Company ejection seat as do the B-52s. First flight of the B-52s was in April 1952. The U-2s were held secret for many years. They came out of Lockheed's famous "Skunk Works," also initially in the 1950s.

The only Martin-Baker seat currently in Air Force inventories is in the few remaining F-4s, now used as drones. The Martin-Baker seats are Mark-7 series, and about 20 years old.

The Navy ejection seat inventories include Marine Corps seats on the AV-8s and those on Reserve Unit aircraft. At the end of 1996, a total of 3,124 seats were installed in 1,805 aircraft (average of 1.73 seats per aircraft). The Navy has many more two seaters than the Air Force. Martin-Baker ejection seats total 1,818 or about 58 percent of the Navy total. The NACES seat totals 630, slightly more than one-third the company's total. The Douglas Escapac is on the S-3 (four seater) and the TA-4s (two seater).

U.S. Navy Aircraft Inventory with Ejection Seats (1996)				
Aircraft	**# of Aircraft**	**Ejection Seat Maker**	**Ejection Seat Designation**	**# of Seats**
F-14A	209	Martin-Baker	GRU-7 (Mk-7 Series)	418
F-14B	80	Martin-Baker	GRU-7 (Mk-7 Series)	160
NF-14A	5	Martin-Baker	GRU-7 (Mk-7 Series)	10
NF-14B	1	Martin-Baker	GRU-7 (Mk-7 Series)	2
NF-14D	5	Martin-Baker	GRU-7 (Mk-7 Series)	10
EA-6B	64	Martin-Baker	GRU-7 (Mk-7 Series)	256
AV-8B	198	Stencel (Talley/UPCO)	SJU-4/A	198
YAV-8B	2	Stencel (Talley/UPCO)	SJU-4/A	2
TAV-8B	36	Stencel (Talley/UPCO)	SJU-13A & SJU-14A	36
S-3 T/M/S	135	Douglas (McDonnell Douglas)	Escapac (IG-3)	540
T-2C	2	North American (Rockwell)	LS-1A	4
NTA-4 T/M/S	2	Douglas (McDonnell Douglas)	Escapac (IG-3)	4
TA-4J	122	Douglas (McDonnell Douglas)	Escapac (IG-3)	244
F/A-18A	276	Martin-Baker	SJU-6/A (Mk-10 Series)	276
F/A-18B	33	Martin-Baker	SJU-5/A & 6/A (Mk-10 Series)	66
F/A-18C	143	Martin-Baker	SJU-6/A (Mk-10 Series)	143
F/A-18D	52	Martin-Baker	SJU-6/A (Mk-10 Series)	104
F/A-18C	228	Martin-Baker	NACES	228
F/A-18D	78	Martin-Baker	NACES	156
F/A-18E	1	Martin-Baker	NACES	1
T-45A	75	Martin-Baker	NACES	150
F-14D	47	Martin-Baker	NACES	94
T-38A	11	Northrop	70200 Series	22
Total Aircraft:	1,805		Total Ejection Seats:	3,124

Source: NSWC Indian Head Division

3. Summary of Industry Survey and Site Visits

3.1 The Shrinking Business Base

Major reductions in U.S. and worldwide defense expenditures in the last decade have severely damaged the competitive position of U.S. companies participating in the ejection seat industry. Military spending reductions impact this sector severely because the product has no commercial counterpart. As new ejection seat requirements decline, private resources are shifted out of ejection seats into other areas. A critical economic mass may no longer be sustainable, given the lack of near-term business prospects, and continued decline in expert competence in the sector. Although the military requirement for ejection seats will continue, albeit at a reduced level, private U.S. companies are hesitant to invest scarce capital resources and reluctant to train their best technical personnel in ejection seat-related areas for the future.

3.1.1 Defense Budget Cuts - Survey responses and conversations with company representatives clearly underscore the damage done to the U.S. industrial base. Universal Propulsion Company (UPCO) in Phoenix, Arizona is not currently making ejection seats and sees little, if any, prospective business in the near future. The firm is aggressively shifting its attention to more promising commercial outlets. McDonnell Douglas vacated a more mechanized Long Beach manufacturing operation to reduce overhead costs, but continues assembling seat structures from purchased parts at near minimum economic quantities at its plant in Titusville, Florida. The company may move the seat operation to St. Louis if the production quantity continues to decline.

Other companies have experienced difficulties also. Weber Aircraft Company, the "follower" on the ACES II program under the U.S. Air Force's Leader-Follower program, closed its ejection seat production operations in Fullerton, California, in 1992, after losing the winner-take-all competition to McDonnell Douglas for the ACES II seat.

East-West Industries closed its Hauppauge plant on Long Island, New York, and lost a large investment as the selected "follower" on the U.S. Navy's NACES ejection seat when that program was canceled in 1992, due to substantial reductions in requirements. By order of Congress, the Navy converted East-West's status to one of "directed supplier" (i.e., must use) of specified NACES components (the seat bucket, survival kit, firing handle, and snubbers). Other high value items were also directed to U.S. suppliers. In 1997, with less than 40 new NACES

seats on order, components will account for only a small portion of East-West's production at its Ronkonkomo facility on Long Island.

The reductions in business have caused a sharp drop in employment, including early retirements and shifts of engineers and designers into other areas. In the United States, new capital investment has been minimal or non-existent for a number of years. Internal research and development expenditures are being directed to other activities. The supplier base for major ejection seat components, propulsion units, cartridge actuated devices, and metal parts for the seat structure is shrinking, as firms exit the business, file for bankruptcy, or fail to meet quality and performance requirements. Sole sourcing has become more commonplace. Also, unit prices at all levels of the supply chain are rising as overhead is spread across smaller production lots.

Cuts in military expenditures compelled both the U.S. Air Force and Navy to close down their Leader-Follower programs, and led to sole sourcing of the ACES II and NACES ejection seats. One affected firm said that sole sourcing "will in the long run lead to higher prices because of the lack of competition."

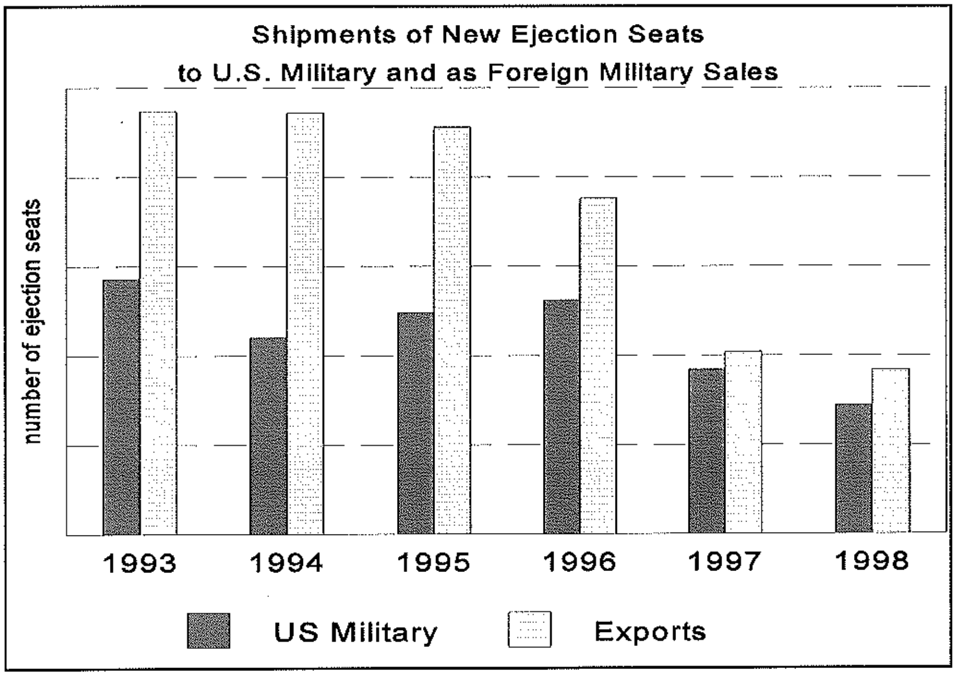
All eight of the survey participants commented on the impact of defense budget cuts on their ejection seat activities. Several companies protested the sending of scarce research and development dollars to foreign competitor firms by the U.S. Government. One firm reported that the willingness to generate internal research and development could be lost if foreign funding continues. Another company said that a majority of its own R&D funds are already flowing into non-ejection seat/non-DoD activities. One company noted that the U.S. Government will have to fund ejection seat development and demonstration projects, which private U.S. firms cannot afford under current risk assessments. However, private firms can continue to fund production-related expenses.

Global defense reductions have also negatively affected the two major foreign seat makers, Zvezda in Russia and Martin-Baker in the United Kingdom. Sales by both companies have declined as a result of both the reduced requirements for new seats and the retirement of exisiting aircraft from international inventories. Both companies are also more aggressively targeting the United States market. For example, Martin-Baker's seat was in the aircraft awarded the Joint Primary Aircraft Training System (JPATS), capturing the ejection seat business in competition with UPCO. This will represent sales of over 1,400 seats over the next decade, and possibly many more in international markets.

The JPATS was very important for UPCO to remain viable in the seat structure end of the business. The loss of this contract diminished the firm's future prospects. However, the firm will continue supplying replacement propulsion units and pyro to both the ACES II and NACES seats as well as the existing inventory of U.S. and foreign ejection seats.

As for Zvezda, U.S. interest in the high speed ejection capabilities of the company's K-36D seat has resulted in a joint $9+ million investment by the U.S. Air Force and Navy, and potentially puts Zvezda in contention for the JSF (Joint Strike Fighter) seat competition. If the seat is successfully adapted to U.S. cockpits, licensed production for all, or almost all parts, will have to be established. Currently, there are no plans to incorporate a Russian manufactured seat directly into U.S. aircraft. It appears to make business sense to cooperate with Zvezda for a number of reasons. The company's technical capabilities are a good match for U.S. marketing skills and business experience. Also, Rosvoorouzhenie (the Russian Import/Export Authority) has no immediate plans to sell Zvezda products to countries that do not now have Russian aircraft in their inventory.

3.1.2 Reported Shipments - Reported shipments of ejection seats for use by the U.S. military and international sales from the United States fell (or will fall) each year from 1993 to 1998. The accumulated drop reached over 50 percent by 1997, and is projected to reach nearly 65 percent by the end of 1998. The U.S. share of the world market (excluding Russia and China) for new ejection seats also fell, from over 55 percent to less than 30 percent. This occurred while the global market was shrinking. The drop was more severe in international sales from the United States. And, if Martin-Baker's shipments from the United Kingdom to the Navy were excluded, shipments to the U.S. military by U.S. sources dropped by nearly 80 percent, while international sales fell by somewhat less. The graph that follows presents these trends. Numbers are withheld to protect company proprietary information. The graph includes Martin-Baker's shipments to the U.S. Navy aircraft.

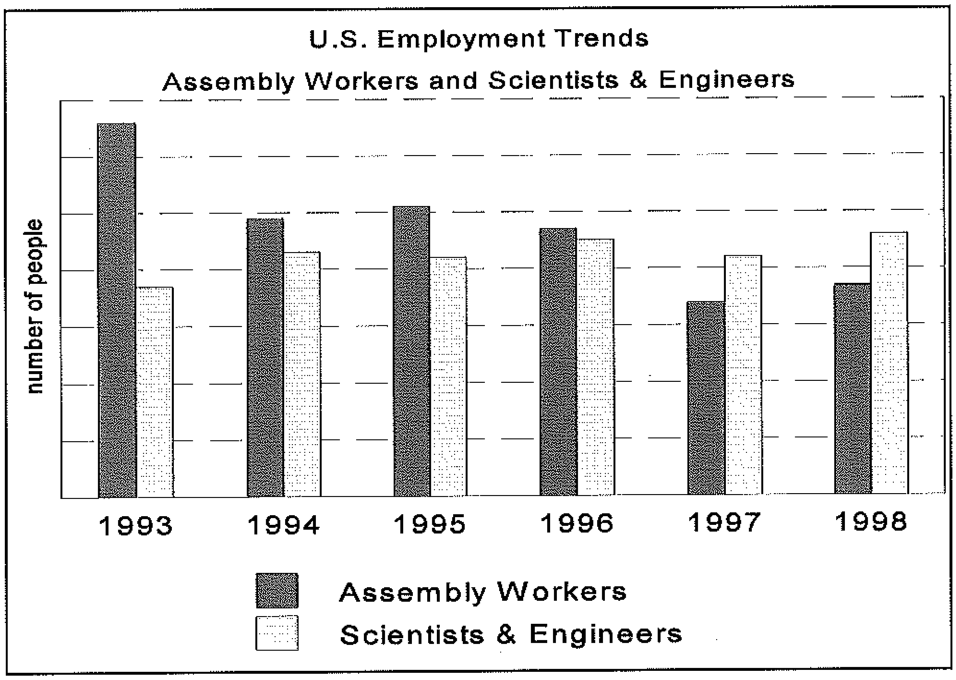


Source: U.S. Department of Commerce, BXA/SIES Industry Survey

Shipments of components and pyro for both new seats and for the spares market also declined, but much less severely compared to new seat shipments. The aftermarket is very important to the overall revenues of UPCO and Martin-Baker, but has little value for MDC, who does not compete in this sector. Revenues for testing and R&D were also significant for some firms, but do not contribute to current ejection seat revenues or aftermarket revenues.

3.1.3 Employment Trends and Concerns - Six of the survey respondents reported employment in the U.S. ejection seat sector will decline by over 20 percent by 1998, from the 1993 base year. Two companies reported that seat assembly workers will drop by nearly 44 percent, tracking the sharp downturn in production. The larger drop in production than in employment indicates a productivity decline. This normally leads to higher costs and prices. Scientists and engineers showed a slight net increase overall, led by a few companies' expansion into ejection seat-related research and development projects. The ratio of production workers fell from over 55 percent of the total workforce to about 40 percent. This displacement resulted in an increase in scientists and engineers. Their ratio in the workforce increased from 40 to about 50 percent.

The chart below is a visual representation of these trends. Again, the numeric values are not displayed to protect company proprietary information. The slight increase in assembly workers shown in 1998 is the anticipated start-up of a new firm into the business, initially on a small scale.



Source: U.S. Department of Commerce, BXA/SIES Industry Survey

Companies were asked to report any labor concerns they experienced in the last five years. Several companies, one of which exited the business, reported no problems. Other firms cited, as expected, that the reduced production rates forced layoffs and reassignments. Expertise is increasingly concentrated in one or only a few individuals. Concerns about age were reported as another issue. Many engineers are nearing retirement age, with little likelihood of replacement under current market conditions.

The major component manufacturers are experiencing similar problems, with increased turnover. Loss or reassignment of experienced people has led to quality and performance problems among some firms in the supply base.

Future prospects for the labor force reportedly will mirror the experience of the recent past.

Mentioned were a continued loss of design experience, including for subcomponent technology improvement. Also, firms expect further concentration of engineering knowledge in still fewer individuals and higher turnover rates. Older, experienced workers will retire without replacement. This impacts both industry and government operations through a continuing erosion of the expertise base. One company reported that employees with specialized skills, who are laid off continue to disappear into other industries or move to other positions and cannot be rehired. The potential for a shortage of skills and expertise is a very real prospect. Only one survey respondent reported a part-time trainee.

In contrast, Martin-Baker's employment was stable over the period (1993-1998), although the company has downsized over the previous decade to align itself with market conditions. Part of the decline is also due to productivity enhancing investments. The company employs many times the combined American total, and has several times as many scientists and engineers. Labor relations in the U.K. are good, without any problems reported by Martin-Baker in the last ten years. The company pointed out that the problems of Northern Ireland have no effect on daily operations at their Langford Lodge facility. The company also has a high percentage of long-term and second-generation employees, including members of the top management.

Laborers work a 37 hour week in the United Kingdom, and have eight paid holidays (bank holidays). The company anticipates a possible shortage of some specialist skills in the next five years, but will meet the need with ongoing internal training programs. The company reported a continuous stream of a half-dozen or so trainees.

3.1.4 Investment and Profitability - Four of the eight survey respondents reported that no capital expenditures were (or will be) made from 1993 to 1998. These four companies, all U.S. firms, considered the "zero investment level" appropriate to support existing orders or planned levels of activity. One of these firms stated that it changed its investment strategy in recent years from one of "anticipatory" investments to a "wait-and-see" approach. The firm now requires an order in hand before allocating needed investment. Two other companies also reported that capital investment was expansionary. Both of these firms hope to enter the business. The following table is a summary of the views reported by the eight surveyed firms.

Company Views on Investment	
Company Considers Investment to be:	**# of Companies Responding**
Not Enough	0
Adequate	6
Expansionary	2

Source: U.S. Department of Commerce, BXA/SIES Industry Survey

The six-year aggregate capital outlay by the seven U.S. companies was much less than $1 million. In contrast, Martin-Baker invested many times that amount. In fact, the firm accounted for well over 90 percent of total capital outlays in each survey year. How much of Martin-Baker's capital investment applied to the company's U.S. business is unstated. However, the company requires more investment merely to sustain its large integrated manufacturing operations. Also, the firm's "do-or-die" dependence on international revenues compels the company to invest very aggressively in the world's latest technologies and equipment to remain competitive.

If the data included the investments of non-surveyed major American subcontractors for whom ejection seats are only a small part of revenue, such as Pacific Scientific, Teledyne, and others, the picture might not appear so overwhelmingly one-sided in Martin-Baker's favor. Some subcontractor equipment may be unique to ejection seats, such as specialized test equipment. However, the bulk of assets would most likely be multipurpose machinery, with only a small portion of any new investment actually allocated to ejection seats.

With the market shrinking, the fragmented U.S. ejection seat sector has little or no compelling reason to invest. Some investment is undertaken by the U.S. Government. For example, the U.S. Government owns and pays for the upkeep of some of the tooling needed for producing and assembling structural details of the ACES II structure.

All companies reporting shipments also reported profits. In fact, no survey respondent reported a loss for any surveyed year. The regulations allow companies to operate on a cost-plus basis. Profitability on ejection seat activity is not really the issue so much as the "opportunity cost," that

is, the cost of maintaining resources in the ejection seat sector that companies could conceivably redeploy more profitably elsewhere. This cost is rising in the United States. It implies the U.S. military will have to pay a higher price to keep a domestic capability in place, unless the market is enlarged.

3.1.5 Subcontractor Developments - The drop off in ejection seat business was accompanied by a significant drop in the number of U.S. subcontractors supplying various components to the ejection seat sector. Counting the machine shops that supply metal parts for the seat structure, the overall number of first-tier subcontractors may have dropped from over 100 to less than 50. With Weber's ACES II production line closed, and UPCO not currently making seats, the number will undoubtedly decline further. MDC reduced its subcontractor base to one-third the former number in an effort to reduce administrative costs and maintain economic production quantities at selected subcontractors.

Several survey respondents reported that they had discontinued business relations with a total of 12 U.S. subcontractors since 1993. The respondents provided reasons for doing so, and reported the impact these closed accounts had on their operations. Frequently, more than one reason was cited, and problems in one area often indicated problems in other areas. The most frequently cited reasons for discontinuing specific subcontractor sources were quality and performance problems, both of which are critical to ejection seat costs and delivery schedules. Each of these reasons was cited six times. Three subcontractors went out of business, one of which was also cited for quality and performance difficulties. Three subcontractors were no longer price competitive. One of these also reportedly had quality problems, and another was cited for performance problems. One subcontractor exited the product line, and one had to be dropped because there was not enough business to keep it active.

A variety of products were supplied by the discontinued subcontractors. These included parachutes, oxygen cylinders, control assemblies, thermal batteries, machined tubes, castings, and structural details. The loss of these subcontractors disrupted the seat makers' operations by causing schedule delays, quality concerns, and cost increases. In a few instances seat makers had to find and qualify new sources. There was also a shift of some business to foreign sources, and concern was expressed over the potential lack of available sources for oxygen cylinders and thermal batteries.

Along with recently closed subcontractor accounts, the survey respondents reported on subcontractors that may become problematic in the future. Environmental prohibitions on

calcium chromate have already caused problems for more than one ejection seat company in the procurement of thermal batteries. The major source of the highly specialized batteries used on ejection seats is Eagle Picher in Joplin, Missouri. Eagle Picher has been in bankruptcy for a number of years, which raises additional concerns. The company also had a fire in its facility. To deal with the environmental issue, MDC switched to lithium batteries. The battery price rose at first, but then settled back. The battery also has maintained its quality and performance. Martin-Baker took action to qualify a second source, MSA Company, located in Scotland.

The information on closed subcontractor accounts is presented on the following table.

Reported Subcontractor Accounts Closed (1993 - 1996)		
Reason Account Closed	**Total Number of Mentions**	**Number of Times Mentioned as Only Reason**
Had quality problems	6	1
Had performance problems	6	1
Went out of business	3	2
Was no longer competitive	3	1
Exited product line	1	1
Not enough business	1	0
Other (facility fire and envir.)	1	1

Source: U.S. Department of Commerce, BXA/SIES Industry Survey

Other reported problems are related directly to the low level of ejection seat business. For example, a second source is also being developed for time delays and gas actuators for the NACES seat. The current manufacturer, a sole source for these items, reports that the low order quantities are not economical. In addition, the present manufacturer of oxygen cylinders for the ACES II seat may exit the product line. An alternative source is not presently qualified.

There are several implications for the U.S. military. First, the impacts of declines in the ejection seat business are spread very unequally across the subcontractor group. For any particular

subcontractor, the impact would be a function of the relative importance of ejection seats to overall revenues. Under this criterion, most subcontractors would not be significantly injured economically by a decline in their ejection seat business. Most could quite easily recover lost revenues by boosting efforts in other product lines. In other words, they have low investment, low risk options. This implies that companies in this class could easily exit the ejection seat business as business drops, but also re-enter when needed. Companies in this class include some of the metal benders, fastener makers, raw material melters, and electronic subcomponents.

In contrast, other subcontractors would be more severely impacted, and be forced to cut their workforces and, in some instances, perhaps go out of business. This group, which probably includes some of the major component manufacturers and some of the pyro companies, has the most urgent incentive to find ways to enlarge their market horizon. For example, they might consider expansion into global markets, or diversification into more lucrative product lines. Both avenues would require capital outlays, and involve considerable risk. The implication is that these subcontractors have an incentive to reduce the relative importance of the U.S. ejection seat market on their business. A company's best engineers and other people are seldom left on obsolete, secondary, or declining business lines. This could add to the brain drain and loss of entrepreneurial dynamics and innovation within the sector.

Second, current low production volumes are near levels where only one, or at most two, sub-component manufacturers can be sustained economically. As already witnessed, prices have crept upwards. This leads to two implications. One, the occurrence of sole sourcing should increase, in part as a measure to save costs, but also to preserve at least one viable domestic source. And two, the incidence of foreign sourcing of ejection seat parts and components can be expected to increase. Global sourcing in a shrinking market would contribute to lower costs.

Reports on subcontractors were received from MDC, Weber, UPCO, and Martin-Baker. Martin-Baker stipulated its report applied to the NACES only. Sole sources were reported for inertia reels, stabilizers (the gyro), emergency oxygen, and electronic sequencers.

3.1.6 Competitive Prospects - Competitive yardsticks in the ejection seat industry include prices, quality, timely delivery, technical competency, and support. Competition occurs on several levels in ejection seat related activities. These include 1) new seat competitions, 2) the aftermarket for major component and pyro products, and 3) government and private sponsored R&D projects. Political considerations, nationally and internationally, are also ever present, and frequently may determine outcomes.

Martin-Baker competes successfully in each of the three areas. By maintaining its strong position in the global aftermarket, Martin-Baker can bid lower on new ejection seat contracts (and/or spend greater amounts on front-loaded marketing) with the prospect of recovering expenses over the life of the ejection seats. This confers a major competitive advantage over companies that compete in just one area.

Two additional critical factors, especially affecting the U.S. ejection seat sector, include 1) the pervasive presence of the government in all aspects of the business; and 2) monopsony (single buyer) power of the military to influence company behavior. Apparent consequences of the government's pervasiveness, which includes many anti-competitive aspects (e.g., small or minority business set-asides, difficult to change product specifications, splitting procurement, export controls, low-priority in budget battles, etc.), have been mostly negative. They have encouraged industry fragmentation, discouraged marketing activities, and stifled innovation.

A measure of a competitive firm is one that *maintains* or *expands* its relative market share over time. Under this definition, a firm may still be competitive, even in a shrinking market. However, most American firms have lost market share to a degree greater than the decline in the global market, and would be judged non-competitive. In contrast, Martin-Baker appears to be increasing its relative share of a smaller pie, and so would be judged competitive. This is evidenced by their expansion into supplying the Swedish market since Saab exited the business and their gaining the JPATS contract. The company is also aggressively pursuing the JSF contract. Moreover, there appear to be mounting financial pressures in other countries to shut down various production sharing agreements in Martin-Baker's favor.

The drop in U.S. firms' competitive standing is tied directly to the rapid decline in U.S. military requirements for ejection seats. However, to put this in historical context, the U.S. ejection seat market *was* the global market for many years. In the decade ending in 1965, the United States purchased about 75 percent of the free world's military aircraft. Britain was a distant second, at only eight percent. Over the next decades other countries built up their air forces, and in selected countries an aircraft industry, steadily eroding America's dominance. Also, the U.S. military took the technology path, and focused on building better, but fewer, aircraft. This also contributed significantly to lowered ejection seat requirements.

Despite indications that one of the JSF competitors may use a U.S. made seat in their concept demonstrator aircraft, the overall competitive prospects of U.S. ejection seat makers are not strong at this time. The two or three seats used in the concept demonstration phase do not mean

that seat will be chosen by that competitor should they win the JSF production contract. A glimmer of hope expressed by American seat makers would require advancing by a few years the anticipated T-38 trainer re-seating program, displacing Martin-Baker in the JSF, and more intense export marketing efforts.

However, real gains in long-term competitiveness hinge on developing the world's finest "core" ejection seat, pursuing aggressively domestic and global marketing opportunities, and presenting customers with a fast-response, full-service capability. This core seat would represent a hybrid of current and fourth generation technologies. It's doubtful this can be accomplished without consolidation and integration of the scattered and decentralized ejection seat assets in the United States. Moreover, a new seat has not been developed by a U.S. firm since 1975. In contrast, Martin-Baker has developed the NACES and the Mark 16, and is continuously trying to improve its product.

Based on survey responses, U.S. firms involved in the industry see their competitive prospects on the decline. Two companies did not answer, although in discussions, their prospects were not presented as promising. U.S. companies heavily involved in research and development expressed more optimism. One of these companies reported its prospects would improve greatly. Two other companies reported prospects as improving somewhat.

Competitive Prospects		
Prospect	**Mentions**	**Ejection Seat Activity (# reporting)**
Improve greatly	1	R&D
Improve somewhat	2	Seats (1), R&D (2), Components (2)
Stay the same	1	Components
Decline somewhat	2	Seats (2), Components (1), R&D (1)
Decline greatly	0	-
Did not answer	2	Seats (1), R&D (2), Components (1)

Source: U.S. Department of Commerce, BXA/SIES Industry Survey

The ACES II and NACES ejection seats are not subject to competition in the conventional sense. They are produced in quantities to meet requirements. Competition in the short term is not

viewed as particularly relevant. However, efforts continue at both Martin-Baker and MDC to contain costs and pursue strategies that might enlarge the market, including exports.

As discussed above, two trends eroding the competitive prospects of the U.S. ejection seat industry are: 1) a lack of new business opportunities; and 2) a dwindling technical expertise base with design/production experience. The first trend is of immediate concern. The second trend is longer-term with serious consequences. A worst case scenario would be for the United States to lose the technology and know-how. Some industry spokespersons believe we may be well along that path, and in the future it will be costly to catch up with the state-of-the-art producer. The number of persons with ejection seat design/manufacturing experience is at a critically low level, and is projected to fall to a still lower level in the future. The entire world probably employs fewer than 50 such persons, and most are employed by Martin-Baker and Zvezda. Considering that it takes 10-15 years of apprenticeship to gain this competence, the United States is indeed confronted with the possibility of a critical skill shortage.

3.2 Reported Research and Development

3.2.1 Major Government Initiatives - It is estimated that over 90 percent of the U.S. R&D dollars for ejection seat development and testing comes from the Air Force and U.S. Navy. Most of the actual dollar outlay is funneled to private companies with the wherewithal and technical expertise to conduct the R&D. A major thrust of the current effort is the need to expand the seats' capabilities to accommodate the expanded crew weight range (103-245 pounds). Also, the performance envelope of newer aircraft is expanding. Improved stability at higher speeds, and low-level adverse attitude ejections is also a high priority. Headway is being made on both these efforts.

McDonnell Douglas is under contract to the U.S. Air Force for the joint Air Force/Navy funded Fourth Generation Escape System Technologies Demonstration Program. The "4th Gen" program is a five year program initiated in February 1993, at a total cost of about $20.5 million. The primary objectives of the program are to demonstrate propulsion, flight control and high-speed protection technologies. The propulsion requirement is for a controllable propulsion system, which will stabilize the seat and occupant at high-speed and propel the seat and occupant away from the ground in an ejection at low altitude adverse attitude conditions.

Phase I included the generation of operational requirements and the preliminary design of the

primary subsystems: controllable propulsion unit, digital flight controller, inertial measurement unit, life-protection devices, recovery parachute, and the seat structure. In Phase II, which began in July 1995, all the various subsystems were mounted on a standard ACES II seat structure for sled testing to demonstrate controlled propulsion and the high speed protection devices. The propulsion system is equipped with a computer-controlled pintle nozzle system that opens and closes small valves to direct the rocket thrust for stabilization. The demonstration tests are being conducted at the rocket sled test facility at Holloman AFB in New Mexico in a series of ejection seat tests at speeds for 0 to 700 KEAS (i.e., knots equivalent air speed).

The Implementation Development Program for fourth generation technologies must address the major technical issues needed to make the full aircrew accommodation seat operationally suitable for fleet use. Seat hardware and design will be modified and tested in order to fully accommodate the issues of maintainability, reliability, safety, logistics, affordability, and life cycle costs.

Another on-going program is Technology Upgrades, which provides an opportunity to upgrade existing seat assets. This program applies the technologies demonstrated under the Fourth Generation Program, Small Business Innovative Research Program investment, and other developments to design, fabricate, and test components. These technologies include controllable or variable thrust catapult, advanced propulsion, computer controller logic, signal transmission, and recovery systems.

The Russian K-36D Ejection Seat System Technology Demonstration program has received much publicity. The K-36, produced by Zvezda, is installed in all Russian high-performance combat aircraft. An upgraded version was also used in the Buran space shuttle. Seventeen K-36D tests have been successfully completed under the Foreign Comparative Technology funded evaluation in Russia and at Holloman AFB. These tests demonstrated excellent stability throughout the speed range from zero to 755 KEAS, and exceptional performance under low-speed, adverse-attitude conditions. They also demonstrated excellent windblast protection and reduced occupant accelerations. Those Russian ejection seat technologies which proved to be superior to ours could be adapted to the U.S. development program with the assistance of Zvezda engineers.

3.2.2 Surveyed Projects and Totals - Seven of the eight respondent companies reported research and development activity. The total amount reported for the six years (1993-1998) was $118 million, or just under $20 million a year. About 15 percent ($18 million) was company financed; the remainder came from the U.S. or foreign governments. The three companies with the largest R&D accounts totaled nearly $101 million, or more than 85 percent of the total.

The seven respondents reported a total of 15 on-going R&D projects totaling nearly $80 million. The largest of these, all government funded, were the Fourth Generation, the U.S. Navy's Advanced Technology Escape System, and the Eurofighter 2000 project. These three programs alone amounted to well over $50 million. Other large government projects included "subcontracts" on the Front Line Ejection Equipment Test (FLEET) and the K-36DM3.5 Project. The two-year K-36DM3.5 project (Rockwell-Zvezda) is also co-sponsored by the U.S. Air Force and Navy.

3.2.3 Potential Additional Projects - The survey respondents suggested several areas for consideration. With no production programs on the five-year horizon, R&D money could be targeted at maintaining the industrial base. For example, methods to reduce the development and acquisition costs of seat improvements could be examined. Cooperative programs between industry consortiums and the U.S. Government could be funded to develop and demonstrate alternate "back-to-basics" approaches to providing ejection seats that work and are simple to operate and maintain. And, the design, development and qualification of a core ejection seat design could form the foundation for ejection seats that are competitive on the world market.

In other areas, the upgrade of existing seats on some aircraft could improve the ejection seats' performance and accommodate small female pilots as well as help the industrial base. Aircraft such as the T-38A Talon (the advanced trainer) that currently uses a Northrop seat and the F-14A/B (with a Mk7 Martin-Baker seat) are also candidates for upgrading. The ACES II and NACES could also be upgraded and retrofitted for small occupants.

The need for improved high speed and adverse attitude seat performance, and the decision to allow female pilots to routinely fly ejection seat equipped aircraft, have been a driving force in the development of so-called fourth generation technology. While this technology might eventually lead to a next generation seat, the same technology could potentially be applied to current seats as a retrofit effort to improve overall seat performance. Certainly the ACES II seat, with over 5,000 currently flying worldwide, could be a candidate for such an upgrade program.

Various efforts are underway to develop systems upgrades for the ACES II Continuous Improvement Program (CIP), especially in the areas of seat stability and limb restraint. One such program is a joint U.S.-Japanese effort, initiated at the request of the Japanese. This project is still in the planning stages pending final funding authorization and the signing of a formal memorandum of understanding between the United States and Japan. The purpose of the effort is to share in the development of technology to produce retrofit kits for improvements in ACES II seat performance. While the program does not address the actual retrofitting of seats, it will result in all necessary technology to initiate retrofit kit production. Both sides will have the data to build the kits, with the decision to produce and install the kits to be made separately by each country.

If a decision were to be made to upgrade the ACES II fleet with a retrofit kit, the impact on the U.S. ejection seat industrial base could be quite significant. With over 3,700 seats in the U.S. inventory alone, the development and production of such kits would equate to multi-million dollar contracts for the company(ies) involved. Marketing the kit internationally would further boost the value of such an effort.

Respondents also suggested follow-on research. These included: 1) funding for the concept demonstration of the system-level integration design developed by the Advanced Technology Escape System program; 2) design, development and qualification of a fourth generation seat utilizing technologies being demonstrated in the fourth Generation program; 3) a JSF program to fully integrate life support systems with the cockpit environment; 4) an ejection seat and occupant to match performance and operational requirements of the aircraft; 5) funding for further improvements in performance capabilities of the NACES under the Pre-Planned Product Improvement program; and, 6) balance the emergency escape value and the aircraft mission capability of the seat configuration by using "smart-mission" related improvements packaged into seat volume.

3.3 Government Regulatory Issues

3.3.1 Export Controls - Exports of ejection seats, major seat components, and ejection seat pyro devices require a validated license under the International Traffic in Arms Regulations (ITAR) administered by the U.S. Department of State, Bureau of Political-Military Affairs, Office of Defense Trade Controls. The State Department controls these exports under authority of the Arms Export Control Act. Items under the jurisdiction of the ITAR are collectively known as the munitions list. The United States and other NATO countries, notably the United Kingdom where Martin-Baker is located, each maintain such a list.

(Note: Information from the 1995 "National Security Assessment of the Cartridge and Propellant Actuated Industry" page 58-59, was relevant to developing this section.)

The implementation of licensing procedures is different from country to country, making the actual export license less costly and more quickly attainable in some countries than in others. For comparative purposes, we reviewed the procedures of the United Kingdom. The British, with a relatively small domestic market, must trade to maintain their standard of living. A very large share of the country's gross national output is exported, and by no accident the British Government is very supportive of exports. Martin-Baker exports over 80 percent of their production. The firm has received eight Queen's Awards for exporting over the years for this outstanding performance.

In the United Kingdom, two levels of control govern munitions ("weapons" in U.K.) exports. The less strict control applies to most of Martin-Baker's exports. The company acquires a "general undertaking" from its foreign customers that the "end-user" is on an approved countries list. A blanket license covers the exports. A stricter control on more lethal products requires a specific license against each purchase order, and end-user statements from the actual end-user.

Munitions exports to certain countries, such as Iran, Iraq, and Libya are never licensed by the United Kingdom or by the United States. In other situations, licensing decisions may vary depending on U.S. or UK foreign policy. For example, Martin-Baker obtained approval to export ejection seats to Pakistan, while in the United States, U.S. companies believe that the U.S. policy is to deny any munitions exports to Pakistan, including ejection seats. Consequently, MDC viewed this as a deterrent to supplying seats to the Swiss firm Pilatus that had plans to export aircraft to Pakistan. A result is that MDC will also miss out on Pilatus shipments to other countries, since it's uneconomical to support more than one seat type.

In the United States one level of control applies to all munitions exports. A specific license is required on each transaction. Several respondents noted that the export license review process should be simplified and speeded up because it is cumbersome, time consuming, and frustrates foreign customers. It was reported that the lead time required to obtain a license is typically 3 months, and may take a year in rare instances. Delay or denials have caused export opportunities to be lost, and interfere with planning production runs and shipment. Timing is a critical factor, especially for components in which very aggressive international competitors benefit from a more expeditious export licensing regime.

The United States has changed its licensing policy from time to time due to international conditions. One ejection seat firm was forced to write off a large sum as a result of such a change. One firm said the current system makes it extremely difficult to be competitive in the world market. Based on our discussions with the State Department offices of licensing and commodity jurisdiction, we have gone back to the survey respondents to request additional detailed information. Specifically, we requested details where State Department procedures and policies delayed or denied U.S. ejection seat-related exports.

Several firms suggested that life-saving items such as ejection seats should be removed from munitions control. Another spokesman said his firm simply wanted a level playing field. He added, "the rigid procedure now in place is fine for certain weapon systems, but does it really apply to ejection seats?" He said that the State Department should consider a two-tier system, and simplify the licensing process for U.S. firms that must compete against U.K. firms for the same sales of non-lethal equipment.

According to the State Department, there are several areas where improvement can be made by the exporter to ensure that license determinations are issued in a timely manner. The exporter must first submit required company information to register with the State Department. Once the formal registration is completed, license requests for the export of munitions will be reviewed.

Export license applications should be thoroughly reviewed by the applicant prior to submission to the State Department to ensure that all proper supporting documentation has been submitted which is pertinent to the transaction, such as import certificates and contract documents. The supporting documentation must also contain a full product description of each item to be exported along with literature which outlines the technical parameters of the product. An end-use statement must outline specifically the intended end use of the product and the full name and street address of the ultimate end user. All end-use statements must be specific and not general

in nature. For example, if the intended end use of the exported item is for scientific research, a full description of the ultimate end user's facility, as well as information concerning the type of research, name of the project, and nature of expected results, is required.

3.3.2 Leader-Follower Program - The Leader-Follower (L-F) programs in ejection seats were efforts on the part of the U.S. Air Force and Navy to: 1) ensure prices paid for ejection seats by the U.S. taxpayer were competitive; and 2) provide second source security. However, eventually both of the L-F programs were overtaken by defense downsizing, which led to their early cancellation. Had events played out differently, such as a major increase in the procurement of combat aircraft, both services' programs would be judged successful in accomplishing their objectives.

An important rationale for instituting the L-F program was that ejection seats are <u>not</u> optional equipment in modern combat aircraft. Ejection seat requirements represent what is called a perfectly "inelastic" demand curve; that is, a situation where price increases will not change the requirement for the product. This would give pricing leverage to a single-source company, and arguably weaken the company's incentives to control production costs. Presumably, competition would remove this leverage. Another consideration, which may not have clearly applied at the time these programs were initiated, is that competition in small or limited markets such as ejection seats, with high start-up and overhead costs, can also be destructive.

L-F was used by the Air Force to re-establish competition, following a decision to go with a single basic ejection seat, the ACES II, from a sole manufacturer, MDC. It was thought that establishing a viable second source to compete against MDC would moderate prices, and save the taxpayer money. The Air Force program, initiated in 1976, was successfully implemented and did, in fact, moderate ejection seat prices. In 1992, with new seat business falling, it was no longer cost effective to support two producers; the program was abandoned following a winner-take-all competition, which MDC won. The Navy began a L-F program in 1985, when Martin-Baker was awarded the NACES contract. However, the Navy effort was never brought to completion. The Navy project was also abandoned in 1992, because of sharp declines in new orders for ejection seats.

The ACES II Program

The Air Force decision to go with just one basic seat was premised on cost efficiencies. By using mostly common parts and components across airframes, one seat type could be supported at a much lower cost. Further, greater production quantities of a single type seat (i.e., economies of scale) for all Air Force combat aircraft would potentially add production efficiencies and further lower the actual per unit cost of the seat.

As previously stated, L-F requirements were written into the August 1976 production contract awarded by the U.S. Air Force to MDC for the ACES II. Under the L-F, a competition was conducted, which resulted in MDC's selection of Weber Aircraft Company as *follower* in September 1977. Other entrants included Stencel, East-West Industries, Tally/UPCO, and American Gear. Weber and several other entrants had prior experience making ejection seats, which probably increased the likelihood of success in this program and made the effort less costly.

Weber did not risk its own capital. Capital for the project was furnished by the Air Force through MDC, which had hands-on training responsibility. Over the next several years, Weber was provided the necessary design data and tooling, and also trained, tested, and audited at a cost of about $11 million. Weber delivered its first operational seat in June 1981, after almost four years. This long gestation period demonstrated the difficulties of transferring ejection seat production know-how, even though the firm had prior seat-making experience.

How should the ACES II L-F program be evaluated? A second source was created, a positive development that contributed to the national security. Also, four major competitions were conducted between MDC and Weber prior to the winner-take-all award to MDC in 1992. The program succeeded in bringing per unit prices down. Prior to Weber's competitive entry, ACES II prices rose rapidly from about $45,000 to $70,000, although double-digit inflation rates prevailed in the general economy during the period (1978-1981). After Weber's entry, prices moderated with each succeeding competition. However, without knowing all associated costs, or what actions to reduce costs MDC would (or could) have taken in the absence of the L-F program, it cannot be said with absolute certainty that money was actually saved. For example, the 10-year administrative burden of the program, certain duplicative tooling, and other costs are not counted on the liability side of the equation.

Another issue: How much did MDC's per unit costs rise by splitting orders with Weber? Larger

production runs would have reduced MDC's per average unit costs. By how much is unclear. Prices also would be somewhat lower with economies of scale. However, it's apparent these savings were not enough to make up the difference Weber made. Weber had comparatively little overhead and no engineering or design staff to contend with, and certainly much less than MDC. This essentially made Weber the "price setter" in the competitions.

How did the program impact the industrial base? The program's impact on MDC's ejection seat business was quite severe. No business is motivated to create its own competitor. In MDC's case, the ejection seat business was less than one-half of one percent of corporate revenues, and of little importance to the company's primary focus on multi-million dollar aircraft. Directives to cooperate with the program's objectives apparently flowed down from the company's upper echelons, and therefore cooperation was given. Under different circumstances, perhaps the company would have resisted, or better still, assisted the Air Force in developing other methods to ensure competitive prices.

In 1986, MDC moved the assembly operations for the ACES II ejection seat from Long Beach to the company's missile plant in Titusville, Florida. The major stimulus for this move was the upcoming F-16 seat competition for a large four-year contract extending from 1986 to 1989. MDC realized Weber could underbid them and win the contract.

The move to Titusville squeezed about $5,000 out of the seat's cost, and enabled MDC to win the F-16 seat contract. Weber was awarded the smaller F-15 contract.

However, other factors were also involved. Long Beach was a high-overhead, high-labor cost area. MDC's primary products in Long Beach were aircraft, namely the commercial MD-80 and MD-11, valued at $30 and $120 million per plane. They also made defense products, including the T-45, and part of the F-15 wing. Under the company's Special Programs Division, the firm produced bomb racks and ejection seats. A group of multi-purpose machines were used to make parts for several of these programs, but mainly for the commercial aircraft. The machines were not organized around the ejection seat business, which added inefficiency to the process. Also, without a primary focus on ejection seats, the machined part defect rate was reportedly rather high.

Another issue was the impact of the Defense Priorities and Allocations System (DPAS). Under the DPAS, priority must be given to DOD orders over commercial work, as necessary to meet DOD delivery requirements. In Long Beach, commercial orders were delayed occasionally by

the need for MDC to make timely delivery against certain DOD orders. Thus, in addition to the other benefits described above, moving the DOD business out of Long Beach avoided these conflicts.

The move to Titusville was accomplished in two stages. The painting and final assembly of major components and pyro onto the seat structure remained in Long Beach until 1990, at which time this work too was transferred to Titusville. Initially, Titusville machined structural parts, borrowing time on the missile section machinery. As in Long Beach, machine conflicts created inefficiency. MDC then elected to outsource all structural details. Titusville became a final assembly operation, where the fully configured seat is assembled from purchased parts and components.

The ACES II L-F program left MDC with few options other than to liquidate a portion of its ejection seat assets in order to lower prices. In doing this, the firm transferred value added to outside vendors. The company effectively lowered its stake in the ACES II. It can be argued that MDC was in a less than ideal situation in Long Beach because of the way ACES II production was organized. To that extent, the L-F program halted the subsidizing of an inefficient operation. However, the program also fragmented the production, which almost certainly was not its intent.

The *follower* in the Air Force's program was established as a bare-bones manufacturer, not at all structured like, or created in the image of the *leader*. The competition put MDC at a distinct disadvantage, and effectively leveled prices below an equitable return on the true economic costs. MDC was overhead heavy, in some respects perhaps too heavy. However, the company had very real development costs to recover, a design and engineering staff to support, and various ongoing research projects, some of which involved internal funding targeted at the future. The follower had none of these costs to contend with, and was restricted from expanding because MDC was named "Custodian of the Technology."

In summary, the ACES II L-F program saved money, but damaged the competitiveness of MDC in the process. The program compelled MDC to reduce its stake in the ejection seat business, and hurt the long-term competitiveness of MDC's ejection seat operations. The net worth of MDC's ejection seat business declined. Incentives to invest in productivity improvements were largely stifled. In fact, the company divested itself of assets, and invested nearly nothing. MDC also failed to pursue export markets, which Weber could have challenged as well as better capitalized foreign firms.

The NACES Program

The L-F program for the NACES never achieved its objectives. Written into the initial NACES contract in May 1985, the L-F program ended abruptly more than seven years later in September 1992, because of lower-than-expected seat requirements. Conceivably, it could have taken another year. The ACES II L-F program took less than five years to fully qualify the follower and begin competing for business. However, from the start the Navy program differed from the Air Force program in an important way: NACES was a "paper seat," while ACES II was an existing seat. The Navy spent around $20 million to finance development of the NACES. And first delivery of a fully configured seat did not occur until October 1988.

To recap, the NACES had its origins in 1983, when the Secretary of the Navy called for a Navy common ejection seat. In March 1984, a Request for Proposal went to MDC, Stencel, and Martin-Baker. After a competition based on technical, management, and price factors, Martin-Baker's proposal was selected and a contract awarded on May 3, 1985. The contract stipulated that Martin-Baker, as *leader*, was to select a *follower* with Navy concurrence. To provide an incentive for creating its own competitor, the Navy offered Martin-Baker an incentive of $1 million to meet certain performance milestones. Martin-Baker met the milestones and collected the $1 million bonus.

A total of 16 companies, including MDC, Weber, and UPCO/Stencel, competed for follower status. This number was reduced to five, and then to three finalists. The three finalists were Weber, UPCO/Stencel, and East-West Industries. Martin-Baker and the Navy conducted intensive assessments of the final three candidates. In October 1986, East-West on Long Island, New York, was selected as follower. The President of the company had prior experience working with ejection seats as an engineer at Republic Aircraft. He worked on Republic's F-84 and F-105 ejection seat programs.

Unlike the Air Force, the Navy did not finance the follower's development. The follower was given a token $1.00 contract, and expected to assume the risk of any capital investments in the program. East-West, a small firm, was willing to assume this risk based on the history of U.S. Navy ejection seat procurement. East-West then proceeded to invest several million dollars in the effort. The company purchased a 100,000 square foot facility in nearby Hauppauge and several major pieces of manufacturing equipment to produce the NACES seat. People were hired to expand the expertise of the staff. The firm's intent was to provide a facility totally dedicated

to NACES manufacture. Martin-Baker placed representative on site to monitor the technology transfer portion (the first phase) of the contract.

In 1987, Martin-Baker advised the Navy that a single common seat was inappropriate. In September that year, East-West was put on hold for nine months, pending an investigation into this issue. The redesigned seat had a wide and narrow version. In June 1988, the L-F program resumed, but previous efforts at East-West would have to be repeated due to the significant design changes. East-West thought it unfair to continue risking its own capital, and petitioned the Navy to fund the program. The Navy agreed, but the funds were not available until later, when the program was funded on an incremental basis.

The new L-F program had five phases. These included: 1) technology transfer; 2) manufacture of all tooling; 3) manufacture of first article seats; 4) limited production of seats with Martin-Baker oversight; and 5) first competition with Martin-Baker. Completion of the first phase and a production readiness review were not successfully completed until March 1992. The next phase also suffered from lack of funds, so the Navy ordered three modules (seat bucket, survival kit, and oxygen equipment) subcontracted to East-West by Martin-Baker as an interim measure.

In September 1992, the Navy canceled the L-F program because seat requirements fell below 100 per year. The Navy determined that two production lines would not be viable with quantities this small. The next month, the Navy directed Martin-Baker to procure the three modules from East-West under a "Directed Subcontract" to assist East-West in recovering its investment.

The opportunity for a full-up capability to produce the NACES in the United States was lost. Unlike the ACES II L-F program, the NACES would have been a net gain for the domestic ejection seat base. It also would have been produced in a dedicated and mechanized facility. Between May 1985 and September 1992, the U.S. dollar weakened against the British pound by about 40 percent. This made imported seats from the UK more expensive. Had the L-F program succeeded, this would have favored more U.S. production at a lower price. At one point, Martin-Baker even considered the purchase of East-West to establish its own production in the United States and reduce the exchange rate risk. This was not to be because the requirements dropped so sharply.

3.3.3 Other Regulatory Issues - The military is transistioning from process to performance guided specifications. The previous method outlined in great detail the how component *X* should be produced, assembled, cleaned, tested, packaged, and shipped and what firms were qualified to do so. The new performance method provides guidance as to what component *X* must do; the manufacturer decides how to make the component. The new guidance will give the manufacturer more freedom to innovate as well as more responsibility for his product. The impact this change will have on the intensely managed ejection seat sector is not entirely clear because of product liability concerns.

The movement toward performance specifications began with the avionics manufacturers more than 20 years ago. Electronic technology was advancing so quickly that military specifications were stifling innovation. The avionics on commercial aircraft were moving ahead of the military. Over the years, the military codified about 55,000 separate specifications for military aircraft production alone. The specifications documented the knowledge and experience gained over many years, evolving almost in lock-step with industry technology with frequent updates and amendments. The system was increasingly difficult to keep current, and costs were increasing. In 1994, Defense Secretary William Perry acknowledged the problem and advocated a transition to performance specifications.

The ejection seat uses a number of outdated component technologies that could improve and become cheaper as a result of this change. The sequencers, for example, on the ACES II and NACES both use electronic technology that is over 20 years old. Testing technologies have also advanced. Perhaps expensive reliability and performance tests, which were appropriate for older technology, could be reconsidered. The hidden costs of constraining innovation are very high. At the same time, it is difficult to foresee how companies will deal with the product liability burden that apparently will now be their responsibility.

The Defense Federal Acquisition Regulations (DFAR) are procurement procedures governing the purchase of ejection seats and other military items. The DFARs are written to implement statutes periodically enacted, such as the National Defense Authorization Act (updated annually). Subcontractors reported several specific concerns with the DFARs. The regulations call for small business and minority business set-asides, which compel the splitting of orders or business opportunities and preferentially soliciting offers from at least two Defense-qualified small or minority businesses. Set-asides apply when the initial Defense contract is greater than a minimum dollar value, against which all subsequent subcontracts carry the set-aside clause. This divides the business and forces subcontractors to carry one or more contract administrators, or, at

a minimum, pay for the time of an individual to ensure compliance. Subcontractors note that in a declining market these measures can be economically counterproductive.

Another DFAR issue is the "Buy American" provisions. The provision dates back to the early 1950s, when the Buy American Act of 1953 was enacted. It's premised mainly on concern about shipment interdiction similar to the wartime experience of World War II. Since that time, the world has vastly changed and grown in terms of economic integration, world trade, and complexity. The notion that the United States can maintain the world's best military in the long-term, without using the technology, skills, and talents of the rest of the world, is historically inaccurate.

The Germans developed the first operational ejection seats in World War II. This technology was recovered and brought to the U.S. by the U.S. Army Air Force in August 1945, shortly after the victory in Europe. Later, Martin-Baker of the U.K. developed the safest low-level ejection seat in the 1950s. The U.S. Navy urgently needed the technology and ordered 11 types of its aircraft retrofitted with the Martin-Baker seat. Today the Russian firm Zvezda has developed what many consider the best seat in the world for very high speed ejections. The Air Force and Navy are jointly funding research on Zvezda's technologies to examine if they can be adapted to American cockpits.

A specific problem with the DFAR Buy American provision is that it can lock procurements into a limited number of suppliers. This is done sometimes by Congressional mandate written directly into the law, or by Defense's specific implementation. This is not to say most firms that hold on to or gain new business by virtue of these provisions are non-competitive. The issue is rarely that simple. However, some do fit that pattern, and they can add to the price of the system or item procured.

In the case of ejection seats, it was learned in the course of this assessment that certain electronic components must be sourced from U.S. (or Canadian) vendors. Also, Martin-Baker noted that it must use U.S. vendors for certain high valued items. With declines in the number of NACES seats being procured, the unit cost for these items has increased. More flexibility in the DFAR would almost certainly allow prices for these items to come down. However, some domestic component production capacity may be lost in the process.

The Competitiveness in Contracting Act of 1984 (CICA) is also implemented through the DFARs. Here, Defense issues a request for proposal to at least two firms on every contract.

Should only one firm be available, Defense attempts to locate or establish a second source. In unusual cases, normally occurring with high-overhead, high-valued items produced in small quantities, a sole source may be the better and cheaper option. However, in these instances, a great deal of paperwork and justification is necessary.

CICA is a double-edged sword. It probably saves the taxpayer money in most instances, but costs more in others. Where several existing suppliers operate efficiently, the competitive bidding process almost certainly saves money. But does it save more money than any other alternative? For example, CICA discourages the concept of "partnering," in which a supplier company agrees to meet certain quality standards and operate efficiently in return for a steady and predictable stream of business.

Partnering, based on trust and long-term relationships, is at the core of the Japanese "keiretsu" (group). The concept has been tried by U.S. companies such as Motorola and Hewlett-Packard. Partnerships reduce transaction costs, and tend to make the attainment of quality cheaper with longevity. Another important, perhaps most important, possibility is adoption of a continuous improvement program with objectives to raise productivity, improve quality, and lower costs throughout the system. Like a pyramid, every stone is structurally equally important and all come together and prop up the top stone, which may be an aircraft, cellular phone, or ejection seat. Martin-Baker has such a system, formed through close family ties. Langford Lodge in Northern Ireland and Ronaldsway on the Isle of Man are set up as independent companies for tax purposes, but nearly all their output is sold to Martin-Baker in England.

3.4 Other Industry Comments

Survey participants were asked to provide any additional comments or information regarding their operations or other related issues impacting their firm. One respondent was very optimistic about the results of their advanced ejection seat research and development recently completed for the Defense Department. The firm reported that the seat design will provide safe escape throughout the operating envelope of current and future tactical aircraft and will accommodate the full range of the expanded aircrew population. The firm also mentioned that they are currently evaluating the manufacturing, tooling, facility, capital and support requirements necessary to transition this technology into seat production.

Another company mentioned that it is contemplating a new ejection seat program, but that it is

uncertain about prospects in the current market. The firm states that U.S. Government support is needed in development of a new seat that is adaptive to virtually any aircraft platform. The development of a seat of this design will help to ensure a domestic production base for ejection seats.

A third survey participant also discussed the need to take steps toward preserving ejection seat capabilities within the United States. The firm mentioned that the largest ejection seat manufacturer in the world is a foreign company that must have access to the U.S. market. However, this should not preclude the U.S. from taking the position similar to that taken by most foreign governments when a U.S. company secures a contract from them. This position requires some form of work reciprocation such as an offset or the Leader-Follower Program where the burden for successful compliance must clearly be placed upon the foreign company.

A fourth survey participant addressed the shrinking demand for ejection seats by suggesting that the U.S. Government consider a joint foreign/U.S. company in the United States which would manufacture ejection seats for U.S. programs.

4. Recent and Future Market Opportunities

4.1 Trainers

4.1.1 Joint Primary Aircraft Training System (JPATS) - The objective of the JPATS program is to replace the Air Force T-37B and the Navy T-34C trainer aircraft. The primary mission of the JPATS is to train entry-level Air Force and Navy student pilots in primary flying and to prepare them to fly advanced aircraft leading to qualification as military pilots. Each plane will have two ejection seats.

Raytheon (Beech) Aircraft won the JPATS primary trainer competition in June 1995, with its Beech Mk.II turboprop. Beech has been producing training aircraft since 1940. Performance of the aircraft, and a relatively low acquisition and operating cost for the turboprop were primary reasons for selecting the Beech aircraft.

A new manufacturing facility has been built in Wichita, Kansas to build the Mk.II. It is anticipated that Raytheon will manufacture as many aircraft for international sales as it will produce for the U.S. Government. Some 1,000 aerospace employees are expected to be associated with the JPATS program by the year 2000. Raytheon will build up to 711 of the Mk.II primary trainers in the Wichita facility for the U.S. Air Force and Navy, at a delivered cost of under $3 million each. The Air Force will receive 372 of the aircraft beginning in June 1999. The Navy is scheduled to receive the balance (339) beginning in early 2002, with the last delivery in 2017.

The airframe, originally the Pilatus PC-9, was a Swiss design extensively modified by Beech. The JPATS will incorporate several features that are not found in the military's current primary trainer fleet. It has a newly developed turboprop engine, pressurized cockpit, improved flight characteristics, and electronic flight instrumentation and digital cockpit display. The cockpit layout of the original PC-9 was modified to include digital avionics and equipment necessary to prepare pilots to fly advanced combat aircraft.

The Mk.II is the first plane designed from the ground up to meet the new standards for accommodating both male and female pilots. Aircraft must now be designed to fit 95 percent of the eligible military population in the United States. The Air Force defines the "expanded pilot population" not just by extremes in height and weight, but as a range of body types that includes

"shortest reach with high shoulder" and "short limbs with short sitting height".

The trainer will accommodate two occupants in tandem with a zero-zero ejection system manufactured by Martin-Baker. The fully configured seat has an estimated cost of $119,000. The initial order of 1,422 seats for 711 aircraft will amount to approximately $169 million, not including spare parts for maintenance. The aircraft, engine, and other advanced features provides the military with a safe aircraft that will fit a wide range of pilots, both male and female, at a low cost.

Because of the reduction in defense spending, competition for the JPATS contract was intense and drew numerous candidates to compete for the opportunity not only to supply the trainer for the United States, but also for potential sales to foreign governments. The seven contenders are shown on the table that follows.

Seven Finalists in JPATS Competition		
Seat Maker	**Aircraft**	**Contestant(s)**
Martin-Baker	Beech MkII based on the Pilatus PC-9	Raytheon
UPCO	Tucano-H	Embraer (Brazil) and Northrop Grumman
UPCO	Citationjet	Cessna
Martin-Baker	Siai Marchetti S211	Northrop Grumman
UPCO	Ranger 2000	Deutsche Aerospace from Rockwell International
Martin-Baker	Aermacchi MB-339	Lockheed Martin
Martin-Baker	Pampa	FMA (Argentina) by Vought Corporation

Source: Wright-Patterson AFB, JPATS Program Office

Martin-Baker seats were chosen by the airframe contractors on four of the trainer entries. UPCO was selected in the other three. Martin-Baker spent a large sum marketing its seat in this competition. UPCO spent much less. Cessna developed a new turbofan trainer for the competition, and submitted the only all-American entry, with its selection of UPCO's seat. The Beech Mk.II and the Tucano-H were the only turboprop entries. Pampa was rejected early in the competition.

The June 1995 contract award to the Beech Mk.II was followed by formal protests by Cessna Aircraft and Rockwell filed with the Comptroller General of the United States. This led to an investigation and issuance of a Decision (February 5, 1996) by the Government Accounting Office (GAO) which denied both protests. As judged by the Source Selection Evaluation Board (SSEB) made up of U.S. Air Force and Navy personnel, the JPATS competition was based on a number of factors, including crew accommodations (ejection seats). Beech won the competition by scoring higher on a preponderance of these factors.

Complaints by Cessna and Rockwell covered various aspects of the evaluation process. Both firms lodged specific complaints about the rating given to Beech on the crew accommodations factor. The UPCO ejection seat was rated higher than the Martin-Baker seat in the evaluation process. Both Cessna and Rockwell (the UPCO) seats received an *acceptable* rating under the crew accommodations factor. The Beech (Martin-Baker) seat received a *marginal* rating.

Cessna argued that the Air Force improperly evaluated Beech's proposal in that Beech failed to provide a functional ejection seat. The SSEB concluded that Beech's proposed seat design did not meet the required criteria. Based on data submitted by Beech, the acceleration of the ejection seat exceeded acceptable limits. The problem was more pronounced for light-weight occupants. However, the review board concluded that problems with the seat could be overcome with close government monitoring. The decision to assign a marginal rating to Beech was based on the ejection seat portion of the crew accommodations factor. Cessna's position noted that a mission of the program was to use existing component systems, and minimize developmental costs. UPCO's seat would accomplish that goal, while the Martin-Baker seat would not.

Rockwell argued that its crew accommodations factor was *exceptional,* while the SSEB had judged it *acceptable* under this factor. The SSEB in final evaluation noted several strengths in Rockwell's crew accommodations. However, none of these clearly distinguished Rockwell's proposal from the rest of the competitors. The GAO concluded that the rating of Rockwell's crew accommodations factor was reasonable. The GAO report denied both protests, and Beech continued with the JPATS program.

Each survey participant was asked to forecast the competitive prospects for their firm's production operations over the next five years. UPCO reported that competitive prospects will decline without the JPATS contract because no other new programs are on the horizon. The company noted that while JPATS was a significant program, it did not provide production potential until 1998. In the interim, the only new seat business of significance is foreign, and that

is viewed as speculative. UPCO also noted that increases in pyro sales were not anticipated because of the diminished inventory of aircraft in U.S. military fleets.

4.1.2 T-38 Talon Upgrade - The Northrop T-38 Talon is the Air Force's advanced jet pilot trainer. It is a twin-engine, high-altitude, supersonic jet aircraft used in a variety of roles because of its simplicity of design, economy of operations, ease of maintenance, and high performance. The instructor and student sit in tandem on Northrop rocket-powered ejection seats in a pressurized cockpit. Critical components are readily accessible by maintenance crews and refueling and pre-flight inspections are easily performed due to the aircraft's low height.

Student pilots fly the T-38A to learn supersonic techniques, aerobatics, instrument flying, and cross-country navigation. A special version, the AT-38B, is used to prepare pilots and weapons systems officers for combat aircraft such as the F-15, F-16, A-10, and F-111. This model can carry external armament and weapons delivery equipment for more specialized training. Pilots from most NATO countries are trained in the T-38A at Shepard Air Force Base, Texas, through the Euro-NATO Joint Pilot Training Program. More than 60,000 pilots have earned their wings in T-38A aircraft.

The Talon first flew in 1959. More than 1,000 were delivered to the Air Force beginning in 1961 at a cost of $756,000 each. Production ended in 1972. An Air Force T-38 seat upgrade program is plausible and could involve 850 seats (plus spares) for 425 aircraft in a five or six year time period (1998-2005). Such a program would offer crucial business for domestic ejection seat producers. The international potential could offer additional business in Turkey and Taiwan.

In December 1996, the Air Force released proposals to modernize 425 T-38 Talon trainers with extensive avionics upgrades at a cost of $700 million during the 1998-2005 time frame. The avionics in the T-38 are antiquated and provide trainees with little preparation in this area for front-line combat aircraft. The gap would have been more apparent after student pilots finished their primary training in the JPATS with its electronic cockpit.

The avionics upgrade program was established to raise the sophistication of the T-38 with modern digital avionics and a heads-up display to better match the capabilities of active fighters and bombers. Another ongoing program is called Pacer Classic, the structural life extension program for the T-38. This program will integrate 10 modifications, including major structural enhancements, into one process. As a result of these upgrade programs, the service life of the T-

38 will be extended beyond 2020. Increasing the longevity of military aircraft makes sound economic sense when the inordinate cost of replacements is considered.

In view of the current agenda to modernize and maintain the T-38 well into the next century, it would be consistent to integrate a modern ejection seat upgrade program into those plans. The T-38 is equipped with an ejection seat that was designed by Northrop in the mid-1950s with slight additional modifications affected in the 1970s and 1980s with the addition of drogues and improved lap belts. The original Northrop seat does not lend itself to the extensive modifications that would be necessary to meet current DOD requirements related to pilot safety and the accommodation of a wider range of body sizes.

We note that NASA, which operates 35 T-38s for astronaut crew proficiency training, has already announced its intentions to upgrade the ejection seats in their aircraft. NASA has identified increased difficulty maintaining the older Northrup seat and its performance limitations, especially with regard to small/lightweight aircrew, as primary factors in their decision. Several ejection seat manufacturers have already approached the space agency with preliminary designs to install their seats in the NASA aircraft.

While NASA is prepared to undertake this effort unilaterally if necessary, they have expressed a strong desire to conduct this upgrade program in conjunction with the Air Force to ensure a common logistics capability. This seemingly would present the Air Force with not only an opportunity to participate in the selection process, but also to benefit both NASA and the Air Force financially as a result of shared acquisition costs associated with the program and in terms of the increased performance capabilities gained from a modern seat.

Market Potential for T-38 Talons				
Country	**Taiwan**	**Turkey**	**United States**	**Total Seats**
T-38	80	138	920	1,138

Source: U.S. Air Force, Jane's Defense Systems Modernization - November/December 1996 pp. 15-19

The ACES II seat would require modification before consideration as a suitable replacement upgrade for the T-38 because the headrest and seatback adjust up and down with the seat bucket, rather than independently of it. In some instances full canopy closure would not be possible

because there would not be enough clearance between the seatback/headrest and canopy. UPCO's S-IIIS-3 design has a fixed seatback and headrest with an adjustable seat bucket that will adjust up and down to fit the size of the pilot. An ejection seat manufactured by UPCO has already been qualified in a T-38/F-5 derivative, Northrop's canceled F-20.

4.2 Fighters

4.2.1 F-5 Freedom Fighter - The Northrop F-5 Freedom Fighter is the combat version of the T-38 trainer. It is largely identical to the T-38 but has more powerful engines and additional avionics such as radar. The F-5A has a single seat while the F-5B has dual tandem seats. The F-5 was developed primarily for export and has been manufactured and assembled in several different countries. Consequently, there are many variations of the airplane around the world. For example, Canadair obtained a license to build them under the CF-5 designation. Some CF-5s were sold to the Netherlands as NF-5s. In the Far East, the F-5s were nicknamed "Tiger", and the F-5E/F was officially named "Tiger II". The F-5E is the single seat version while the F-5F is the two seat version. Yet another variation is the RF-5E Tigereye, which has been modified to carry reconnaissance equipment for both day and night photo missions.

On April 4, 1973 the first Tiger II was delivered to the Air Force at Chandler Air Force Base in Arizona. These F-5E/F Tiger II aircraft were put into service to train aircrews of nations that had acquired the F-5 under the Mutual Assistance Pact. The U.S. Air Force never adopted the F-5E as a front-line combat fighter. However, it did adopt the F-5E as a specialized aircraft for dissimilar air combat training. Since the F-5E had approximately the same size and performance characteristics as the MiG-21, it was used to simulate this Warsaw Pact aircraft in realistic air combat training. The U.S. Navy's "Top Gun" Fighter Weapons School at Mirimar, California, also acquired a number of F-5 Tiger II's for its dissimilar air combat training.

Northrop Grumman has been selected by the U.S. Air Force to be the primary supplier of F-5 structural and avionics upgrades as part of the Service's FMS support of F-5s worldwide. Annual meetings of F-5 user-country representatives are hosted by the San Antonio Air Logistics Center. In March of 1996, the Air Force selected Northrop Grumman as the manufacturer of 14 major structural elements and related replacement parts for international aircraft. The company subsequently received $32 million in orders last year for new wings and structural repair kits under that program.

As with the T-38, the international market potential for replacement of the original design

ejection seat(s) in the F-5 is substantial. Approximately 1,700 earlier designed F-5A/Bs and later F-5 E/F versions are still in service in 26 countries, including Greece, Malaysia, Norway, the Phillippines, Saudi Arabia, Spain, Switzerland, Taiwan, and Turkey. It is often more economical and more practical, particularly for smaller nations, to install modern radar equipment and avionics in their existing combat aircraft rather than buy expensive new fighters. An ejection seat upgrade program in conjunction with other upgrade initiatives could be an objective for the Air Forces in F-5 user countries.

Several key countries have large numbers of the F-5 aircraft in their Air Force fleets. The largest number of operational F-5s are in service with the Republic of China (Taiwan) Air Force. It has received over 400 F-5's, including over 300 Tiger IIs built under license by the Aero Industry Development Center at Shuinan. Between 1973 and 1986, 242 F-5Es were built by AIDC, along with 66 F-5Fs.

The Republic of Korea (ROK) Air Force is the second major operator of the F-5, and flies all models with the exception of the RF-5E Tigereye reconnaissance version. The Hanjin Corporation, utilizing facilities owned by Korean Air Lines, assembled the last 68 of the 233 F5E/Fs delivered to the ROK Air Force between 1974 and 1986. First flight of an Hanjin F-5E powered by J85 engines assembled by Samsung Precision took place September 9, 1982.

Another example of a foreign country with a potential for ejection seat upgrades in the F-5 is Switzerland, which ordered 66 F-5Es and 6 F-5Fs under the 1976 "Peace Alps" program. As part of an offset program agreement, 53 of the F-5Es were to be assembled by FFA in Switzerland. A total of 91 airframes were delivered by FFA to supplement the 19 U.S. built machines that were airlifted under the F-5E support program.

MARKET POTENTIAL FOR FOREIGN MILITARY SALES OF UPGRADED F-5 EJECTION SEATS													
Country	Fs				CFs		NFs		RFs		SFs	SRFs	Row Totals
	5A	5B*	5E	5F*	5A	5D*	5A	5B*	5A	5E	5A/B	5A	
Bahrain			8	8									16
Botswana					10	6							16
Brazil		8	47	8									63
Canada					23	64							87
Greece	45	24					10	2	10				91
Honduras			10	4									14
Indonesia			10	8									18
Jordan			44	26									70
Kenya			6	4									10
ROK			160	70									230
Malaysia			13	6						2			21
Mexico			9	4									13
Morocco	8	4	22	8					1				43
Norway	7	16											23
Philippines	2	2											4
Saudi Arabia		30	61	42						10			143
Singapore			30	16						9			55
Spain											32	10	42
Switzerland			90	24									114
Taiwan		12	210	114									336
Thailand	14		40						4				58
Tunisia			10	6									16
Turkey	100	60							16				176
United States			34	20									54
Venezuela					14	6	6						26
Yemen		8	10										18
Total	176	164	814	368	47	76	16	2	31	21	32	10	1,757

Source: Jane's Defense Systems Modernization - November/December 1996 pp. 15-19

* Denotes 2-seat version of aircraft

4.2.2 F-22 Air Superiority Fighter - The proposed F-22 tactical fighter is intended to replace the McDonnell Douglas F-15s now in service. The primary mission of the plane is air superiority with "first-look, first-kill" capability against multiple targets. It will be highly maneuverable at sub and supersonic speeds, employ advanced stealth technology, and have air-to-air as well as air-to-ground capabilities.

Lockheed Martin and Boeing Corporation are jointly developing the F-22. Lockheed Martin is manufacturing the front fuselage and front end work about two-thirds of the value of the plane. Boeing's portion consists of the wings and tail section, and part of the fuselage. The aircraft's quantum leap in performance capabilities over existing fighter aircraft requires modifications to enhance the ACES II ejection seat. The seat modifications are included in the engineering and manufacturing development, or non-recurring, pre-production costs, of bringing the F-22 to life. Total EMD and demonstration/validation phase costs are estimated to be about $16.5 billion (in 1990$) by the time the project is completed near the end of 1998. This EMD includes building nine aircraft to gain manufacturing experience, debugging the process, and testing the plane. The first of these initial nine aircraft is now under construction. As of early January, 1997, a total of 438 planes are slated for production from 1999 to 2010, at an estimated cost of about $48 billion (in then year dollars).

Projected Annual Purchases of the F-22 by U.S. Air Force (number of aircraft)											
1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
4	12	24	36	48	48	48	48	48	48	48	26

Source: F-22 Program Office, Wright-Patterson AFB

Lockheed Martin is responsible for the ejection seat on the aircraft, and tendered a subcontract to McDonnell Douglas in 1992 to improve the ACES II seat's high speed capability. The contract called for the construction and testing of 28 ejection seats for $4.97 million, and additional development costs of $0.82 million. These values were increased due primarily to various design changes made by Lockheed. The 28 seats ultimately cost $6.05 million, while development costs increased to $1.7 million. The final contract came to about $7.75 million.

The major modifications, and the most costly, were for a fast-acting drogue chute and the

installation of arm restraints. The fast-acting drogue will enhance seat stability and should reduce injuries at higher speed ejections, while the arm restraints will reduce, if not eliminate, upper limb flailing injuries at high speeds. Other modifications include an increased oxygen supply and a change in the initiation system from expanding gas to a battery-operated electronic system. The oxygen cylinder's size is increased from 22 to 50 cubic inches. This will be useful for higher altitude ejections, and do double duty as a back-up to cockpit oxygen.

The current estimate for the seat's cost is about $95,000 (in 1990 dollars). The cost is subject to wide swings depending on production volumes. It reportedly could go as high as $150,000 (1990 dollars) if McDonnell Douglas decides to shift production from Titusville, Florida, to a more expensive labor area. One option available to Lockheed would be to accelerate production of the ejection seats to ensure McDonnell Douglas maintains economic production quantities in Titusville, and keep prices below projected levels. This option involves risk to Lockheed because of the uncertain future aircraft production volumes.

However, Lockheed contacted Weber Aircraft, Inc. in Fullerton, California as a possible alternate source. Weber, as the "follower" on the ACES II, was forced to shut down ejection seat operations with the selection of McDonnell Douglas as sole source the ACES II in the winner-take-all competition in 1991. Weber apparently would welcome the opportunity to produce the ACES II again. However, up-front money would be needed to bring the company up to speed. Based on the B-1B and T-46 seat programs, Weber may lack the engineering expertise and corporate knowledge to make modifications or upgrades, or to trouble-shoot any problems once the seats are deployed.

4.2.3 Joint Strike Fighter (JSF) - In this new era of redefined defense procurement, Defense is seeking to reduce expenditures by building a single-engine, single-seat aircraft that will incorporate radar-evading stealth technology. The JSF effort will attempt to produce a joint services aircraft that will replace, at a minimum, the F-16s and A-10s in the Air Force, the A-6E in the Navy, the AV-8B Harrier and the F/A-18C/D in the Marine Corps, and the Sea Harrier in Britain's Royal Navy.

Three JSF versions are planned: a conventional take-off and landing (CTOL) aircraft for the U.S. Air Force; a heavier carrier-based aircraft (CV/CTOL) for the U.S. Navy ; and a short take-off and vertical landing (STOVL) aircraft for the U.S. Marine Corps and Royal Navy. To reduce production costs, the three JSF variants should have approximately 80 percent compatibility,

meaning, 80 percent "cost commonality," as stated within JSF program documents. The Congressional Budget Office has estimated the cost of the program at $219 billion.

Projected Buys of JSF (2005 to 2030)	
U.S. Air Force	*2,036
U.S. Marine Corps	642
U.S. Navy	300
UK Royal Navy	60
Total	3,038

Source: *Air Force Magazine*, October 1996, p.22; *JSF Program Office, U.S. Air Force

The Pentagon wants to broaden international participation in the program that could include such countries as Norway, Holland, Denmark, and Canada. At present, the United Kingdom Royal Navy has contributed $200 million under the Joint Advanced Strike Technology (JAST) program. Foreign participation is expected to increase.

The JSF could incorporate a seat with fourth generation technologies. However, this decision will be left to the selected contractor. Martin-Baker ejection seats are reportedly placed with each of the contenders in the JSF concept demonstration aircrafts (CDAs). The contending contractors' choice to use these seats was apparently driven by a desire for an effective, off-the-shelf, non-developmental ejection seat.

To date, no American firm has fielded a seat that can accommodate the expanded weight range of female pilots, or for consideration in the JSF CDAs. However, the fourth Generation R&D project and other technologies including the Russian K-36D program will continue to receive funding and the interest of the parties involved. Now that Boeing has merged with McDonnell Douglas, Boeing is in a unique position to bring many of the latest technologies together, test, and possibly field a new seat to participate in future ejection seat competitions, including the JSF.

Martin-Baker has put forth the most significant marketing effort with regard to the ejection seat for the JSF. It is evident the firm is willing to risk a great deal to win this competition. It is also evident that Martin-Baker would be materially injured, and has far more to lose in the way of past investments and sunk costs than any of its potential American competitors, should the firm not get the JSF contract. With as many as 3,000 aircraft at stake, the JSF accounts for a very substantial share of future world business (perhaps about one-third or more) in the first 20 years of next century. This will be very important to whichever company ultimately gets the contract.

5. Findings and Recommendations

5.1 Findings

- Ejection seats enhance the national security by preserving the lives and operational experience of war fighters.

- All examined economic indicators highlight a dramatic decline in the U.S. industrial base for ejection seats. Shipments, employment, investment, and competitiveness are all trending downward.

  - Shipments have declined about 80 percent in the last decade primarily due to defense downsizing.

  - Employment of assembly workers has fallen by almost half. There has also been a serious thinning in the expertise level (design and engineer) that jeopardizes the future ability of the United States to maintain the technology.

  - U.S. company-generated investment has been almost non-existent in the last few years, with little prospect of increasing.

  - The competitive standing of the U.S. companies has declined as indicated by falling market share to a degree greater than the decline in the world market.

- The number of subcontractors has declined by more than 50 percent, as the seat makers consolidated operations and attempted to maintain economic purchase quantities.

- Development of advanced techonology in ejection seats, especially in the area of female weight and size accommodation, offers the best opportunity for the relative near-term health of the industry in the United States.

- A potential world market for U.S. developed ejection seats could emerge should governments decide to retrofit aircraft currently flying second generation seats. U.S.

manufacturers have had little success in selling seats abroad, except where their seats were installed in aircraft sold through U.S. Foreign Military Sales programs.

- Recent ejection seat procurement has been below economic production quantities, raising the per unit cost of these seats.

- The total U.S. requirement for ejection seats in the next five years may not be adequate to ensure the continued economic viability of a domestic capability.

- The U.S. industry is highly fragmented compared to its major foreign competitors, Martin-Baker and Zvezda. This is a significant competitive disadvantage.

- Martin-Baker controls about 75 percent of the world market (excluding former communist countries) and is the major competitive challenge to a revived U.S. capability. More than 95 percent of the company's $100+ million in annual revenue is from ejection seat-related sales.

- Martin-Baker is integrated into most facets of the industry in terms of design and engineering, manufacturing, testing, marketing, and life cycle technical servicing. This structure confers a major competitive advantage over any other producer.

- Comparatively, no U.S. ejection seat company or subcontractor has more than 4 percent of revenues generated by ejection seat sales, and most have much less. Total annual U.S. revenues are estimated at less than a third of Martin-Baker's.

- Based on survey results, the United States spends over 50 percent of the ejection seat RD&T in the world. This RD&T is primarily funded by the U.S. Air Force and Navy, including portions that go to foreign contractors, or indirectly, through prime contractors. However, an experienced and economically viable industrial base is critical to turning the RD&T into operational products.

- Without continued U.S. Government RD&T funding to this sector, the remaining U.S. industrial base would quickly disappear.

- Additional factors that have adversely affected the U.S. ejection seat industrial base include the following:

-The Air Force Leader-Follower program for ejection seats saved money, but unintentionally may have damaged the long-term competitiveness of McDonnell Douglas Corp.'s (MDC) ejection seat operations. Leader-Follower, by creating a low-overhead, low-cost competitor, appears to have deprived MDC of a fair return on its capital investments. As a result, MDC decreased its stake in the industry and failed to expand operations.

-Export controls administered under the ITAR regulations (munitions list) by the Department of State are relatively more burdensome on U.S. companies than are the UK's regulations on Martin-Baker. The State Department treats ejection seats in the same way as weapons, the British have a two-tier system that expedites the processing of ejection seats and their components. Unilateral U.S. licensing policy has also deterred potential customers.

o The Boeing takeover of Rockwell and merger with McDonnell Douglas, combined with contractual relationships with UPCO and Zvezda, are positive developments. This presents industry with an unprecedented opportunity to revitalize the domestic sector. Moreover, it would strengthen the national security by maintaining U.S. control over leading-edge technology and promote a manufacturing base capable of deploying these advances.

5.2 Recommendations

- Facilitate greater rationalization (elimination of redundancy) and consolidation in the U.S. ejection seat industry with procurement and RD&T policies, and discussions with industry.

- Where appropriate and possible, support U.S. teaming/licensing agreements with foreign manufacturers for production sharing and technology exchange on a worldwide basis.

- Additional steps to stimulate the competitiveness of U.S. ejection seat industrial base:

  - Establish multi-year contracting for all levels of the ejection seat sector to increase economic efficiencies and industry-funded investment.

  - For this sector, establish a temporary waiver from the provisions of the small-business set-asides and other non-defense related regulations so as not to further subdivide procurement and decrease economic efficiencies.

  - Support the joint U.S.-Japanese initiative, proposed by the Japanese, to share in the development of technology for improvements in ACES II performance to handle the expanded aircrew weight/size distribution.

  - Open discussions between the U.S. Departments of Defense and State and industry to examine possibilities of modifying the munitions export controls to mirror the United Kingdom's simplified two-tier system for non-lethal items such as ejection seats. The objective of these discussions would be to enhance U.S. companies' ability to compete in world markets, while maintaining the integrity of the munitions export control system.

Appendix A

Letter Requesting Study

DEPARTMENT OF THE AIR FORCE

HEADQUARTERS AERONAUTICAL SYSTEMS CENTER (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

ASC/ENFC
2530 Loop Road West
Wright-Patterson AFB OH 45433-7101

25 Jul 96

Mr. Robert Kugelman
Director Of Administration
Bureau of Export Administration
U.S. Department of Commerce
Room 3889
Washington, DC 20230

Dear Mr. Kugelman

The Crew Systems Branch of the Engineering Directorate at Wright-Patterson Air Force Base is concerned about the continued ability of its suppliers of ejection seats to meet national security requirements, given the decline in the defense budget and procurement, as well as other factors. We request the assistance of your Office of Strategic Industries and Economic Security (SIES) in conducting an in-depth assessment of this industry.

Specifically, we would like SEIS to assist us by developing and conducting a survey of ejection seat producers and analyzing factors affecting the industry's ability to meet national security needs. These factors would include production capabilities, financial health, defense conversion potential, regulatory environment, product liability, and others. The attached Project Overview provides more details on the scope and goals of the assessment. We are prepared to cover SIES expenses associated with this assessment on a cost-reimbursement basis through a Military Interdepartmental Purchase Request (MIPR), which Brad Botwin has already received. It should be noted that any expenditures beyond the amount in this MIPR must be authorized in writing by us prior to obligation.

Preliminary discussions on this cooperative project have been held between Brad Botwin, Director, Strategic Analysis Division, SIES, and myself. Questions can be addressed to either of us. You can contact me at 513-255-8608.

I look forward to launching this cooperative project in the near future.

Sincerely

Robert Billings

ROBERT BILLINGS
Chief, Crew Systems Branch
Flight Systems Engineering Division

Enclosures:
Project Overview

Project Overview

U.S. Department of Commerce/U.S. Air Force Engineering Directorate National Security Assessment of the Ejection Seat Industry

Introduction

The Department of the Air Force, Crew Systems Branch of the Engineering Directorate at Wright-Patterson AFB, and the Department of Commerce, Bureau of Export Administration, will work together to conduct a national security assessment of the U.S. ejection seat industry, with particular emphasis on the impact of defense budget and procurement cuts on the health of this sector. In addition, special attention will be given to the product liability and export control issues that may be affecting this industry. For purposes of this assessment, the ejection seat industry includes domestic and foreign manufacturers of ejection seats and public and private test sites.

The Department of Commerce will provide its expertise in data collection and industry analysis to this project; the Air Force will provide technical expertise in ejection seats and assess the current and future demand for ejection seats. The goal of this joint assessment is to analyze the long-term health and competitiveness of the ejection seat industry, to identify factors affecting the industry, and to develop recommendations to ensure the continued ability of the industry to support Department of Defense missions and programs.

Industry Overview

As of July 1996, the only American company active in the design and manufacture of ejection seats is the McDonnell Douglas Corporation of St. Louis, Mo. Two other American companies, Universal Propulsion (Phoenix, AZ) and Weber Aircraft (Fullerton, CA) have produced ejection seats in the recent past. Neither is doing so now due primarily to the decreased demand for seats brought about by decreases in defense procurement. Additionally, Simula Incorporated (Tempe, AZ) the Aerojet Corporation (Sacramento, CA), and Boeing (Seattle, WA) have all expressed an interest in the ejection seat business.

Two very active foreign manufacturers of ejection seats are direct competitors to the American manufacturers of these seats. Martin-Baker Ltd. (UK) and the Zvezda Design Bureau (Russia) market their seats world-wide, and both are active in efforts to sell their seats for use by the U.S. armed forces for current and future aircraft procurement.

Considering only limited procurement of manned aircraft for use by the American military is foreseen in the near future, the American market for ejection seats must be considered critical for American seat manufacturers. Should foreign companies win these contracts, it is feared American companies could be forced to get out of the ejection seat business as no further seat acquisition would be planned in the mid-to-long term. This, in turn, could leave the United States with no domestic source for the manufacture of ejection seats and totally reliant on foreign sources for this defense-critical item.

Appendix B

Survey Document

U.S. Department of Commerce
Bureau of Export Administration

NATIONAL SECURITY ASSESSMENT OF THE EMERGENCY AIRCRAFT EJECTION SEAT SECTOR

PURPOSE OF THIS ASSESSMENT

The U.S. Department of Commerce/Bureau of Export Administration was requested by the U.S. Department of Air Force, Air Force Materiel Command, Wright-Patterson Air Force Base to conduct a national security assessment of the Emergency Aircraft Ejection Seat Industrial Base. The goal of this assessment is to assess the health and competitiveness of the ejection seat sector and develop recommendations to ensure the continued viability of this sector to support defense missions and programs.

YOUR RESPONSE IS REQUIRED BY LAW

This assessment is conducted pursuant to the Defense Production Act of 1950, as amended (DPA) (50 U.S.C.A. app. section 2061 et. seq. (1993)) and as delegated to the Secretary of Commerce in section 401(4) of Executive Order 12656 (3 C.F.R. 585 (1988)). Your response to this questionnaire is required under section 705 of the DPA (50 U.S.C.A. app. section 2155). Any information submitted in response to this questionnaire will be deemed **BUSINESS CONFIDENTIAL** and treated in accordance with section 705 of the DPA.

EXEMPTION

If your firm has not participated in any program related to Aircraft Ejection Seats, or Major Sub-Components or Parts related to Ejection Seats in the United States since January 1, 1993, you are not required to complete this form. If this is the case, please provide the information requested below and return this page.

______________________	______________________
Name of Company	**Address (City, State)**
______________________	______________________
Signature of Authorized Official	**Date**
______________________	______________________
Name of Official - Please Print	**Phone**

Appendix B - 2

GENERAL INSTRUCTIONS

1. Please complete this questionnaire in its entirety as it applies to your company's Aircraft Ejection Seat related business. The questionnaire has 3 parts as follows:

PART I	Company Identification
PART II	Statistical Information
PART III	Competitiveness

2. It is not our desire to impose an unreasonable burden on any respondent. IF INFORMATION IS NOT READILY AVAILABLE FROM YOUR RECORDS IN THE FORM REQUESTED, PLEASE FURNISH ESTIMATES AND DESIGNATE BY THE LETTER "E".

3. Report calendar year data, unless otherwise specified in a particular question. Please make photocopies of forms if additional copies are needed.

4. You may attach additional sheets of paper if space available for any question is inadequate. Please ensure all such additional sheets identify page and question number they address.

5. Questions related to the questionnaire should be directed to:

   John Tucker, Senior Industry Analyst, (202) 482-3755, or
   David Villarreal, Industry and Trade Analyst (202) 482-3795, or
   Brian Nilsson, Industry and Trade Analyst (202) 482-3795

   You may also Fax these gentlemen at: (202) 482-5650

6. Before returning your completed questionnaire, please be sure to sign the certification on the last page and identify the person and phone number to be contacted (if necessary) at your firm. Please return the questionnaire by October 31, 1996 to :

   Mr. Brad Botwin
   Director, Strategic Analysis Division
   Room 3876, BXA/SIES
   U.S. Department of Commerce
   Washington, DC 20230

Appendix B - 3

DEFINITIONS

AIRCRAFT EJECTION SEAT - An aircraft escape system designed to safely eject a pilot or aircrew from an aircraft under emergency conditions.

DEFENSE SHIPMENTS - Direct and indirect military shipments, including: 1) weapon systems, support equipment, and all other defense related end-use items, identified by purchase orders bearing a DO or DX rating and/or a contract number from the Department of Defense, Nuclear Regulatory Commission, Central Intelligence Agency, Federal Aviation Administration, National Security Agency or the National Aeronautics and Space Administration; 2) the orders of your customers which you can identify as producing products for defense purposes; and 3) items tested and certified to military specifications.

EJECTION SEAT COMPONENTS:

PROPULSION UNITS - A rocket powered device employed in aircraft ejection seats to perform such functions as propulsion, acceleration, deceleration, ejection seat divergence, man-seat separation, parachute deployment, stabilization, etc., including rocket catapults and under-seat rocket motors.

CAD/PAD ITEMS - A Cartridge Actuated Device (CAD) releases cartridge energy to perform a controlled system or work function. A Propellent Actuated Device (PAD) is a rocket powered device that releases controlled propellant energy to perform a work function.

SEAT STRUCTURE - Consists of backrest, bucket, sides, and headrest, and normally constructed of lightweight Aluminum.

INERTIA REEL - Immobilizes and positions the pilot in the seat prior to the seats ejection from the cockpit

PARACHUTES - Includes the drogue and the recovery parachutes.

SEQUENCER - May be electronic or mechanical controller and its connections to each event location controls the timing and sequence of events in the execution of a pilot's ejection.

OTHER SUB-SYSTEMS - Includes Survival Kit, Emergency Oxygen, Guide Rails, Adjustment Actuator, Harness Release Mechanism, etc.

MAINTENANCE AND REPAIR - Planned and unplanned upkeep of ejection seats based on part and subcomponent life cycles, shelf lives, or as required.

TESTING - Evaluation of performance and reliability of ejection seats or ejection seat parts under controlled conditions.

OFFSET AGREEMENTS - Offsets are defined as industrial or commercial compensation practices required by Governments as a condition of purchase of military imports. Common types of offsets include licensed production of the defense item (or parts thereof) in the purchasing country, technology transfer, foreign investment, and counter trade.

UNITED STATES - Includes the fifty States, Puerto Rico, the District of Columbia, and the Virgin Islands.

Appendix B - 4

PART I: FIRM IDENTIFICATION

Definition

COMPANY or FIRM - An individual proprietorship, partnership, joint venture, association, corporation (including any subsidiary corporation in which more than 50 percent of the outstanding voting stock is owned), business trust, cooperative, trustees in bankruptcy, or receivers under decree of any court, owning or controlling one or more business establishments.

1. Company Name and Address: Please provide the name and address of your firm or corporate division responsible for aircraft ejection seat activities.

____
Company or Division Name

____
Street Address

____
City, State, Zip Code (Country)

2. Ownership: If your company or division is wholly or partly owned by another firm, indicate the name and address of the parent firm and extent of ownership.

____
Parent Name

____
Street Address

____
City, State, Zip Code (Country)

Extent of Ownership:________(percent) Year acquired ___________

3. Establishments: Please provide the location of each establishment under your company's control connected with the air ejection seat business. Indicate the type of activity(ies) conducted at that establishment by using the letter code(s) in bold (**R**esearch, **D**esign, **T**esting, **M**anufacturing, **A**ssembly, **S**ervice, **O**ther (e.g., Planning, Integrating, Directing, Marketing, Record Keeping, etc.)).

Definition

ESTABLISHMENT - A location or facility where economic value is added. For this assessment an establishment is a location where aircraft ejection seats, major sub-systems for aircraft ejection seats, or their components and parts are researched, designed, integrated, manufactured, assembled, tested, maintained, or otherwise serviced.

Establishment Name and Locality	Type of Activity(ies)

4. Establishment Non-Air Ejection Seat Activities: Please describe briefly the non-ejection seat activities performed at the above establishments.

____

____

____

____

PART II: STATISTICAL INFORMATION

1a. Shipments and Income Statement of Aircraft Ejection Seats and Related Services: Please complete the following table as it applies to your company's shipments and service revenues for aircraft ejection seats for 1993 to 1995, and projected data for 1996 to 1998.

Aircraft Ejection Seat Shipments and Income Statement						
Product Description	**1993**	**1994**	**1995**	**1996(e)**	**1997(e)**	**1998(e)**
Seat Shipments to U.S. Military **1. Dollar Value (in $000s)**						
2. Number of Seats						
Seat Shipments for Export* **3. Dollar Value (in $000s)**						
4. Number of Seats						
Seat Shipments, all other **5. Dollar Value (in $000s)**						
6. Number of Seats						
Service Revenues (in $000s): **7. Testing**						
8. Maintenance & Repair						
9. Other Services						
Income Statement (in $000s): **(sum rows 1,3,5,7,8, and 9)** **Total Sales**						
Net Income (after taxes) **(**Enter + or -)**						

*Please include both exports under your name and by the Government as a Foreign Military Sale.
** Enter either a plus sign (+) if you made money or minus sign (-) if you lost money on your ejection seat business.

1b. Major Customers: Please identify your top three customers:

1____________________, 2____________________, 3____________________

2. Make/Buy Ratios of Aircraft Ejection Seat Components and/or Services: If your company made aircraft ejection seats during your most recent accounting year, please complete the following table (based on value) for in-house production (i.e., value added) and out-sourcing (i.e., purchases) of aircraft ejection seat components and/or services by your company for your most recently completed accounting year. Enter the ratio as a percent (e.g. an entry of 25 means 25%).

Make/Buy Ratios of Aircraft Ejection Seat Components and Services			
Seat Component Description	**Make %**	**Buy%**	**Total**
1. Seat Structure	+		**= 100%**
2. Propulsion Units	+		**= 100%**
3. Stabilizers	+		**= 100%**
4. Inertia Reels	+		**= 100%**
5. Harnesses	+		**= 100%**
6. Droque Parachutes	+		**= 100%**
7. Recovery Parachutes	+		**= 100%**
8. Sequencers	+		**= 100%**
9. Survival Kits	+		**= 100%**
10. Emergency Oxygen	+		**= 100%**
11. Other CAD/PAD Items	+		**= 100%**
12. Other Components	+		**= 100%**
Seat Services Description	**Make %**	**Buy%**	**Total**
13. Testing	+		**= 100%**
14. Maintenance & Repair	+		**= 100%**
15. Services	+		**= 100%**

3. Major Domestic and Foreign Suppliers: Please identify your major domestic and foreign suppliers for each of the ejection seat components and services shown on the table below. Enter up to two suppliers in each category ranked by purchases from them during your most recently completed accounting year.

Seat Component Description	U.S. Sources (Company Name)	Non-U.S. Sources (Company Name and Country)
1. Seat Structure	1. 2.	1. 2.
2. Propulsion Units	1. 2.	1. 2.
3. Stabilizers	1. 2.	1. 2.
4. Inertia Reels	1. 2.	1. 2.
5. Harnesses	1. 2.	1. 2.
6. Droque Parachutes	1. 2.	1. 2.
7. Recovery Parachutes	1. 2.	1. 2.
8. Sequencers	1. 2.	1. 2.
9. Survival Kits	1. 2.	1. 2.
10. Emergency Oxygen	1. 2.	1. 2.
11. Other CAD/PAD Items	1. 2.	1. 2.
12. Other Components	1. 2.	1. 2.
Seat Services Description	**U.S. Sources**	**Non-U.S. Sources**
13. Testing	1. 2.	1. 2.
14. Maintenance & Repair	1. 2.	1. 2.
15. Services	1. 2.	1. 2.

4. Discontinued Ejection Seat Component and/or Service Sources: Please identify domestic and/or foreign sources of ejection seat components or services that you no longer use (since January 1, 1993) as a source on the table below. Enter the reason(s) in the table's last column using the letter codes that follow.

Company that formerly supplied us:
a. Went out of business
b. Exited product line
c. Sold product line to another company
d. Had quality problems
e. Had performance problems
f. Was no longer competitive
g. Was discontinued because we lacked enough business to keep the firm active
h. Was discontinued so we could make it ourselves
i. Other (specify, e.g., product liability concerns)

Company Name	Product Supplied	Country	Reason Source Discontinued

5. Impact of Discontinued Sources: Please comment on any adverse impact the discontinued source(s) have had on your ejection seat operations. (e.g., quality concerns, price increases, no domestic sources, longer lead times, must make in-house at loss, etc.)

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6. Problem Sources: Please identify domestic and/or foreign sources of ejection seat components or services that are experiencing problems and/or that may withdraw from the supplier base in the near future. Enter the reason(s) in the table's last column using the letter codes that follow.

Company that supplies us:
a. Is near bankruptcy
b. Plans to or may exit product line
c. Plans to or may sell product line to another company
d. Is more interested in commercial opportunities/markets
e. Is experiencing quality/performance problems
f. Is no longer competitive
g. Reports ejection seat business is not economical
h. Has product liability concerns
i. Other (specify)

Company Name	Product Supplied	Country	Nature of Problem

7. Potential Impact of Problem Sources: Please comment on any adverse impact the problem source(s) could have on your ejection seat operations. (e.g., quality concerns, added costs, reduced to sole source, no domestic source, longer lead times, technical expertise hard to replicate, etc.)

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8. Employment by Activity: Enter the number of employees (end of year) from 1993-1995, and projected for 1996 to 1998, for your Aircraft Ejection Seat activities as requested below.

Activity	1993	1994	1995	1996(e)	1997(e)	1998(e)
Administrative						
Maintenance/Service						
Research						
Design						
Development/Testing						
Production/Assembly						
Total Employment						
No. of Scientists and Engineers in above Total						
Trainees in above Total						

9. Labor Concerns: If in the **last 5 years** you experienced any labor concerns, such as shortages of certain skills, excessive turnover, liability claims, etc. that adversely affected your aircraft ejection seat operations, please describe them below:

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10. Projected Labor Concerns: If in the **next 5 years** you foresee experiencing any labor concerns, such as shortages of certain skills, excessive turnover, etc. that could adversely affect your aircraft ejection seat operations, please describe them below:

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11a. Capital Expenditures: Please enter capital expenditures for plant, and new machinery and equipment from 1993 to 1995, and projected amounts for 1996 to 1998, that apply to your aircraft ejection seat activities. Please select the reason(s) for investing from the letter coded list provided. Enter the most important reason first, the second most important second, etc.

Investment was targeted to:
a. Replace old equipment
b. Improve productivity
c. Expand capacity for existing ejection seat
d. Add new capability for new or modified ejection seat
e. Upgrade technology
f. Meet specific customer's requirements
g. Comply with environmental or safety requirements
h. Other (specify)

(Enter Dollar Values in $000's)

	Plant	Machinery and Equipment	Reason(s)
1993			
1994			
1995			
1996 (e)			
1997 (e)			
1998 (e)			

11b. Adequacy of Future Investment: Is future investment: 1) to little____, 2) adequate____, or 3) expansionary____ with respect to maintaining your aircraft ejection seat capabilities at their current level? Please comment on the basis for your answer.

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12. Research and Development Expenditures and Sources of Funding: Please enter research and development (R&D) expenditures and sources of funding related to Aircraft Ejection Seat Products and Services conducted (or subcontracted by you to another firm) by your firm from 1993 to 1995, and projected for 1996 to 1998.

Definition

RESEARCH - Includes expenditures in basic and applied research to do with aircraft ejection seats, i.e., a planned search for new knowledge; or the application of existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses; or the application of existing knowledge to problems involved in the improvement of a present product or process.
DEVELOPMENT - Includes expenditures on new or first time product development in the science, engineering, design or development of prototype products and processes to do with aircraft ejection seats.

(Enter Dollar Values in $000's)

	1993	1994	1995	1996 (e)	1997(e)	1998(e)
Expenditures: **Research**						
Development						
Funding Sources: **1. In-House (self-funded)**						
2. U.S. Customer						
Federal Government:						
3. Air Force						
4. Army						
5. Navy						
6. Other Defense						
7. Other Govt. (e.g., NASA)						
Foreign Sources:						
8. Foreign Govt.						
9. Other Foreign Entity						
Total (add 1 to 9):						

Top two rows (i.e., Expenditures) should total to Funding Sources.

13. R&D Projects: Please describe the major current research and development projects your firm is involved with respect to aircraft ejection seats. Cite the name of the project, its duration, the funding source, the dollar amount, and brief description and the goal of the project on the following table. If you have more than two projects, please photocopy page to accommodate additional projects.

Project Name	Duration (in months)	Funding Source	Dollar Amount
Project Description and Goal(s)			

Project Name	Duration (in months)	Funding Source	Dollar Amount
Project Description and Goal(s)			

14. Additional Research: In what ejection seat areas should additional research and/or development dollars be targeted?____________________________________

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PART III - COMPETITIVENESS

1. Competitive Prospects: How do you foresee the competitive prospects for your firm's U.S. production operations (regarding, for example, price and technology) over the next five years?

Our competitiveness should:
a. Improve greatly
b. Improve somewhat
c. Stay the same
d. Decline somewhat
e. Decline greatly

Please discuss the basis for your answer.

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2. Defense Budget Cuts: Please indicate what impacts defense spending reductions have had or will have on your Aircraft Ejection Seat operations. Also indicate what steps your company is considering to offset any negative impact that these reductions have had on your business (i.e. reduced employment, entered new lines of business, closed plants, consolidated product lines, reduced costs).

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3. U.S. Export Controls: Please comment on your firm's experience with export controls on ejection seats as administered under the International Traffic in Arms Regulations (ITAR) by the Department of State and the impact on your ejection seat business.

4. Government Policies: What reasonable adjustments could be made in U.S. Government procurement policies, standards, laws, or other regulations that would moderate any competitive disadvantages that your company might face as a result of these policies, laws, and regulations?

5. Foreign Barriers to Exports and Trade Practices: Please comment on any trade practices (e.g., tariffs or other trade barriers, market access, foreign government offset agreements, subsidies or incentives, etc.) that you have encountered in the international market that have reduced your ability to compete in the U.S. and or internationally. (See definition of Offset Agreements on page 3.)

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6. Effects of Imported Aircraft Ejection Seats, Major Sub-Systems or parts on your ejection seat related operations: How have imports of aircraft ejection seats and ejection seat sub-components (including those for your own use) positively and/or negatively affected your domestic operations?

a. Positive Effects: (e.g. lower costs, expanded markets, improved efficiency, access to foreign markets, etc.) Please explain below:

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b. Negative Effects: (e.g. product lines dropped, customers lost, retired capacity, laid-off work force, etc.). Please explain below.

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7. Future Strategies: Please describe any future strategies your firm is implementing or thinking of implementing to ensure your long-term participation and competitiveness in the aircraft ejection seat business.

A. Mergers, Acquisitions, Consolidations
B. Conversion
C. Expansion of Current Operations
D. Exports
E. Testing
F. R&D
G. Other

CERTIFICATION

The undersigned certifies that the information herein supplied in response to this questionnaire is complete and correct to the best of his/her knowledge. The U.S. Code, Title 18 (Crimes and Criminal Procedure), Section 1001, makes it a criminal offense to willfully make a false statement or representation to any department or agency of the United States Government as to any matter within its jurisdiction.

__________________________________ ____________________________

Signature of Authorized Official Date

____

Area Code/Telephone Number

____

Type or Print Name and Title of Authorized Official

____

Type or Print Name and Title of Person to Contact re this Report if Different

____

Area Code/Telephone Number

GENERAL COMMENTS

Is there any other information that we did not request above or that you would like to offer that you believe would be important for this national security assessment of the Emergency Ejection Seat industrial base? Please use the space to provide any additional comments or information regarding your operations, or other related issues that impact your firm.

Appendix C

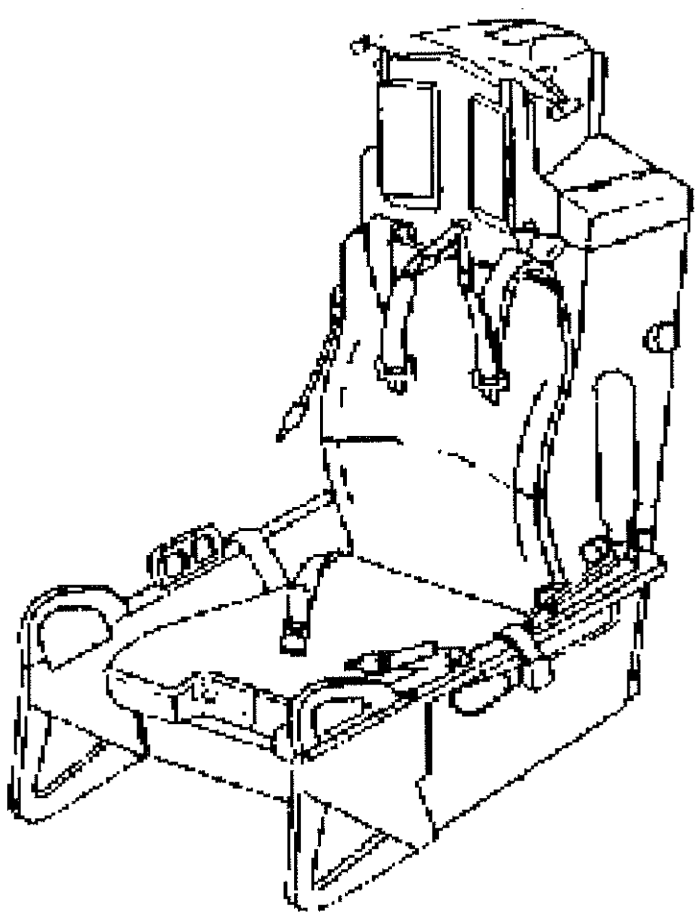
Ejection Seat Descriptions and Illustrations

APPENDIX C: EJECTION SEAT DESCRIPTION (ACES II)

The mission of the ejection seat is to eject the aircrew from a plane under emergency conditions in a safe manner. While the mission has not changed in more than forty years of innovation and design, current seats (which have a higher survival rate) are considered to be the third generation. Although the generational boundaries are not clearly defined, the first generation was a seat with a catapult. The pilot had his own parachute, and had to release his safety belt and kick away from the seat. The second generation saw the addition of rocket motors that greatly improved survival rates for lower altitude ejections. The third generation saw improved stability and performance.

The seat itself is a complex system composed of as many as 5,000 parts and components. The modern third generation seat uses electronic sequencers and multi-mode operation to deal with variables such wind velocity and altitude to achieve the safe return of the aircrew to the ground with little or no injury. The seat structure described below is modeled after but not exclusively representative of the McDonnell Douglas seat the Advanced Concept Ejection Seat (ACES II) used by the U.S. Air Force.

ACES II



ESCAPE SYSTEM ASSY

Major Components

The **Seat Structure** is the skeleton of the ejection seat. All components are fixed to the seat structure. The materials of the seat can vary, although the main material is aluminum. The structure can also vary between a monocoque structure (e.g., ACES II) or a more modular construction (e.g., the Navy Aircraft Common Ejection Seat (NACES) has five major modules). The moncoque structure, composed of hundreds of metals pieces fastened together with rivets and other fasteners, appears as a single solid structure. The modular seat was designed for the limited service space on aircraft carriers. Each modular section can be disassembled from the seat, inspected, and serviced separately. One of the major related components is the *guide rails,* which are attached to the aircraft cockpit. The seat rides on these rails as it's fired out of the cockpit by the catapult (a.k.a. ejection gun). Also, the *adjustment actuator* is a vital component that raises and lowers the seat in order to fit the weight and size range of aircrews. This fit is important since the center of gravity is dependent on the aircrew member fitting in the seat correctly.

The **Firing Control Handle**(s) are pulled when a pilot or aircrew wants to begin the ejection process. The handles (depending on the seat) can be located above the operator's head, at each side by the seat buckles, or placed in the center between the operator's legs.

A **Catapult (or Ejection Gun)** is used to propel the ejection seat from of the aircraft. The catapult functions by harnessing the power of an exploding cartridge. The force of the explosion propels the ejection seat up the guide rails and away from the aircraft. In older generations of seats the catapult was the only means for the seat to separate from the aircraft, in what was more or less an assisted bailout.

Rocket Packs create sustained thrust, where catapults only produce thrust for a brief period of time measured in a fraction of a second. Rocket packs are located under the seat area or along the back of the seat framework. Rocket power adds greatly to the distance the aircrew was propelled from the aircraft. This allowed for safer ejections at low speeds and altitudes, where a greater altitude is needed for full parachute deployment.

The **Pitch Control Subsystem** promotes ejection seat stability. It counters the tendency of the ejection seat to tumble out of control due to high wind speeds or misalignment of the rocket pack's thrust with the ejection seat's center of gravity. The system on the ACES II is called "STAPAC." The STAPAC is made up of a gyro and a small rocket motor that corrects any misalignment in the early phase of the ejection process.

The **Trajectory Divergence Subsystem** is used for aircraft that have two aircrew. This system allows for the two crew members to escape without striking each other. This goal is achieved by the use of an extra rocket motor to separate the two ejection seats.

Drogue Parachutes are used for the slowing and stabilization of the ejection seat in higher speed

ejections. This parachute is small and designed to withstand the pressures of high velocity deployment. The drogue parachute is deployed by the extraction parachute fired from the drogue gun in the early stages of the ejection process.

The **Recovery Parachute** can be deployed by the force of the drogue parachute, or it can be deployed by a mortar, as it is on the ACES II. The main parachute on the ACES II is 28 feet in diameter. The time it takes for the main parachute to deploy is a function of airspeed and altitude. At high speed the chute deployment is delayed to reduce the deceleration stress on the aircrew. At lower speeds the parachute is deployed quickly. On the ACES II the recovery parachute is also used to separate (or "yank") the crewmember from the seat.

The **Sequencers** are designed to control the timing of complex seat reactions. Most people in the ejection seat community consider the sequencer to be the highest-tech portion of the seat. Modern sequencers consist of analog (on ACES II) or digital circuitry (on NACES) with the digital sequencers being capable of more flexible responses to various environmental conditions. The ACES II analog system contains senors that can measure the airspeed and altitude of the seat The system will then choose between three different modes depending on the conditions. The modes optimize chances for safe ejection at conditions ranging from low-speed and low-altitude to high-speed and high-altitude (the performance envelope).

The **Harness Release Mechanism** allows the aircrew to release from the seat as instructed by the sequencer. In less than a second the after the main parachute is deployed the separation occurs by the drag of the parachute. This is accomplished by the automatic release of the lap belt and inertia reel pins. The seat pan latch is also released which allows the survival kit to be deployed from the seat bucket with the crewmember.

The **Survival Kit** is another important component of the ejection seat. The survival kit is stored under the seat area and contains several important pieces of survival equipment. Some of the most important items include the life raft, radio, compass, flares and other signaling devices, water, and a rucksack. The rucksack and the life raft can be deployed either manually or automatically on the ACES II. If manually deployed, the life raft and the rucksack will hang 25 feet below the ejectee on a lanyard (cord) to avoid losing the raft or rucksack.

The **Inertial Reel and Restraint System** solves the problem of crewmember bodies from moving and possibly being injured by the forces of the ejection process. Belts and restraints are used to keep the aircrew in place during the rapid accelerations that occur during the ejection process. Some seats have arm and/or leg restraints that synch up during ejection so that loose limbs are not injured by hitting the cockpit side or by the sudden wind blast.

An **Emergency Oxygen** system is provided by the ejection seat for the aircrew. On the ACES II the oxygen cylinder can be used either automatically or manually. This container can also be used for emergency oxygen if the aircraft's own oxygen system fails.

Appendix C - 4

Pyro is a term that describes all cartridge actuated and propellent actuated devices (CAD/PAD) that are utilized by an ejection seat. CAD/PADs are precisely measured explosives that are used to perform many seat work functions. In other words, pyro is the muscle of the ejection seat. For instance, the catapult is a device that consists specifically of a gas actuated, solid propellant booster rocket, which provides the initial power for the actual ejection of the seat from the aircraft. The catapult also consists of an outer barrel telescoped over an inner barrel attached to the cockpit floor. This is in contrast to the rocket catapult which is a self contained, mechanically initiated, two stage, solid propellant booster rocket. Other uses of pyro include turning the inertial reel, firing the drogue, releasing the lap belt, and cutters which sever connections with spent sections of the seat (e.g., the drogue chute after the main chute has deployed).

Time Line of a Successful Ejection

The process of ejection usually happens in under two seconds. However, in that time, many functions are performed. The example used for this demonstration is the UPCO SIIIS-3 which has three ejection modes (each mode depending on the ejection conditions). The example used here will be the low speed/low altitude ejection such as may occur on the Marine Corps' vertical take-off and landing AV-8B Harrier.

1. The pilot pulls the firing handle which begins the firing the dual primary initiators, which release high pressure gas. The gas simultaneously ignites the impulse cartridges that fire the catapult and the inertial reel gas generator.

2. The catapult fires. The seat begins to travel up the guide rails as the separation of inner and outer catapult tubes occur. All connections from the pilot are severed and the locator beacon and oxygen systems are started.

3. After about 20 inches of travel up the guide rails, the drogue chute assembly is deployed by the pressure from the catapult.

4. After the seat has been jettisoned from the aircraft the Seat Back Rockets (SBRs) fire. The seat is stabilized by the Directional Automatic Realignment of Trajectory Assembly (DART) which consists of two lanyards and a bridal that are connected to the seat and to the aircraft. The tension on the lanyards keeps the seat in alignment until the length of the lanyards has been exhausted and they fall away.

5. Another pyro device fires to open the parachute container.

6. The Wind Oriented Rocket Deployment (WORD) Motor pushes the main parachute away rapidly for low altitude ejections.

7. The main parachute is also assisted in opening by the Ballistic Inflation Aid. This is an

assembly of a cartridge, 14 slugs and other parts that promote the rapid uniform deployment of the chute.

8. The aircrew releases from the seat as it lays parallel to the ground just after main chute deployment by way of mechanical and pyro devices.

9. After four seconds the survival kit self deploys by dropping down away from the aircrew by way of lanyard. The aircrew can also deploy the survival kit manually as well by way of a "T" handle.

10. The ejectee makes a normal parachute landing.

Appendix D

Escape Modules

APPENDIX D: ESCAPE MODULES

The use of escape capsules for emergency exit from airborne vehicles was first used in WWI. Germany developed and tested an escape capsule to rescue personnel who had to abandon their observation balloon. In WWII, the German Bachem Natter jet became the first powered flight vehicle to employ an escape capsule and recovery parachute. After WWII, rapid technology growth in the aerospace industry led to the development of higher and faster vehicles which flew at the speed of sound.

* * * * *

Separable Nose Capsule

In 1947, the U.S. Air Force developed the X-2, a research aircraft, designed to reach speeds of Mach 3. The X-2 was the first aircraft to use an ejectable module for pilot emergency escape. The module consisted of the nose section of the aircraft which was separated from the fuselage by four pyro-pistons attached to the main body of the aircraft behind the pilot. The design required the pilot to manually bailout from the capsule after subsonic conditions were reached. One emergency egress was initiated by the pilot but was unsuccessful. The escape system was used during a high-altitude Mach 3 test flight in 1956 when the plane went into uncontrollable flight. The pilot initiated the capsule separation but was incapacitated and unable to perform critical functions when the capsule became severely unstable.

In 1960, a study was conducted by the U.S. Navy to design a separable nose capsule for a Navy fighter aircraft. The recovery envelope covered a wide range of altitudes and speeds. The state-of-the-art, at the time did not include maneuvering rocket control technology. The capsule depended upon aerodynamic stabilization fins during the initial escape sequence. Stabilization of the capsule was a major factor of concern in the success of the design. Aerodynamic devices such as fins and drogue parachutes to control pitch, yaw and roll during the entire range of the escape sequence were at best a compromise.

Encapsulated Seats

In the 1960's, the XB-70, an experimental aircraft, was designed to fly at an altitude of 70,000 feet at speeds of Mach 3. It incorporated a separate escape capsule for both the pilot and copilot. The initiation of the escape sequence was followed by 23 cartridge and propellant actuated devices that retracted the crew member into the capsule, closed the clam shell doors, started the emergency oxygen and ignited the capsule ejection rocket. The XB-70 system utilized a single rocket catapult delivering approximately 3,500 pound-seconds of thrust. The parachute systems were extensively tested on sled ejections and air launched drops. In 1966, an XB-70 was involved in a mid-air collision where both crew members initiated the escape procedure. The pilot and his escape capsule were successfully recovered, however, the copilots' capsule malfunctioned, which proved fatal.

The B-58 Encapsulated Seat Program was approved in 1958 by the U.S. Air Force. The purpose of this program was to develop a capsule that would ensure aircrew survivability greater than 50,000 feet at speeds of Mach 2. This high altitude, high speed environment had resulted in injuries to crew members when using open ejection seats. The B-58 system utilized twin rocket catapults, delivering approximately 1,475 pound-seconds of thrust. The main problem in the development of the enclosed capsule design, as in the past, was controlling severe aerodynamic instability particularly in yaw. The problem was solved successfully by adding several spoilers to the outside of the capsule to increase stability. In 1962, a pilot successfully ejected from a B-58 flying at a speed of 565 mph and at an altitude of 20,000 feet.

<u>Inset Escape Module</u>

The B-1 crew escape system was intended for use at speeds exceeding 600 KEAS and altitudes of 50,000 feet to provide emergency escape for all crew members, to protect the occupants from the escape environment, and provide shelter and flotation during the survival phase of the escape. The requirements dictated a "flying lifeboat" to safely recover the crew under almost every emergency egress situation. The Air Force wanted the crew members to perform their mission in a shirtsleeves environment, without confining pressure suits and oxygen breathing equipment associated with non-module crew stations. The B-1 module utilized two identical spherical rocket motors. Both motors were used for propulsion, as well as for the module stabilization and trajectory control, in accordance with an onboard control system.

The problem arose in that the crew station was to include equipment that had yet to be designed such as the avionics defensive and offensive system. This resulted in continual changes to the design which added weight and adversely effected the stability characteristics during the ejection sequence. The costs incurred on the development of the B-1 module were $117 million plus $15 million for aerial and sled testing. The estimated cost to design and qualify a heavier 11,000 pound version, which met more of the intended design requirements, was an additional $72 million. Consequently, in 1974, it was decided that the escape module was to be replaced by an ejection seat for each crew member. Module weight growth and stability problems warranted extensive redesign which made the program cost prohibitive.

The only other inset escape module application was the F-111 swing wing fighter-bomber. The range of the F-111 escape envelope included "on the deck" ejections from static to 800 KEAS. The inset module is structurally released from the aircraft at .35 seconds after ejection initiation. A single fixed position rocket motor is used to thrust the module away from the aircraft. The F-111 escape module is a two crew member inset module and provides a true "shirt sleeves" cockpit environment.

There were significant performance problems encountered during the F-111 crew egress development program which centered around excessive acceleration and deceleration forces on the crew members during high speed module ejections, stabilization and landing. The capability to safely recover under zero altitude - zero speed conditions was also adversely effected.

Appendix D - 3

Excessive module weight growth continued to be a negative factor.

The initial use of the escape system occurred in October 1967 and was a success. The overall survival rate of the escape module has reached 94 percent. However, weight growth due to additions of equipment and other changes resulted in increased rates of descent and greater impact forces causing some non-fatal crew injuries.

August 11, 1999

U.S. Department of Commerce
Bureau of Export Administration
Office of Strategic Industries and Economic Security
Strategic Analysis Division

PUBLICATIONS LIST

The U.S. Department of Commerce's Strategic Analysis Division is the focal point within the Department for conducting assessments of defense-related industries and technologies. The studies are based on detailed industry-specific surveys used to collect information from U.S. companies and are conducted on behalf of the U.S. Congress, the military services, industry associations, and other interested parties. The assessments are completed with the assistance of industry experts, both from the private sector and other government agencies. The collected data serves as the core of the Division's analyses, as in most cases data with this level of detail is unavailable from other sources.

Italics indicate forthcoming studies

PUBLICATION TITLE	GPO ORDER #	PRICE
National Security Assessment of the U.S. Maritime Industry-Winter 1999		
National Security Assessment of the Cartridge and Propellant Actuated Device Industry: Update-Winter 1999		
National Security Assessment of the U.S. High-Performance Military Explosives & Components Sector-Fall 1999		
Critical Technology Assessment: Assistive Technology-Fall 1999		
Offsets in Defense Trade - Conducted under Section 309 of the Defense Production Act of 1950-Summer 1999	003-009-00677-5	$9.50
Critical Technology Assessment: Optoelectronics - October 1998	003-009-00678-3	$7.00
Offsets in Defense Trade - Conducted under Section 309 of the Defense Production Act of 1950 - August 1998	003-009-00674-1	$7.50
National Security Assessment of the Emergency Aircraft Ejection Seat Sector - November 1997	003-009-00680-5	$10.00
Offsets in Defense Trade - Conducted under Section 309 of the Defense Production Act of 1950 - August 1997	003-009-00681-3	$9.50
Critical Technology Assessment of the U.S. Semiconductor Materials Industry - April 1997	003-009-00682-1	$1.50
Offsets in Defense Trade - Conducted under Section 309 of the Defense Production Act of 1950 - May 1996	003-009-00683-0	$9.50
National Security Assessment of the Cartridge and Propellant Actuated Device Industry - October 1995	003-009-00676-7	$14.00
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Critical Technology Assessment of U.S. Artificial Intelligence - August 1994	003-009-00685-6	$19.00
Critical Technology Assessment of U.S. Superconductivity - April 1994	003-009-00706-2	$7.00
Critical Technology Assessment of U.S. Optoelectronics - February 1994	003-009-00686-4	$13.00

PUBLICATION TITLE	GPO ORDER #	PRICE
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