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Problems and Alternatives in the Combat Rescue of Navy Aircrewmen

November 1980

BioTechnology, Inc.
3027 ROSEMARY LANE • FALLS CHURCH, VIRGINIA

OFFICE OF NAVAL RESEARCH

Final Report

Problems and Alternatives in the Combat Rescue of Navy Aircrewmen

by
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FOREWORD AND ACKNOWLEDGEMENTS

This report was prepared for the Naval Air Systems Command and the Office of Naval Research as part of a program to examine problems and alternatives associated with air combat escape and rescue. Mr. Henry A. Fedrizzi and Mr. Doug King, Life Support Technology Division, Naval Air Systems Command, sponsored and served as Technical Monitors for the study. Commander Donald H. Reid, MSC, USN; and Dr. Arthur Callahan, Biological Sciences Division, Office of Naval Research, served as Contract Monitors during the course of the project. We are most appreciative of their support and help.

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INTRODUCTION

Since the first manned test of an ejection seat in the United States in October 1946, the Navy has made tremendous progress in improving aircraft escape systems. Today's naval aviator is equipped with the most advanced and sophisticated escape and survival equipment to be found in the world. Ejection systems now in use permit escape from aircraft traveling at speeds approaching MACH 1 as well as from aircraft sitting on the flight deck of an aircraft carrier. The Maximum Performance Ejection Seat (MPES), now under development, will allow safe egress from an inverted aircraft at altitudes as low as 50 feet above ground level. Extremity restraint systems, constantly being improved, are reducing the number of injuries resulting from high speed flail. Parachute deployment time can be advanced with spreader guns or retarded until a safe speed is reached. For in-water landings, both parachute release and flotation equipment activation can be automatic. Signaling devices, especially survival radios, have improved and now are quite effective as survivor locators for Search and Rescue (SAR) forces. Rescue forces are well-trained and equipped to begin emergency medical treatment at the point of rescue.

The above elements form an escape and rescue system which has proven remarkably successful in minimizing losses from aircraft ejections occurring during peacetime training operations. Even during combat conditions, rescue rates are quite good when the pilot is able to get his stricken aircraft back to a friendly area prior to ejecting. However, in those instances in which an aircrewman is forced to abandon his aircraft over hostile territory, the escape and rescue system no longer functions in a continuous and effective sequence. This is attested to by the fact that only nine percent of the naval aviators who ejected over North Vietnam were rescued.

This report addresses the problems associated with combat rescue and discusses the combat SAR organization, its effectiveness, and vulnerabilities. The report analyzes alternative methods of combat rescue and describes how an air-to-air rescue system might have worked in Southeast Asia.

PROJECT OBJECTIVES AND PROCEDURES

The purpose of this series of projects for the Naval Air Systems Command and Office of Naval Research is to provide data and analyses for an evaluation of the combat effectiveness of aircraft escape, survival, and rescue systems. In early phases of this program, Navy combat ejection and survival data were collected and analyzed to identify the kinds of problems associated with combat escape. These analyses established causal factors associated with the injuries and problems occurring during the ejection-through-survival sequence.

Later efforts studied the effectiveness of combat Search and Rescue (SAR) for downed aviators. The primary objectives were to: (1) describe the extent of the Navy combat SAR effort in the Southeast Asia conflict; (2) discuss specific problems in combat rescue under various conditions (e.g., geographic, time, vegetation, population density, etc.); (3) summarize the SAR loss/recovery rates for geographical areas of Southeast Asia; (4) describe key factors that would have to be considered in alternative combat SAR systems; (5) formulate a model that could be used to evaluate the effectiveness of an air-to-air pickup system under the conditions found in Southeast Asia.

The present study deals principally with the rescue phase of the escape event. The objectives of this effort were to:

1. ***Analyze escape-through-survival problems that affected search and rescue operations.*** Each phase of the combat escape sequence was analyzed to isolate any element that might have had a positive or negative effect on the SAR effort. Table 1 presents a matrix of the variables examined. A checkmark represents a combination of variables known to have presented a problem or believed to be relevant in the development of an alternative rescue system. For each checkmark, a worksheet was completed that discusses the conditions affecting and linking the variables, the extent of the problem, and the status of aircraft and rescue systems associated with these variables. For each problem, a computer printout was obtained listing the individual Navy combat cases experiencing the problem. The forms entitled "Variables Affecting Combat Rescue" presented later in this report were developed from these worksheets and printouts.

2. ***Update air-to-air rescue model.*** Utilizing new and revised information on the capabilities of the different subsystems, the air-to-air rescue model previously developed was updated. The results show the ejection conditions and number of potential rescues, using a feasible air-to-air rescue system, for those Navy aircrewmen who ejected over North Vietnam but were not rescued.

Table 1
Variables Affecting Combat Search and Rescue

		Injury: Location	Injury: Type and Severity	Flight Conditions: Aircraft Speed	Flight Conditions: Aircraft Altitude	Flight Conditions: Aircraft Attitude	Flight Conditions: Weather	Flight Conditions: Aircraft Damage	Procedures: Standard	Procedures: Communications	Procedures: Training	Mishap Location: Distances to Safe Area	Mishap Location: Population Density	Mishap Location: Vegetation	Mishap Location: Terrain Features	Mishap Location: Time of Day	Mishap Location: Distance to Main Prison Area	SAR Related: Time	SAR Related: Anti-Aircraft Weapons	SAR Related: Availability of SAR	SAR Related: Capability of SAR	SAR Related: Vulnerability of SAR	Cockpit Related
Phase of Mishap	Pre-Ejection	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓						✓	✓	✓	✓		✓
Phase of Mishap	Ejection	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓							✓			
Phase of Mishap	Parachute Opening & Descent	✓	✓	✓	✓		✓				✓							✓	✓	✓	✓		
Phase of Mishap	Parachute Landing	✓	✓		✓		✓			✓	✓			✓	✓								
Phase of Mishap	Escape and Evasion	✓	✓				✓				✓		✓	✓		✓		✓		✓	✓		
Phase of Mishap	Search	✓	✓				✓		✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	
Phase of Mishap	Rescue	✓	✓				✓		✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	
Phase of Mishap	Capture	✓	✓							✓	✓		✓					✓			✓		
Phase of Mishap	MIA / KIA Status	✓	✓										✓	✓			✓						
Injury	Location			✓	✓	✓								✓	✓					✓			✓
Injury	Type and Severity			✓	✓	✓								✓	✓		✓		✓				✓
Injury	Time of Occurrence			✓																	✓		
Flight Conditions	Aircraft Speed											✓											
Flight Conditions	Aircraft Altitude											✓									✓	✓	
Flight Conditions	Aircraft Attitude																						
Flight Conditions	Weather																				✓		
Flight Conditions	Aircraft Damage											✓							✓				
Procedures	Standard																			✓	✓	✓	
Procedures	Communications																	✓					
Procedures	Training																			✓	✓		
Mishap Location	Distance to Safe Area																	✓		✓	✓	✓	
Mishap Location	Population Density																		✓	✓	✓	✓	
Mishap Location	Vegetation																			✓	✓	✓	
Mishap Location	Terrain																		✓	✓	✓	✓	
Mishap Location	Time of Day																				✓		
Mishap Location	Distance to Main Prison Area																						
SAR Related	Time																						
SAR Related	Anti-Aircraft Weapons																						✓
SAR Related	Availability of SAR																						
SAR Related	Capability of SAR																						
SAR Related	Vulnerability of SAR																						

EQUIPMENT

	COCKPIT RELATED	AIRCRAFT CANOPY	EJECTION SEAT	PARACHUTE	SURVIVAL EQUIPMENT	RADIOS	SURVIVAL BEACON	FLARES	MIRROR	LIFE VEST	LIFE RAFT	HELMET	GLOVES	ANTI-G-SUIT	OXYGEN	KNIFE OR SHROUD CUTTER	WEAPON	RESCUE DEVICE	CLOTHING (GENERAL)
	✓												✓						✓
		✓	✓									✓							
			✓	✓		✓	✓			✓	✓	✓			✓				
				✓	✓					✓	✓	✓		✓		✓			
					✓		✓										✓		
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✓				✓		✓		✓	✓	✓	✓							✓	
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	✓		✓	✓															
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			✓	✓															
			✓	✓		✓		✓											✓

3. ***Collect data on and evaluate alternative rescue systems.*** Data were collected on existing alternative rescue systems and on those components that might be used as part of such systems. These data include information on the engineering state-of-the-art of the systems, plus a review of research being done or planned. Evaluations were conducted to determine how each component might function as part of a complete combat rescue system. The air-to-air rescue system was divided into key subsystems, with a discussion of each. The following is a list of these subsystems, including key personnel visited or contacted for information.

Ejection Seat

Mr. H.A. Fedrizzi
Life Support Technology Division
Naval Air Systems Command
Washington, D.C.

Mr. Fred Guill
Crew Systems Division
Naval Air Systems Command
Washington, D.C.

Mr. Alan Hellman
Life Support/Survival Branch
Naval Air Development Center
Warminster, PA

Discretionary Descent Systems

Dr. John Nicolaides
Head, Aeronautical Engineering Department
California Polytechnic State University
San Luis Obispo, CA

Mr. Jon T. Matsuo
Naval Weapons Center
China Lake, CA

Air-to-Air Recovery Systems

CDR Harv Gregoire, USN
Naval Air Test Center
Patuxent Naval Air Station, MD

Mr. Robert Veazey
Manager, Aerial Recovery Programs
All American Engineering Co.
Wilmington, DE

Mr. Frank W. Ault
President
International Protein, Inc.
Arlington, VA

Rescue Aircraft

Mr. Tommy Thomason
Manager, Tilt Rotor Programs
Bell Helicopter Textron
Fort Worth, TX

Mr. Robert W. Kress
Director of Advanced Concepts
Grumman Aerospace Corporation
Bethpage, NY

Survivor Locator Systems

LTCOL Richard A. Raymond, USAF
Headquarters, Aerospace Rescue and
Recovery Service
Scott AFB, IL

Soviet Threat to Air Rescue Operation
1980 - 2000 Briefing (SECRET)

Combat SAR Joint Development Meeting
Maxwell AFB, AL 17 January 1980

COMBAT SEARCH AND RESCUE

This section describes the organization and operational structure of combat Search and Rescue (SAR) during the Southeast Asia (SEASIA) conflict. The description is followed by a series of summary sheets discussing, by time of occurrence, those variables that affected the success of the SAR effort.

In SEASIA, when an aircraft received severe enemy-inflicted damage, the catastroph. nature of the damage often allowed only seconds before ejection became mandatory. This lack of time, coupled with the demands of aircraft control, often negated actions critical to the SAR effort. These included: (1) using pre-ejection time to reach the safest ejection area; (2) communicating an accurate geographical fix and injury status report; and (3) establishing proper body position for the ejection sequence. However, the ejection or notice of intent to eject, in any event, set into motion a complex interaction among search and rescue forces.

In Southeast Asia, the primary responsibility for the SAR effort was with the Seventh Air Force. Operational control was exercised by the Third Aerospace Rescue Recovery Group (3rd ARRG), located in Nakhon Phanom, Thailand. This group had control over units assigned to cover specific geographical areas in Southeast Asia. The Navy control center subordinate to this group was responsible for, and located in, the Gulf of Tonkin.

SAR units constantly monitored the primary radio strike frequency during an attack, and, upon notification of a potential or actual aircraft loss, initiated a SAR alert. The initial recommendation to attempt a rescue was normally made by the On-Scene Commander (OSC), who was often a wingman orbiting the downed aircrewman. The two elements necessary for this recommendation were a positive identification of a live crewman, and a reasonable assurance of successful pickup without loss of the rescue vehicle.

If a rescue was deemed feasible, a rescue task force was dispatched to the scene. A typical force in Southeast Asia consisted of one HC-130 aircraft, which acted as Airborne Mission Control (AMC); two helicopters, usually H-3s or H-53s with two more on standby; six rescue escort (RESCORT) aircraft (A-7s or A-1s), which were in two elements of three aircraft. Additional strike or attack aircraft assisted, as needed, and were generally called in from other missions to support the SAR effort. Airborne Mission Control would determine from the OSC what forces and equipment were deemed necessary to suppress enemy forces in the area. The AMC would then form and release the necessary task force. When the RESCORT aircraft arrived in the rescue area, one was generally designated as the new OSC.

While the helicopter was making its final run-in, a RESCORT aircraft was overseeing the entire operation, giving the helicopter heading changes and distances to the survivor. The survivor was also giving information such as height and density of tree cover, speed and direction of wind, level of hostile fire, etc. directly to the rescue helicopter. Only critical radio transmissions were made at this time. After the pickup was completed, the helicopter stayed just above the treetops until it either had climbing airspeed or until the RESCORT aircraft cleared it to climb. This was a very vulnerable period for the rescue aircraft.

The next section consists of a series of forms (Tables 2-19) that isolate those variables influencing the ultimate success of the Search and Rescue effort. These variables are presented by the phase of the survival sequence in which they occurred and are discussed in relation to their positive or negative effect on the overall SAR effort.

Table 2

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Pre-Ejection

VARIABLE Initial Aircraft Damage

EFFECT ON AIRCREWMAN

The destructive ability of anti-aircraft weaponry often disintegrated the aircraft or forced it immediately into uncontrolled flight, leaving only seconds to initiate ejection.

Time from Initial Emergency Until Escape was Initiated (Total Navy Combat)

	1-10 sec.	11-20 sec.	21-60 sec.	1-10 min.	10-30 min.	30-60 min.	No Ans. Unknown
Number of Aircraft	60	14	54	87	24	4	71
Percent of Total	(24.7)	(5.6)	(22.2)	(35.8)	(9.9)	(1.7)	

This lack of time resulted in (a) inability to reach a safe area, (b) poor ejection position, and (c) lack of communication with SAR forces. (Forty-seven [47] percent of the POWs were unable to transmit prior to ejection.) The mean time from emergency until escape for the entire POW group was 1 minute.

EFFECT ON SAR

An immediate ejection near the target area often put the survivor in extremely hostile territory and increased the vulnerability of the SAR forces. Lack of communication denied the SAR forces an early start to the ejection location, and often increased the search time because the SAR forces had no idea of the survivor's location. These delays were especially significant when combined with the relatively fast capture rates found in North Vietnam.

GENERAL COMMENT

The sophistication and destructive power of new anti-aircraft weaponry will only serve to decrease the amount of pre-ejection time available to aircrewmen following aircraft damage in future conflicts.

Table 3

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Pre-Ejection

VARIABLE Injury

EFFECT ON AIRCREWMAN

Most fatalities resulted from injuries received during this phase. Of the survivors, 8 percent of the Navy-recovered aircrewmen and 18 percent of the POWs sustained either a major or minor injury during pre-ejection. Of the aircrewmen known to have ejected, 19 percent of all major or fatal injuries were incurred during the pre-ejection phase. The predominant major injuries during this period included lacerations, fractures, and burns from exploding ordnance. These injuries were highly susceptible to further complications during ejection and later stages of the survival sequence.

EFFECT ON SAR

Incapacitating injuries during the early part of the escape restricted an aircrewman's ability to eject, and if he did eject, his ability to effectively escape and evade the enemy or assist in rescue. Severe lacerations meant heavy loss of blood resulting in death or shock before any chance of rescue. Burns and open wounds were especially susceptible to fatal infection if the aircrewman was immediately captured or not rescued.

GENERAL COMMENT

Proper wearing of flight suits and gloves could have prevented some serious burns. Consideration should be given to the design of ejection seat initiation systems based on the types and severities of pre-ejection injuries.

Table 4

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Pre-Ejection

VARIABLE Flight Conditions

EFFECT ON AIRCREWMAN

The very nature of combat missions dictates that an aircraft has a good chance of being hit at a low altitude and high airspeed. This combination of events produced the high "Q" forces responsible for the majority of ejection injuries in SEASIA. The number of ejections within the safer portions of the ejection envelope was, in all probability, negatively affected by the poor rescue record in North Vietnam. Aircrewmen stayed with their aircraft, in an attempt to reach the safety of "feet wet" well into the outer limits of the safe ejection envelope.

EFFECT ON SAR

If the aircrewman elected to wait until the aircraft was very low to eject, it made it very difficult to mark his ejection location electronically and allowed very little time for him to communicate with SAR forces prior to being on the ground.

GENERAL COMMENT

If, following combat damage, it appeared that ejection was a relative certainty and a pilot would be unable to reach "feet wet," gaining altitude instead of immediately heading for "feet wet" would lessen the ejection forces, permit better location, and allow more alternatives for rescue.

Table 5

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Ejection

VARIABLE Aircraft Speed, Altitude, and Attitude

EFFECT ON AIRCREWMAN

Ejection at high speed resulted in a majority of escape injuries from flail and windblast during this phase. Forty-seven (47) percent of the combat study group ejected at speeds greater than 400 KIAS and 20 percent ejected at speeds greater than 500 KIAS. Only 14 percent of the study group reported being straight and level during ejection, and 45 percent reported the aircraft was in some adverse attitude (tumbling, rolling, spinning, or disintegrating) during the ejection sequence.

EFFECT ON SAR

The high speeds at the time of ejection were responsible for the injuries to be discussed in the next page. The speed and altitude of an aircraft often carried it far from the ejection site prior to ground impact; if communications between the SAR forces and the ejectee did not exist, this greatly hampered the search effort.

GENERAL COMMENT

The high speeds and subsequent extremity injuries due to high "Q" forces during combat ejection make a very good case for upper and lower anti-extremity flail devices on ejection seats.

Table 6

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Ejection

VARIABLE Injury

EFFECT ON AIRCREWMAN

Sixty (60) percent of the major or fatal injuries among Navy aircrewmen known to have ejected were incurred during this phase. Among the Navy POWs, 43 percent suffered a major ejection injury. The primary reasons for these injuries were high speed flail, striking objects, and windblast. The predominant major injuries included extremity fractures and dislocations, spinal compression fractures, and unconsciousness. Through-the-canopy ejections resulted in a disproportionate number of major injuries including fractures and severe lacerations.

EFFECT ON SAR

The high major injury rates encountered during this phase prevented survivors from evading the enemy and from communicating with SAR forces. These were important factors in determining if a rescue effort would even be initiated. If a rescue effort was initiated, severe injuries greatly increased the time to effect the rescue with a consequent increase in the vulnerability of SAR aircraft and crews. The severity of the injuries encountered during this phase was directly responsible for fatalities once the survivor landed in enemy territory. If the survivor was captured, he received minimal first aid, and the subsequent infection severely reduced any chance for long-term survival. If the aircrewman was not immediately rescued or immediately captured, the infection rate for these injuries, again, greatly decreased any chance for his long-term survival.

GENERAL COMMENT

The variety and severity of injuries, and the subsequent problems with these injuries, should be considered in any decisions to change the first aid equipment in the aviator's survival kit during combat. Prevention of infection should be given special consideration.

Table 7

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Parachute Descent

VARIABLE Altitude

EFFECT ON AIRCREWMAN

Approximately 50 percent of the Navy aircrewmen reported ejecting above 4,000 feet AGL. Sixteen (16) percent reported ejecting above an altitude of 10,000 feet AGL.

Altitude provided aircrewmen time to communicate their geographic locations, give their general physical condition, and alert the SAR forces of possible capture and extent of hostile activity.

EFFECT ON SAR

With conventional parachutes, which have a descent rate in the area of 22 - 25 ft/sec, there was not much time to communicate with the SAR forces prior to landing. The quick capture rates found in North Vietnam (discussed later) negated many SAR efforts and jeopardized SAR aircraft and crews which were unaware that the captures had been made.

GENERAL COMMENT

Parachutes were often sighted by wingmen in the air or in the trees. Some coding of chutes would aid in the identification with aircraft carrying two or more crewmen. Additional in-air time gives more options for rescue. The following are in-air times from 10,000 feet at different rates of descent:

25 ft/sec – 6.7 min
12 ft/sec – 13.8 min
8 ft/sec – 20.8 min

Table 8

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Parachute Descent

VARIABLE Injury

EFFECT ON AIRCREWMAN

Parachute-opening shock was reported as severe by 20 percent of the Navy survivors. These forces resulted in some severe muscle strains, bruises, and contusions. It is highly suspected that there were fatalities caused by anti-aircraft and small arms fire during descent. Two survivors reported being hit by gunfire. Others reported they thought they had been fired at during parachute descent, or a wingman reported seeing tracers in the area while watching a fellow aircrewman descend in the parachute.

EFFECT ON SAR

Parachute descent was an excellent time to communicate with SAR forces. Unfortunately, the relatively high number of ejection injuries, shock, and low ejection altitudes, prevented many aircrewmen from effectively doing this. Upper extremity injuries and unconsciousness also prevented aircrewmen from exercising what little steering control they might have had with the parachute.

GENERAL COMMENT

Conventional parachutes which offer negligible horizontal flight control probably offer very good targets because of their steady rate of descent and horizontal drift.

Table 9

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Parachute Descent

VARIABLE Geographic Location and Vulnerability

EFFECT ON AIRCREWMAN

The severity of combat damage to the aircraft often necessitated ejection near a target area and, consequently, parachute descent over heavily populated and defended areas. In Southeast Asia, even if a Navy aircraft had time to get away from an inland target, the aircrewmen generally headed for the coast to reach the "feet wet" safe area. If they were unable to reach the safety of the open ocean, they were forced to eject over the more heavily populated coastal areas of North Vietnam. Conversely, U.S. Air Force aircraft would generally head back to bases in Thailand; and if forced to eject, the aircrewmen would eject over more densely vegetated portions of North Vietnam or Laos.

EFFECT ON SAR

When an aircrewman ejected over a populated area, he was extremely vulnerable to small arms fire. Potential captors could also readily estimate the drift of the parachute and be waiting for immediate capture. If a rescue was attempted in an open, populated area, the chances of being shot down were significantly increased.

GENERAL COMMENT

Aircrewmen needed the capability to reach a geographic location where there might be at least some possibility of evading the enemy until a SAR effort could be attempted. Parafoil (Ram Air) parachutes with 4/1 glide ratio capability would have offered many aircrewmen a much better choice of parachute landing areas. Twenty-seven (27) percent of Navy POWs landed within 4 miles of the Gulf of Tonkin; 45 percent of Navy POWs landed within 13 miles of the Gulf of Tonkin.

Table 10

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Parachute Landing

VARIABLE Injury

EFFECT ON AIRCREWMAN

Parachute landings accounted for 11 percent of the injuries to the Navy POWs. These injuries included fractures from impact and contusions and lacerations from going through trees or being dragged over rough terrain. If in-water entanglements were included in this classification, there would undoubtedly be a significant number of KIAs associated with this phase.

Navy aircrewmen who received damage to their parachute canopies, either due to opening shock or enemy gunfire, had a major injury landing rate almost 3½ times that of those aircrewmen who suffered no canopy damage.

EFFECT ON SAR

The injuries received or compounded during this period severely hampered the aircrewmen's ability to evade, communicate, and assist during rescue.

If injuries proved fatal during this period, SAR units would often continue a dangerous search based on the information that the aircrewman was known to be alive in the air.

GENERAL COMMENT

With the relatively high rates of unconsciousness, as was found during this study, landings in open water or flooded rice paddies could well have accounted for some fatalities from drowning. The extremely dense vegetation, high trees, and rugged rock Karst terrain found over much of these areas of Southeast Asia contributed heavily to the degree of landing injuries.

Table 11

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Parachute Landing

VARIABLE Geographic Location/Vegetation

EFFECT ON AIRCREWMAN

The geographic location of the parachute landing in North Vietnam was directly related to time-to-capture and survival. The high trees, rocky terrain, and thick jungle vegetation were responsible for some parachute landing injuries. This thick jungle vegetation, however, served to give an aircrewman much better cover to avoid enemy detection. If the aircrewman was severely injured and unable to communicate, it could also be responsible for his not being found by either friendly or enemy forces. Open-water landings, while resulting in a high rescue rate, also resulted in some severe parachute entanglement problems.

EFFECT ON SAR

The open, populated coastal areas generally resulted in a survivor's immediate capture (58 percent captured in the first 10 minutes), whereas the heavy, thick jungle areas and open ocean favored recovery.

	Percent	
	Recovered	Prisoner of War
Open Ocean - Deep Water (N = 190)	96%	4%
In Shore, Open Areas, Lakes, Marshes, Rice Paddies, Populated Areas (N = 125)	15%	85%
Thick Jungle, Trees, Heavy Vegetation (N = 21)	91%	9%

GENERAL COMMENT

The above table is slightly misleading in that it cannot give MIA/KIA statistics for this area. It is anticipated, however, that there were more losses in the open ocean due to drowning and in the thick jungle, where severely injured aircrewmen could not be located, than there were in the in-shore areas where capture was relatively certain and quick. These comparisons may well have been balanced by the shooting of aircrewmen prior to or during capture. Unfortunately, no accurate data will probably ever be obtainable on this.

Table 12

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Surviva./Evasion/Search

VARIABLE Injury

EFFECT ON AIRCREWMAN

For those aircrewmen ejecting over open water, the greatest hazard was parachute entanglement and/or the inability to inflate flotation equipment. In the open Gulf the survivor ejection locations were generally very well marked and evasion was only necessary in coastal waters.

In North Vietnam, pre-existing injuries often debilitated the survivor to the point that he could not effectively evade. In several cases where the Search and Rescue attempt lasted several days, it resulted directly in the death of the survivor from loss of blood and/or infection. POWs reported cases of captured aircrewmen being so weak at capture that they were unable to survive. Infection of pre-existing injuries in the jungle environment was an especially big problem at this time.

EFFECT ON SAR

The injuries that were incurred during the early phase of the ejection and parachute descent had a maximum effect on search during this period. This was especially true with the terrain and vegetative features found in Southeast Asia, in that they made for poor radio communication and poor visual signaling. Injuries also prevented the survivors from evading and, consequently, giving the SAR units more time to effect a pickup effort.

GENERAL COMMENT

Better locator and communication devices, now under development, should aid in finding an aircrewman regardless of his condition. The inability to evade because of injury is a good argument for an alternate combat rescue system.

Table 13

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Survival/Evasion/Search

VARIABLE Equipment

EFFECT ON AIRCREWMAN

The URT-33 survival beacon often interfered with voice communication on 243 mhz. Survivors sometimes abandoned an active beacon after landing, which confused the search forces. The survival radio was by far the most important piece of survival/rescue equipment. Forty-eight (48) survivors in this study, however, reported some problem associated with their radios.

Some of the other more common problems reported during this time included "releasing parachutes," "inflating flotation equipment with injuries," "lack of drinking water," and "unsuitability of visual signaling equipment."

EFFECT ON SAR

The biggest complaint of the Search and Rescue forces was improper use of communications during the SAR effort. These complaints included poor quality transmission, lack of power transmitters, and too much unnecessary talk on the primary SAR network. Poor or no communication with the survivors greatly increased the SAR vulnerability. Several SAR efforts that may well have resulted in a rescue had to be abandoned because of loss of communication.

GENERAL COMMENT

The new joint services radio, PRC-112, with its improved range and SAR locator capabilities, will offer some distinct improvements. There should also be more emphasis on training in proper communications procedures among the units associated with the SAR effort.

Table 14

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Survival/Evasion/Search

VARIABLE Terrain, Vegetation, Population Density

EFFECT ON AIRCREWMAN

The heavy jungle terrain and mountainous Karst topography, while excellent for escape and evasion, were extremely poor for signaling. Geographic features cut down significantly on the radio communication range and most visual signaling devices would not penetrate the triple jungle canopy. For those not rescued, search efforts were often quite intensive, in many cases lasting several days. The following compares the time of search for POWs and MIAs where the formal search effort was employed.

Time of Search for POWs and MIAs Where a Formal SAR Effort Was Employed

Hours of Search		1 - 2	2 - 6	6 - 12	12 - 24	24 - 48	>48
POW (N=43)	Percent	37	14	16	16	10	7
KIA MIA (N=56)	Percent	12	23	20	20	20	5

EFFECT ON SAR

Search times in heavy jungle areas were of longer duration but received less enemy gunfire. The thick jungle canopy diffused the MK-13 flare smoke and prevented projectile flares from penetrating the foliage. Consequently, the final pinpointing of the survivor often proved very difficult. One of the primary reasons for the shorter search times for the POWs was that they were often quickly captured--ending any search effort.

GENERAL COMMENT

The terrain and vegetation characteristics over a wide range of probable combat geographic areas must be considered in the development of any future survival and signaling equipment.

Table 15

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Rescue

VARIABLE Injury

EFFECT ON AIRCREWMAN

Almost no injuries were reported during open-water rescues. Overland rescues through heavy vegetation produced lacerations and, in one case, pulled the survivor off the seat, resulting in his death. A severely injured crewman greatly jeopardized SAR craft and crew due to the time required for the helicopter crewman to go down, assist, and then retrieve the survivor back aboard. In addition to the increased hover time, it also took a suppressive gunfire crewman out of the helicopter.

EFFECT ON SAR

The time necessary to extract a survivor was almost directly proportionate to the extent of the injuries to the survivor. This time was all during hover, which was one of the most vulnerable times for the helicopter to receive small arms fire.

Once the aircrewman was rescued, the helicopter crewman was faced with emergency first aid which could include severe hemorrhage, compound fractures, severe burns, spinal fractures, etc. The aircrewman, in addition to treating an injured survivor, was responsible for his regular crew duties and gunfire support.

GENERAL COMMENT

For combat SAR, the rescue crewmen must be trained and equipped to treat a wide range of severe injuries. The rescuee must also be restrained so that the evasive maneuver of the SAR craft departing a hostile area does not further compound existing injuries.

Table 16

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Rescue

VARIABLE Terrain, Vegetation

EFFECT ON AIRCREWMAN

Often the jungle canopy was so thick in Southeast Asia that the survivor could not see the SAR craft even when it was in the immediate vicinity. Injuries often prevented the survivor from moving to an open area, which would facilitate location and rescue. If a rescue was attempted in an area of rugged Karst terrain with steep, sheer rock walls or high trees, it was often difficult to get the helicopter into a safe hover location.

EFFECT ON SAR

The thick jungle canopy made it difficult to locate the survivor and to get the rescue device down through the trees. During retrieval, re-entanglement with the vegetation was a problem.

If rescues were attempted from the sides of steep valleys, the helicopters faced problems from blades striking rocks or trees, unusual wind conditions, and hostile gunfire from above and all sides.

GENERAL COMMENT

The survivors must consider the capabilities and vulnerabilities of the rescue vehicle and do their utmost to reach a rescue area that will minimize these vulnerabilities.

Table 17

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Rescue

VARIABLE Equipment

EFFECT ON AIRCREWMAN

During the actual recovery, radios were practically useless due to the helicopter noise; therefore, the helicopter crews had to rely almost completely on hand signals.

Confusion often existed with rescue equipment that was nonstandard and that the survivor, consequently, did not use correctly due to confusion, injury, or lack of training.

EFFECT ON SAR

During overwater rescues, helicopter downwash was often severe and hampered the recovery effort.

The combat helicopters, although later equipped with armor-plated self-sealing fuel cells, were extremely vulnerable to being downed during the hover period.

Problems with retrieval winches included not enough cable and jamming during high speed operations.

GENERAL COMMENT

During the course of the conflict, vast improvements were made to the SAR helicopters. Their lack of speed, however, made them extremely vulnerable during the entire conflict.

Table 18

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Capture

VARIABLE Injury

EFFECT ON AIRCREWMAN

There were numerous reports of aircrewmen being either shot or shot at just prior to capture. After capture, aircrewmen were often subjected to beatings and harsh treatment, which aggravated existing wounds.

Generally, either minimal or no first aid was given following capture. This resulted in infection being the primary long-term survival problem.

During imprisonment, existing injuries such as dislocations and fractures were used for torture during interrogation.

EFFECT ON SAR

If capture occurred or there was a high probability of immediate capture, SAR efforts would be terminated. It was important that the survivor give accurate synopses of the chances of capture, because if capture did occur and was unknown to the SAR crews, they were extremely vulnerable to a trap. Exact injury information was important in that it let SAR forces know the capability of the survivor to avoid capture, and, consequently, would influence the order of rescue and/or degree of effort in relation to time.

GENERAL COMMENT

Some consideration should be given to the use of a general purpose, time-release antibiotic to be taken immediately if capture appears imminent. The infection rates during the first few days of capture appear more critical than when the survivors were turned over to the regular militia.

Table 19

VARIABLES AFFECTING COMBAT RESCUE

PHASE OF MISHAP Capture

VARIABLE MIA/KIA Status

EFFECT ON AIRCREWMAN

If captured, the chances of survival appeared to diminish almost in direct proportion to the distance of the capture site from the Hanoi prison complex. This may have been due, in part, to the attitudes of the local population, but was certainly due to the long, severe journeys to the Hanoi area with minimal medical attention given en route.

Some aircrewmen who were known to be alive in the air probably really had no chance of survival, because they were severely injured and unable to communicate with either friendly or enemy forces.

EFFECT ON SAR

The treatment of prisoners in North Vietnam, as harsh as it was, was probably better than what would be encountered in many other combat areas in the world. The inability to rescue aircrewmen immediately who have severe injuries, highly subject to infection, greatly restricts their chances for survival in almost any enemy territory combat scenario.

GENERAL COMMENT

When searching for a downed aircrewman, the North Vietnamese were very much afraid of armed resistance. If they felt the downed aircrewman might resist, they would generally fire into an area before entering. This practice undoubtedly resulted in the death and wounding of aircrewmen who were known to be uninjured during the early stages of escape and evasion.

EFFECTIVENESS, VULNERABILITY, AND COST ISSUES RELATING TO COMBAT SAR

This section presents descriptive statistics that define the magnitude, effectiveness, problems, and vulnerability of combat SAR as it occurred in Southeast Asia. Specific equipment and procedure problem areas, cost of SAR efforts, and the cost of SAR failures are discussed. Where appropriate for comparison purposes, these costs are updated to 1980 dollars.

Effectiveness

Figure 1 shows known rescue locations of Navy aircrewmen downed in Southeast Asia. Land rescues were made primarily by land- or carrier-based H-53s and H-3s, and water rescues primarily by the ship-based H-2s and H-3s. The base location of the helicopters making the Navy rescues was destroyer-cruiser, 43 percent; aircraft carrier, 21 percent; land-based, 36 percent.

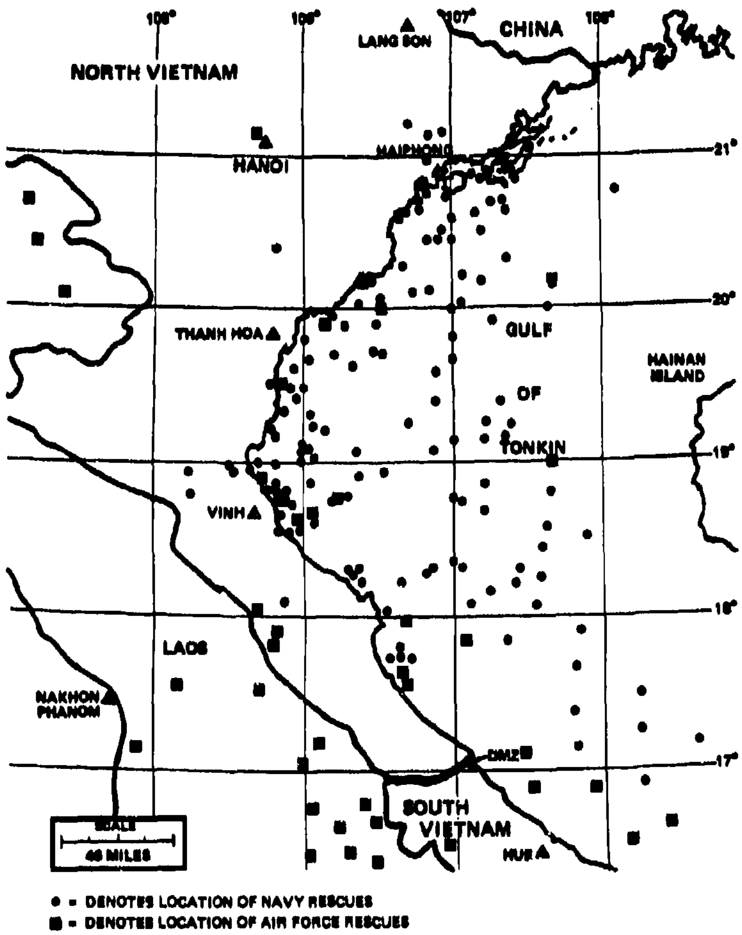

Figure 1. Locations of rescues of Navy aircrewmen during the Southeast Asia conflict.

Figure 2 shows the status of aircrewmen downed over North Vietnam. It is apparent from this that the chances of inland rescue in enemy territory were especially poor for naval aviators. Some of the reasons for the low success rate began at the moment of ejection. With ejection over hostile territory, it was very important that a member of the strike group verify the ejection and pinpoint the geographical position. The problems in doing this are apparent, considering that most of the aircraft in the area were flying around at 400-700 knots and were trying to avoid the same anti-aircraft fire that just hit the crewmen they were looking for. They were also trying to spot an object moving at about 1/500 the relative speed of their aircraft. At these speeds, in just two seconds the search aircraft would have moved a quarter of a mile from the target. It is obvious then why, in many cases, eyewitness verification was lacking and information given to SAR units was incomplete or erroneous.

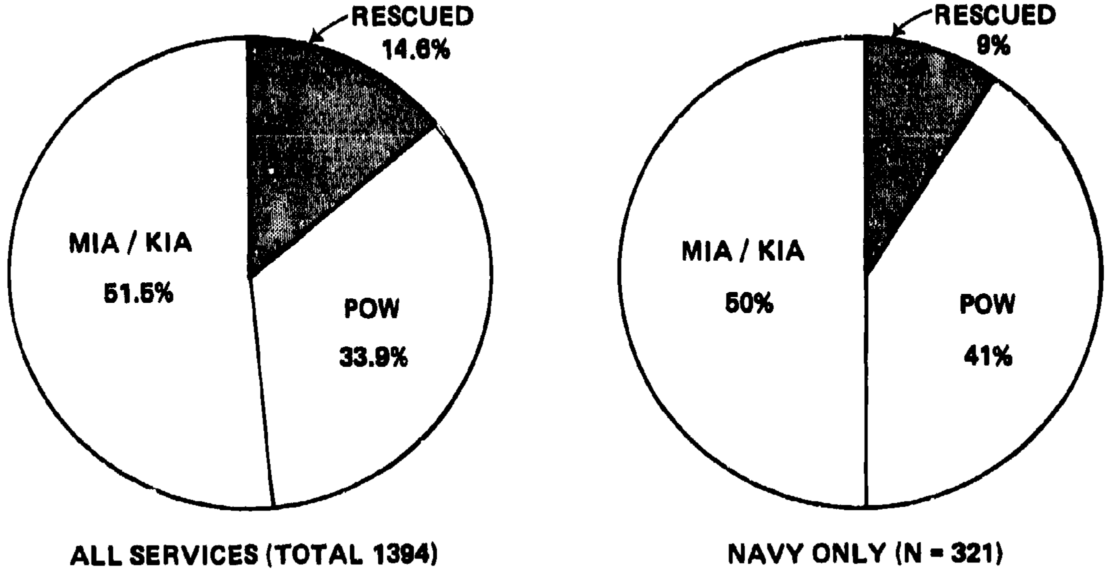

Figure 2. Status of aircrewmen downed in North Vietnam.

Once an aircrewman was on the ground, his chances of evading long enough to justify a rescue effort were small. Figure 3 compares time-to-capture with time to accomplish a land rescue. This figure shows that after 30 minutes, a relatively short time in which to effect an inland rescue, 84 percent of the POW survivors had already been captured.

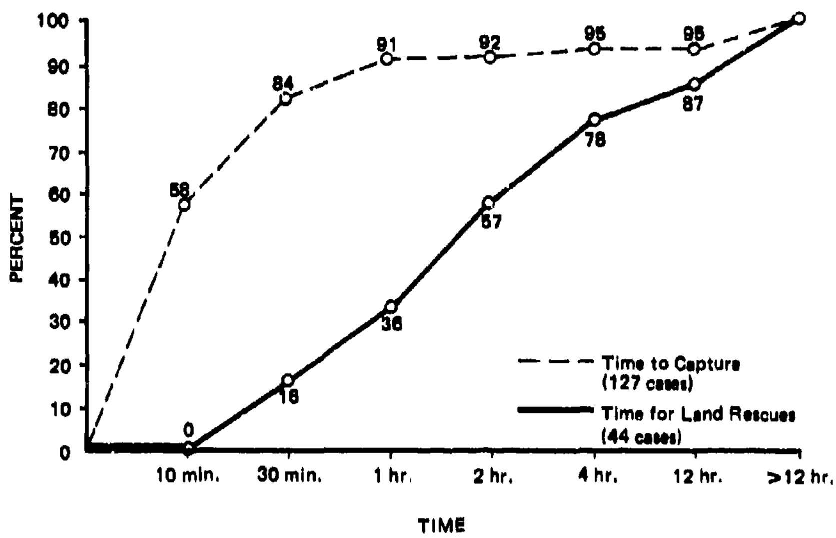

Figure 3. Cumulative percent of times to rescue compared with times to capture.

Figure 4 shows the ejection locations of the Navy POWs. Figure 5 shows the ejection locations of the Navy KIAs or MIAs.

If an aircrewman was downed and not captured, aircraft were immediately assigned to the search effort. These searches were intensive, often lasting for several days. For the MIA and KIA group, there frequently were long efforts, often involving one aircraft that searched an approximate area of loss for signs of wreckage or for a radio transmission. The search effort for those who later became POWs was of shorter duration, because capture confirmation or high probability of capture usually ended the mission.

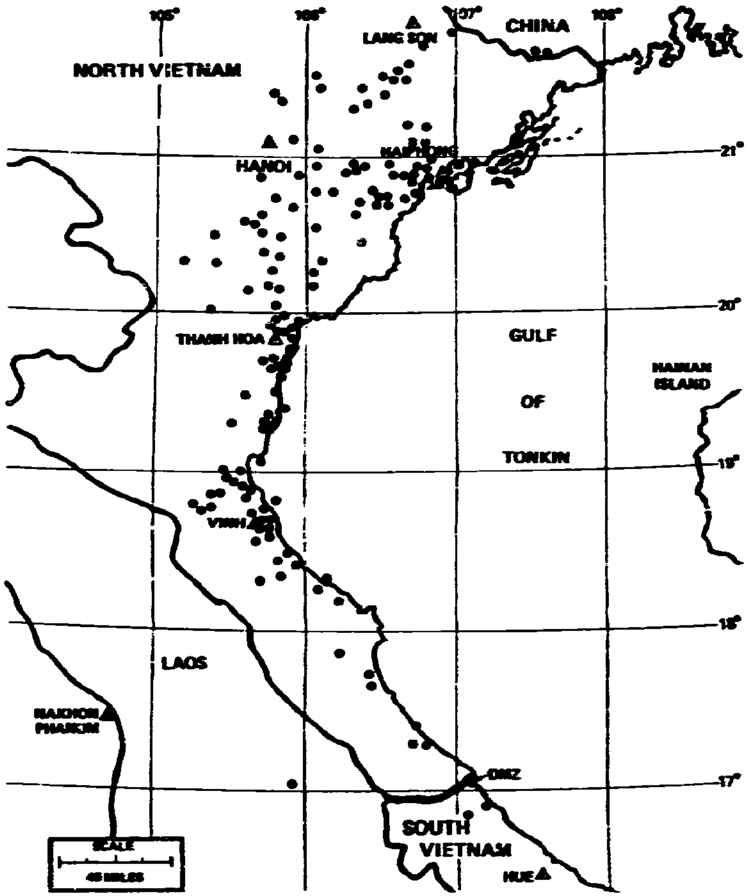

Figure 4. Known ejection locations of fixed-wing Navy aircrewmen who became prisoners of war during the Southeast Asia conflict.

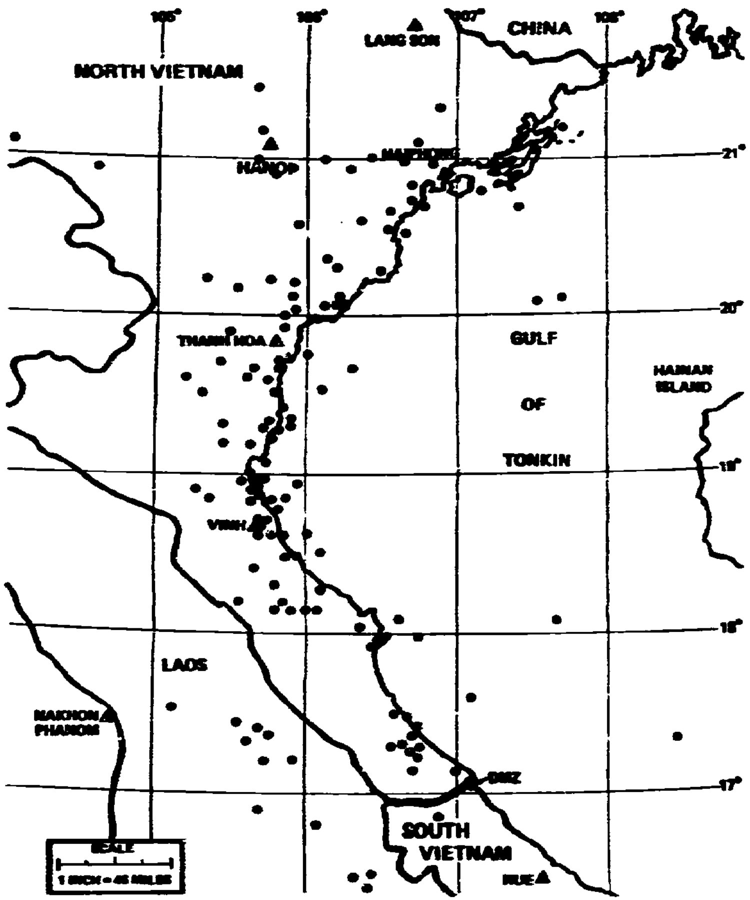

Figure 5. Known ejection locations of fixed-wing Navy aircrewmen who were missing or killed in action during the Southeast Asia conflict.

Vulnerability

The primary inland rescue helicopters (H-3s and H-53s) were equipped with self-sealing fuel tanks, rapid-fire machine guns, and armor. For protection, however, they relied almost completely on the escort aircraft. The A-1 aircraft were ideally suited for this mission because of their ability to fly an efficient cover pattern in the helicopter's airspeed regime; they were durable against anti-aircraft fire; and they could carry and effectively deliver a wide range of suppressive ordnance. Late in the war, the A-1s were retired from this role and were replaced by the A-7 aircraft. The SAR community generally feels the A-7, being a jet aircraft, is not the optimal aircraft to support this mission. The A-7's sustained turn radius is quite small for a jet fighter, but even this radius of turn will occasionally place the escort pilot in a position where visual contact with the helicopter is difficult to maintain. Tests plus combat experience have shown that less than two or three miles of visibility will negate the ability of the A-7 to effectively perform the escort mission. Heavy gross weight and high drag configurations will increase the turn radius, limit maximum speed, and decrease the A-7's ability to operate in the vertical (TACAIRCOM A-7D, 1974).

Since the Southeast Asia conflict, helicopter survivability has been improved by radar warning devices, infrared jammers and suppressors, additional hydraulic pumps, and stronger rotor blades and tail booms. The relatively low cruise speed of helicopters, however, still makes them quite vulnerable and less than optimal for rescue of downed aircrewmen in enemy territory.

The SAR losses per rescue in Southeast Asia were documented for various geographical regions in a previous report in this series (Every, 1979). In North Vietnam the combined loss per rescue for Air Force and Navy SAR forces was one SAR aircraft shot down for every three aircrewmen rescued, and one SAR personnel lost* for every 3.7 aircrewmen successfully rescued. When just Navy search and rescue into North Vietnam is considered, the SAR loss rate drops to one Navy SAR aircraft lost for every 1.4 aircrewmen rescued, and one Navy SAR personnel lost for every 1.8 aircrewmen rescued.

Fixed-wing SAR losses were caused by almost the entire spectrum of anti-aircraft weaponry found in North Vietnam. Aircraft shot down at low altitudes (e.g., below 6,000 ft) were predominantly downed by a mixture of aimed and barrage fire from 37mm and 57mm guns. At higher altitudes, losses were primarily from 85mm guns and SAM missiles. Helicopters were vulnerable to small arms fire because of their lack of speed and the requirements for low hover during recovery operations. Late in the war, another weapon increased the hazard. This was the SA-7 (STRELA) surface-to-air missile. It was man-portable, fired from the shoulder, and possessed an infrared-sensing homing system. This missile was a great threat to helicopters and slow-flying aircraft. The vast improvements in the capabilities of portable fired missiles since the Vietnam era increases further the vulnerability of the helicopter and the slow moving escort aircraft that must support it.

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*Includes both helicopter and fixed-wing aircraft specifically assigned to a SAR mission. SAR personnel losses include KIA and/or POW.

Cost

The cost of a SAR effort, as assessed in "Cost Effectiveness of the Combat SAR Systems," a study conducted by the Air Force Air Rescue and Recovery Service, was on the order of $70,510 in 1973. It would be almost twice that amount in 1980 dollars. While these costs seem high, they are almost negligible compared to the cost of unsuccessful SAR. It is difficult to determine the costs of losing an aviator, because many aspects of the loss (morale, experience, leadership, humanitarianism, etc.) cannot be quantified. The following figures represent only the raw training replacement costs for a naval aviator. These data represent the total cost through 4½ years after a pilot is designated as Naval Aviator. At this point, a pilot will have completed Primary Flight, Basic Jet, Advanced Jet, and Combat Readiness Air Wing (CRAW) training plus training in operational squadrons. The complete cost, given for an A-7 pilot and updated to 1973 dollars, is $651,870 (Walker & Mehaffie, 1974). When these costs are updated to 1980 dollars at a 10 percent per year rate, the cost is $1,270,310; at a 7 percent rate, the cost is $1,046,760. These costs do not include the aircrewman's salary while he is a POW or MIA, the rehabilitation cost for a POW, or insurance settlements if KIA. They do not include the cost of a SAR attempt or the cost of a SAR loss. Known SAR losses in Southeast Asia for downed Air Force and Navy aircrewmen included approximately 80 fixed-wing aircraft (A-1s, F-4s, A-7s, etc.) and 29 helicopters (H-3s, H-53s, H-2s, etc.), for a total of 109 vehicles. There were 63 SAR personnel killed in action and 13 who became POWs. For dollar reference purposes, the 1980 flyaway cost of the majority of SAR dedicated aircraft (H-3, H-53, H-2, A-7) ranges between 8 and 10 million dollars per aircraft.

In Southeast Asia, the intangible but real costs of the prisoner of war pilots dwarf these numbers since the prisoner became a significant political issue. If a rescue system had existed which could have prevented aircrewmen from becoming prisoners, the war might have terminated much earlier. From this point of view, the cost of lost aircrewmen is staggering (Walker & Mehaffie, 1974).

ALTERNATIVES TO CONVENTIONAL COMBAT SAR

This section discusses basic issues in improving the rescue rate for aircrewmen downed in hostile territory. This is followed by a review of some alternative systems to conventional escape and rescue. The last part of this section presents the state-of-the-art of the components that make up an air-to-air rescue system and describes how such a system might have worked in Southeast Asia.

For evaluation purposes as to the inland distance requirements in North Vietnam, Table 20 presents the Navy prisoner of war ejection locations in miles from the Gulf of Tonkin.

Table 20

Distance from NVN Ejection Location to Gulf of Tonkin, for Navy Prisoners of War

Distance (Miles)	Percent	Cumulative Percent
In Gulf	3	3
1–4	24	27
4–8	10	37
8–12	8	45
12–16	11	56
16–20	7	63

Objectives for an Improved Combat Rescue System

Decrease Injury Rate

The prevention of ejection injuries during the escape sequence would eliminate the majority of severe injuries that later affect survival and rescue. Navy ejection seats now are being equipped with more positive restraint systems to prevent flail injury. One very promising high "Q" flail protection system was developed by the Naval Air Systems Command and consists of straps and deployment bladders packed within the sides of the seat and back cushion. Upon ejection seat initiation, a gas generator inflates bladders that then securely position the straps and netting around the shoulders and lower legs (Woodward & Schwartz, 1980).

Many through-the-canopy ejection injuries might be lessened by some re-evaluation and redesign of this method of ejection. Serious injuries from burns would be decreased by proper use and wearing of protective clothing. Injuries from parachute landing impact could be lessened through the use of parachutes with more control and lower rates of descent.

Allow Survivor More Evasion Time

The catastrophic damage associated with air combat mishaps often allows only seconds before ejection. In SEASIA, parachute landing in North Vietnam was followed by capture within a matter of minutes. This virtually precluded rescue since almost two-thirds of the land rescues required over one hour. A survivor must be given more time before capture, either by keeping him suspended in the air or by allowing him to reach a place where he has a reasonable chance to evade enemy forces until a rescue can be attempted.

Provide Faster Locator and SAR Reaction Times

The rapid time-to-capture found in Southeast Asia dramatically illustrates the importance of immediate SAR reaction if there is to be any chance for inland rescue. To facilitate this reaction, a SAR craft ideally should be equipped with a system that will pinpoint survivor location and give hostile force information that can be continually updated during the SAR effort. Survivor locator technology has been greatly improved since Southeast Asia, and there now exist systems that can pinpoint the location of up to six survivors from a coded signal. If this system could also display some graphic presentation concerning the types and numbers of hostile forces in the geographic rescue area, reaction could be more appropriate.

Decrease the Vulnerability of SAR Forces

With any improvement in rescue systems, there must be a concurrent effort to reduce the vulnerability of the SAR aircraft and crews. Countermeasures that have been applied to helicopters include electronic jamming devices, IR suppressors, better armor, better radar warning devices, less vulnerable engine rotor and tail blades, self-sealing and crashworthy fuel cells, and better rapid-fire mini-guns. The biggest improvement, however, would be to increase the maximum speed of the rescue vehicle (to over 400 KIAS).

Alternate and Improved SAR Systems Under Consideration

Improved Conventional Helicopter Rescue

Since Southeast Asia, the speeds of primary SAR helicopters have been improved, but dash speeds are still below 190 mph. The addition to the H-53s of the PAVE Low 3, which includes a sophisticated radar, projected map display system, forward-looking infrared radar, and a Doppler navigation system, greatly improves the navigation and low visibility capability. Many improvements to aircraft survivability, discussed above, have been incorporated into the SAR helicopters. The primary drawback to the helicopter is its lack of speed and its vulnerability during the final search and hover phase of rescue. To its credit, if time and hostile forces are not a problem, no aircraft is more suitable than the helicopter for overland or overwater recovery.

Flyaway Systems (AERCAB)

A study (Walker & Mehaffie, 1974) was conducted at the Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, to assess the operational practicability of an Advanced Crew Escape Rescue Capability (AERCAB). Feasibility studies were conducted on configurations incorporating the Parawing, Rotary Wing, Sailwing, and Rigid Wing lifting surfaces. Two of these concepts are shown in Figures 6 and 7. These systems offer the combined advantages of an ejection and flyaway-to-safe area capability for fighter and attack-type combat aircraft. In effect, these systems represent an "aircraft within an aircraft." The projected range capabilities attributed to these systems do offer an aircrewman a significantly better chance for rescue following ejection over enemy territory. Additionally, they would reduce SAR losses, because SAR operations could be conducted in lower threat areas. There are serious drawbacks to these systems, however. One is the cost to retrofit; the other is the weight of the systems which range from 600 to 750 lbs. Some other areas that require examination include: How would the system affect operational escape statistics? Would the system be more prone to malfunction from combat damage because it is a more complex unit? How would it do in low level, high sink rate ejections? How well could such a system be used, considering the types and severities of injuries found among Southeast Asia aviators?

Fixed-Wing, Ground-to-Air Recovery

A successful airborne pickup system was designed and developed by the Robert Fulton Company for the Office of Naval Research. The U.S. Army subsequently secured several of the Air Force pickup systems for use on Caribou aircraft (Fulton, 1964). The equipment used to perform aerial pickups with these systems falls into two categories, the drop kit components and aircraft components. The drop kit components include: harness, balloon, lift line, and helium bottle. The kit is dropped to a survivor who must put on the harness and inflate the balloon, which in turn raises the lift line hooked to the survivor's harness (see Figure 8). The recovery aircraft is equipped with a yoke that engages the anchor and line. Upon inflight engagement, the line is then connected to a reel-in winch that is capable of hauling in four men simultaneously on one pickup line (see Figure 9). Successful live test pickups of personnel from all U.S. forces were made from various terrains, in water, and out of rafts. There are several disadvantages in using this system: (1) It is impossible to use through heavily wooded terrain or jungle environments; (2) it takes the survivor at least 30 minutes to prepare the system, even if the kit is dropped right on target – during this time, the survivor and the aircraft are both vulnerable to hostile fire; (3) it would be very difficult for a severely injured person to use this system.

A similar concept (Simons & Dixon, 1969) involves a ground-air pickup with a long line loiter. This procedure utilizes a fixed-wing aircraft that positions a towed mass near the center of an on-pylon turn. This mass is then used to locate an attachment point for hookup to a survivor harness, followed by retrieval into the aircraft.

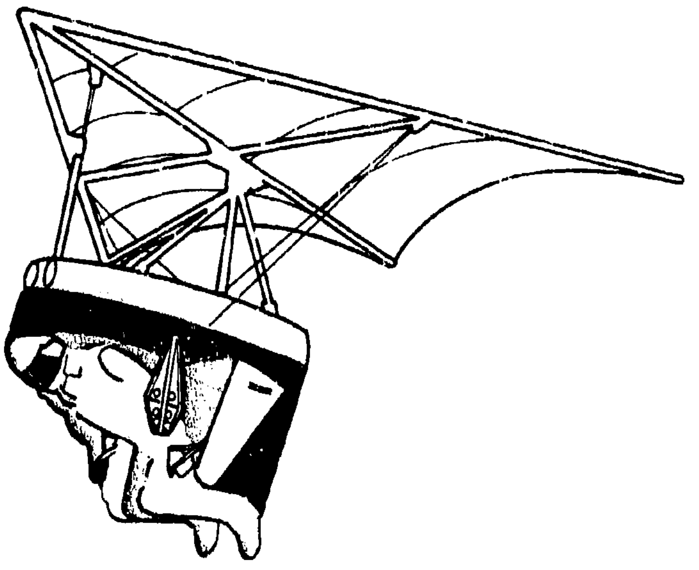

Figure 6. Parawing AERCAB.

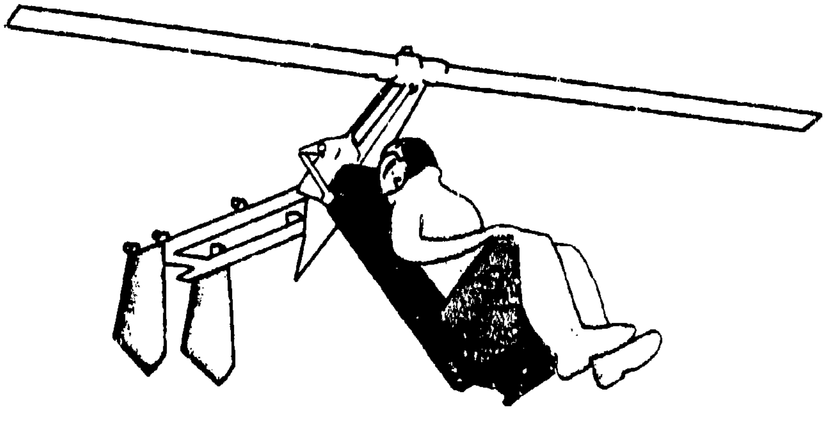

Figure 7. Rotary wing (deployable autogyro).

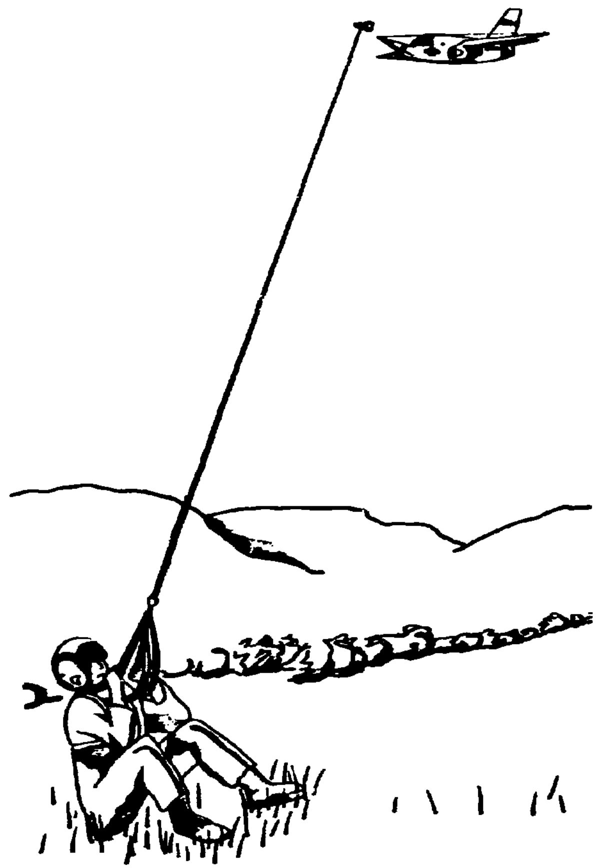

Figure 8. Pickup position with Fulton recovery.

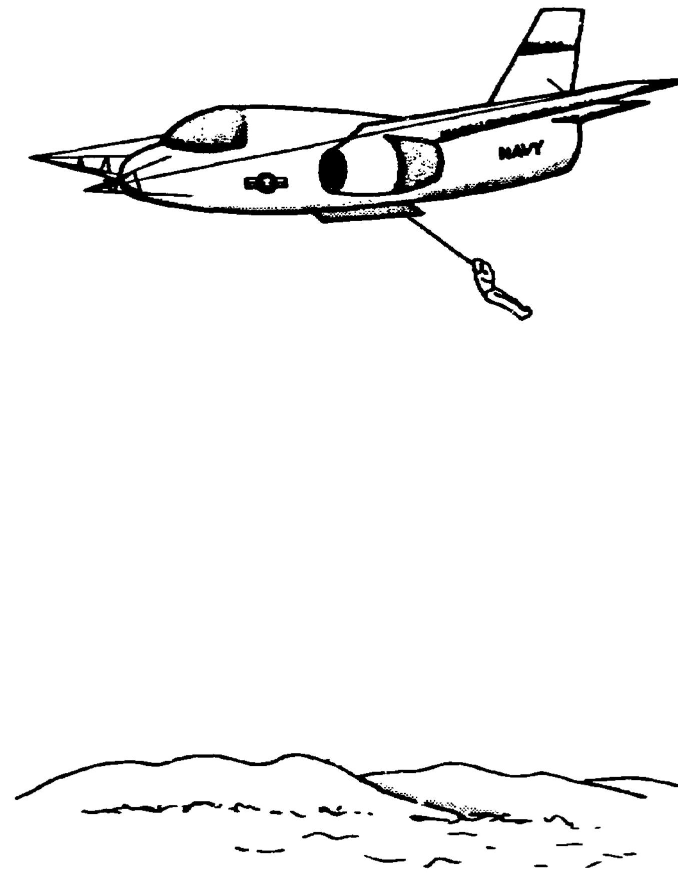

Figure 9. Retrieval into aircraft.

Air-to-Air Rescue

From combat analyses conducted to date, it appears that some form of air-to-air pickup might offer the best alternative for combat rescue of aircrewmen (see Figures 10 and 11). The reasoning is: (1) Much of the basic technology necessary for such a system is operational; (2) it would offer a chance of rescue to a higher number of aircrewmen ejecting over hostile territory; (3) such a system should decrease the vulnerability of rescue aircraft and crews; (4) there would be no major modification or weight increases to the ejection system; (5) it would not degrade the efficiency of operational peacetime ejections; (6) it would offer even severely wounded aircrewmen perhaps their only chance for survival.

In the following section, an air-to-air pickup system is divided into basic subsystems and the state-of-the-art and key components and problems of each of these subsystems is reviewed. This is followed by a discussion of the likely effectiveness of this system had it been available to the Navy POWs in Southeast Asia.

Pre-Ejection Procedures. The success of any air-to-air rescue system is directly related to the amount of air time an aircrewman has in the defined air-to-air pickup zone. With conventional combat escape and rescue systems, very little attention has been given to obtaining additional altitude prior to ejection; in fact, maximum efforts have been almost completely directed at reaching "feet wet." If an air-to-air system was operational it would be most important for pilots to use whatever power and control they had left in their stricken aircraft to both leave the immediate threat area and at the same time to zoom for maximum altitude prior to ejection. The purpose, of course, is to allow maximum time at a pickup altitude. This also will serve to lower the "Q" forces in a majority of combat ejections, and should improve fatality statistics by decreasing the number of ejections at the edge or beyond the limits of the safe ejection envelope.

Discretionary Descent Systems. There exists a variety of systems that might be used to keep an aircrewman aloft or at least to slow his rate of descent. These include glider-type devices, hot-air or gas balloons, oversized conventional parachutes, and Parafoils (similar parachutes called Ram Air). Several Ram Air inflated hot-air balloon systems were developed as discretionary descent systems for aviation use. The Goodyear design was a balloon mounted above a parachute. The Raven Industry device used the balloon itself for a parachute. The system that appears to offer the most flexibility and is compatible with an air-to-air recovery system is the Parafoil concept. The Parafoil is a true flying wing made entirely of nylon cloth with no rigid members (see Figure 12). Early tests of Parafoils (Nicolaides & Tragarz, 1970) demonstrated that when properly trimmed, the 360 Parafoil could produce a sink rate of between 8 and 6 ft/sec with a glide ratio of 4 to 1. Horizontal velocities of 20 to 25 mph were obtained, which is important since it permits a survivor to leave the target area rapidly. It also allows penetration of onshore winds in coastal areas. In personal communications with Dr. John Nicolaides (Chairman, Aeronautical Engineering Department, California Polytechnic State University) on June 23, 1980, he stated, "The number presented from the above report represented old Parafoil designs. Our modern Parafoil designs are now considerably better, yielding sink rates of less than 4 ft/sec with a glide ratio in excess of 6 to 1."

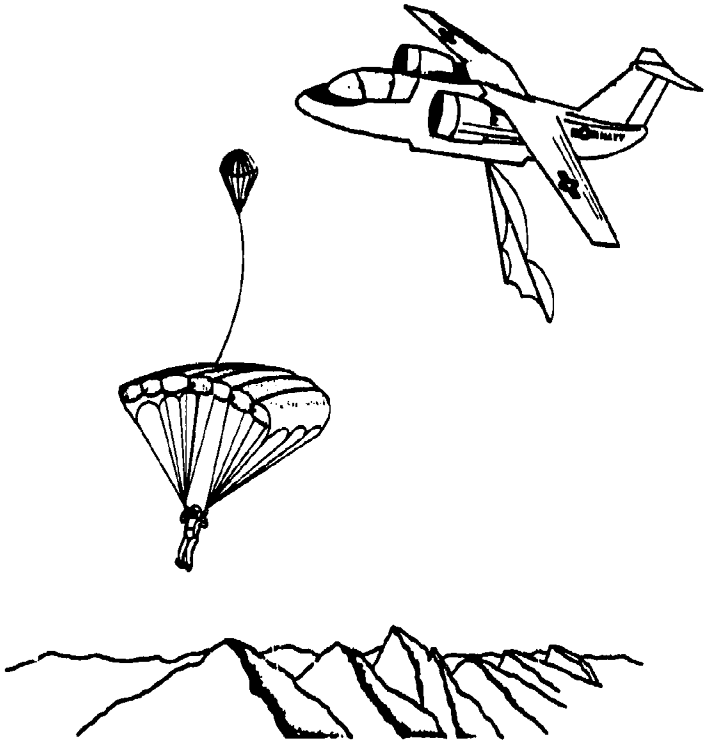

Figure 10. Aircraft lining up for air-to-air rescue.

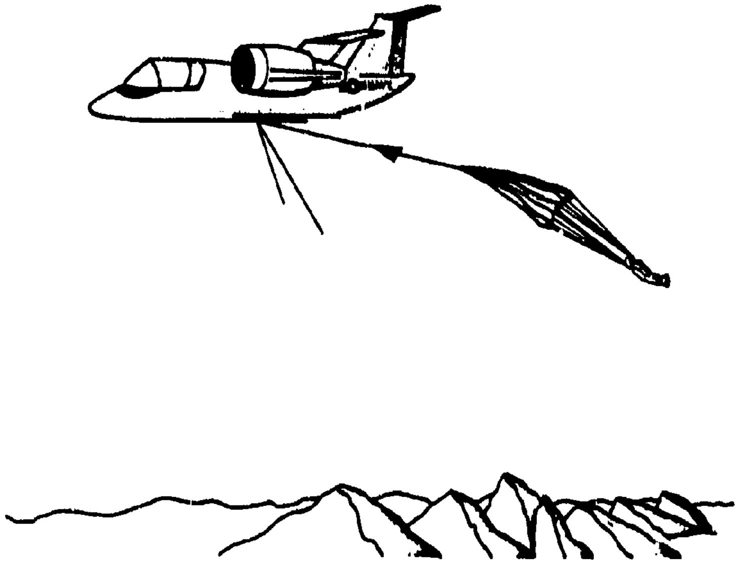

Figure 11. Aircrewman retrieval following drogue chute engagement.

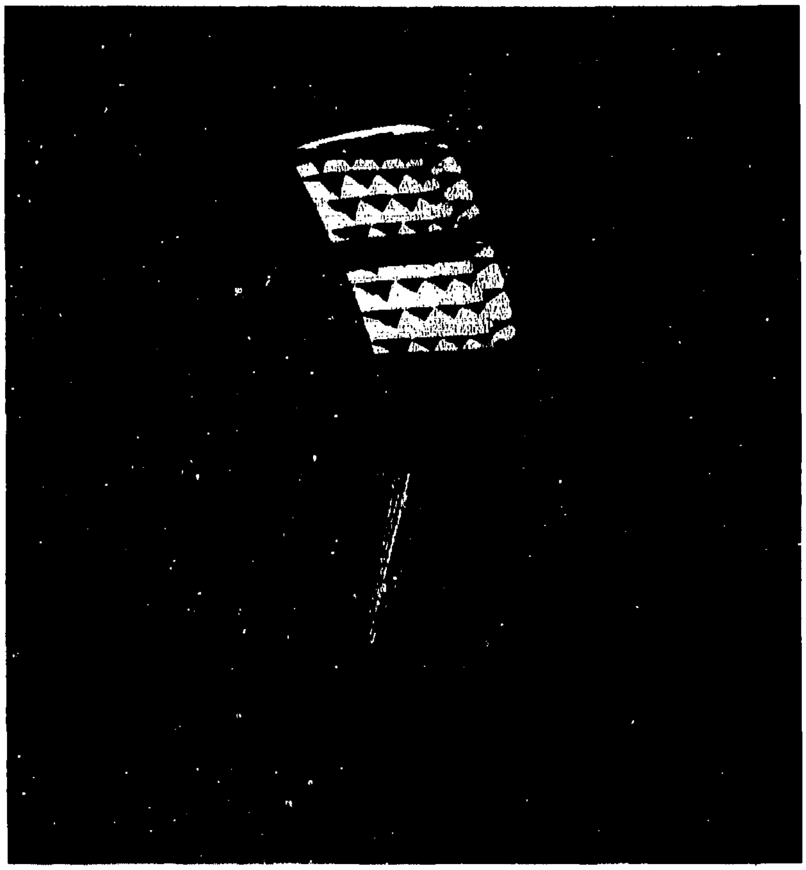

Figure 12. 360 ft.^{2} parafoil. (photo courtesy of Dr. John Nicolaides)

A key task in the development of a system utilizing the Parafoil would be to qualify it for use in the ejection seat. Without some reefing or delayed-opening device, the opening shock would be beyond the acceptable range. Much research has and is being done on this problem, and it appears that once the definitive limits are set for such a system, a solution could be readily obtained. In a paper given on the Ram Air inflated parachute wing at the 41st Combat Search and Rescue Joint Development Meeting, Mr. Jon Matsuo stated that:

> The development of a viable reefing system to cover the anticipated flight parameters is the biggest obstacle and challenge. The premediated sports parachute reefing system does not fulfill the stringent emergency escape operational requirements. The Navy hopes to complete the exploratory development by the end of this fiscal year, and be ready for full scale engineering development in FY 81. (Matsuo, 1980)

When the slow rates of descent are presented for these parachutes, a question arises concerning the vulnerability of an aircrewman to anti-aircraft and small-arms fire. A survivor under a Parafoil certainly would be in the air for a greater length of time than would a survivor who descends under a conventional conical parachute. This disadvantage should be more than offset, however by (1) the ability of the survivor to increase the rate of descent of the Parafoil, and (2) the capability to maneuver the Parafoil with up to a 25 mph horizontal velocity to get away from hostile fire. This last point represents an advantage over the conventional parachute, which offers little option over speed and direction of descent, resulting in the survivor continually becoming a better target to enemy forces as he descends. Another benefit from the steerability of these Parafoil chutes comes from their ability to avoid descending into a fireball, or on high tension wires, buildings, or other dangerous objects.

Modified forms of the Parafoil chutes now are being used by all branches of the military services for their specialty jumpers and by some foreign governments for their paratroop units. The flight characteristics of these chutes, being like a glider, offer the option of adding a lightweight propulsion device to the system that would yield a highly efficient weight-to-distance flyaway capability.

Air-to-Air Recovery Systems. The feasibility of air-to-air recovery of live personnel was demonstrated in 1966 with a mid-air pickup and retrieval of a parachutist by All American Engineering Company. Within a two-week period, a parachutist made two jumps from 9,000 ft and was recovered by a C-122 test aircraft between 7,000 and 8,000 ft. This demonstration was followed by a successful program with the Air Force showing the possibility of using a high performance T-39 aircraft for air-to-air pickup. The egress port just aft of the cockpit was used for retrieval. Basic equipment for these tests included engagement hardware consisting of poles to hold the engagement hook, a boarding davit, and an energy-absorbing winch system that would also control the G loadings throughout the engagement and retrieval. The G forces during the live engagement and tow were found to be well within acceptable limits (All American Engineering Company, 1968).

Mawhinney and Blizard (1969), in their report on air-to-air rescue systems for the Naval Air Development Center, present a wide range of concepts for mid-air parachute engagement. To determine the effects of air towing, Reid et al. (1972) conducted biomedical towing experiments with human subjects at the DoD Joint Parachute Test Facility, El Centro, California. Those tests showed that subjects could be towed at speeds just over 170 KIAS for over 2½ minutes without adverse effects. Fatigue and stress to the neck muscles appear to be the immediate limiting factor in high speed towing. Support for the neck muscles might be achieved by an auxiliary support device or by towing or retrieving an aircrewman while he is still in the ejection seat. Additional research and testing will be required to investigate this and the problems associated with the rescue of two aviators who eject from one aircraft.

Since the early 1960s, both fixed-wing and rotary wing mid-air recovery systems have been in daily use by the U.S. Air Force. This system has resulted in hundreds of thousands of successful recoveries of satellite data packages, missile components, and remotely piloted vehicles.

Rescue Aircraft. The range of aircraft used for air-to-air recoveries testifies to the fact that almost any type of aircraft (propeller, jet, or rotary wing) can be used to make an air-to-air pickup. Questions to be resolved in the selection of an optimum aircraft for combat use include: What aircraft will be capable and available for assignment to this mission during armed conflict? Will it be necessary for aircrewmen to be brought into the aircraft once picked up in the air? What are the vulnerability issues associated with such a mission? What are the alternatives if an air-to-air pickup cannot be accomplished? What are the cost/benefit considerations?

During the Southeast Asia conflict, the Naval Air Test Center at Patuxent River evaluated techniques to make rescues more efficient. One approach was based on the premise that tactical aircraft could be equipped to make inflight retrievals of ejected crewmen. This concept features a small pod that could be attached to any fuselage or wing station of an aircraft involved in an attack mission. The pod would house a line to be dispensed if an inflight retrieval was required. The line, energy absorption, and engagement device would engage the descending parachutist and tow him back to nonhostile areas. The rescuee could then be transferred air-to-air to a winch-capable aircraft such as HC-130 or reparachuted to a friendly area. Reparachuting would be accomplished either by use of the original parachute, or by use of a second parachute that could be in a pod and attached to the engagement line.

It would appear beneficial to be able to bring a survivor directly into the pickup aircraft. This would allow for high-speed evasive maneuvers and high or low altitude high-speed exit from the combat area. It would also offer the survivor immediate first aid and spare him the trauma of being redropped or air-transferred to another aircraft with a retrieval capability.

Ideally the rescue aircraft would be multipurpose and would become SAR-dedicated only during combat. The aircraft should be able to sustain speeds greater than 400 KIAS and have a hover capability. This VTOL capability would serve two important functions: It would be able to operate from destroyers and cruisers, as well as aircraft carriers; and it could also be used to make a ground pickup should an air-to-air recovery prove not feasible. Figure 13 shows a model of Grumman's 698 V/STOL aircraft that is being tested under a joint Grumman/Navy/NASA program. This plane's maximum speed is approximately 500 knots with a maximum ceiling of 50,000 ft. It can operate in a radius of 705 nautical miles. It has a time-on-station at 100 nm of 3.6 hours and is designed to operate off V/STOL-equipped combat ships (Mayfield, 1980).

The effectiveness of any air-to-air rescue system will depend heavily on the accuracy and capabilities of the survivor locator system. Now entering the final stage of engineering development is an excellent system, adaptable to air-to-air rescue, called the Survival Avionics System (SAS). Following an ejection, SAS equipment in the SAR aircraft could be used in the acquisition mode with a capability of monitoring up to six crewmen at ranges of 100 nautical miles. The system is then switched to "Locator Mode." This mode provides a cockpit display of range and bearing information to the survivor. Once the SAR craft is within 3 miles of the survivor, the equipment is switched to "Exact Position Designator." In this mode, the system is designed to bring the SAR

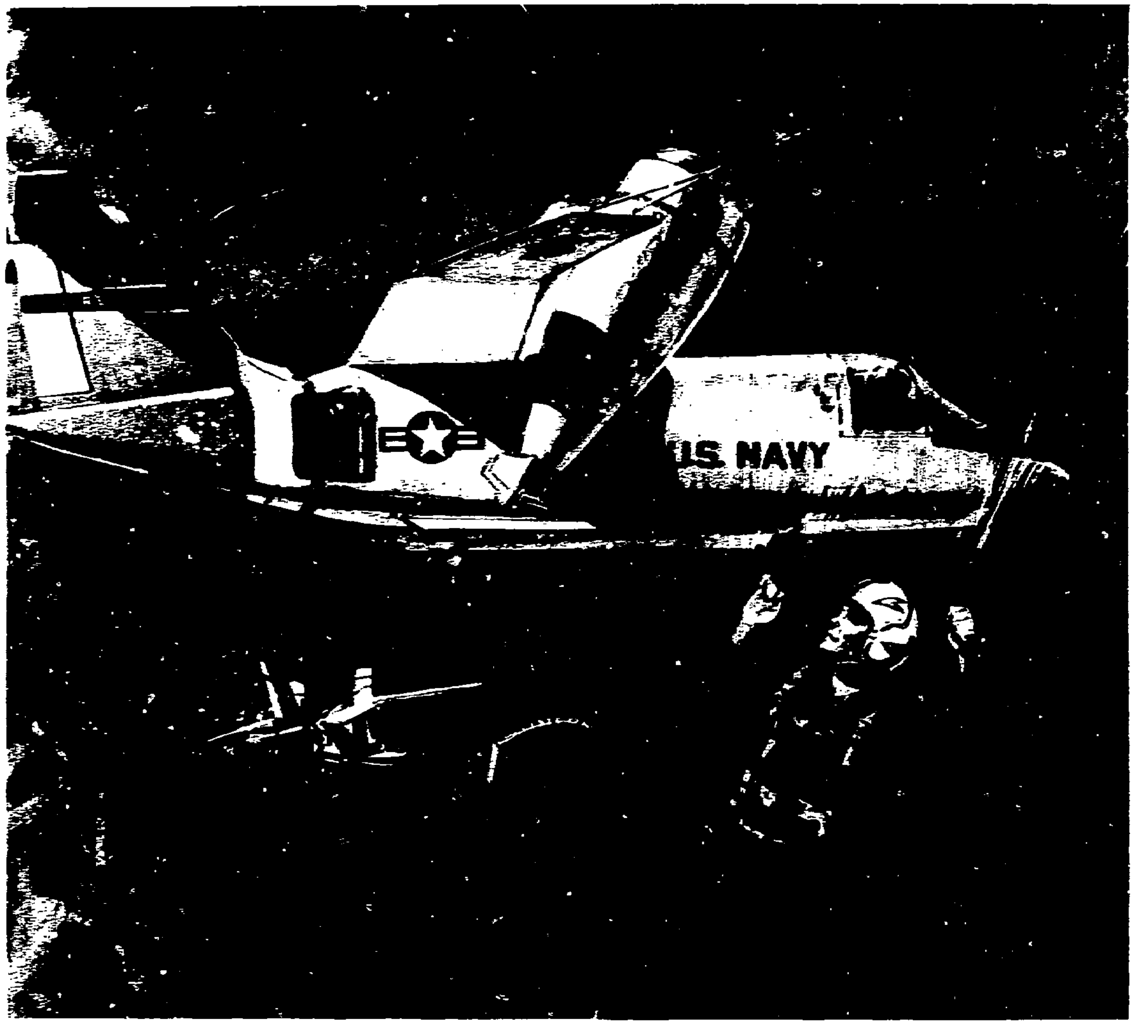

Figure 13. A model of Grumman's 698 V/STOL aircraft.
(photo courtesy of Grumman Aerospace Corporation)

aircraft to within 10 feet of the survivor without visual contact. Once a pickup is made, the aircraft can navigate directly to a second crewman for another recovery. Throughout the entire rescue mission, the SAS can operate essentially as a covert system with interrogation and response sequences automatically taking place in a matter of milliseconds (Root & A'Hearn, 1980).

To answer the question of how many SAR-dedicated aircraft might be needed in a given strike area to handle multiple aircraft losses in a short period of time, the Southeast Asia data were again analyzed. Of over 500 aircraft lost during the conflict, the following are the only cases of multiple aircraft ejection in a short period of time.

Time, in Minutes	Number of Cases*
0-15	3
15-30	5
30-60	1
60-240	2

The survivability of any aircraft selected for a SAR mission would be improved with armor and anti-aircraft fire countermeasure devices such as jammers, radar warning, IR suppressors, missiles, etc. The type and number of such devices would depend on the degree of commitment of the aircraft to the combat SAR mission. The technology arising out of the "Stealth" program would be ideally suited for SAR, by allowing the SAR aircraft to remain virtually undetectable to radar near a strike area.

Potential Effectiveness of Air-to-Air Rescue in Southeast Asia

To ascertain how an air-to-air pickup system might have worked in Southeast Asia, a model air-to-air pickup system was formulated and applied to the Navy POW population. Model parameters for these tests include:

1. ***Population.*** All Navy aircrewmen who ejected over North Vietnam and became POWs qualified for this test. The following information was necessary for each ejectee: (a) time from initial combat damage until ejection was initiated; (b) controllability of aircraft prior to ejection; (c) degree of pre-ejection injury; (d) altitude and speed at time of initial damage; (e) height of the aircraft above terrain at time of ejection; and (f) distance to safe area (in these cases, this was considered one or two miles into open water in the Gulf of Tonkin).

2. ***Model Conditions.*** Two sets of tests were conducted. The first test was called ACTUAL, in that the actual height above the terrain at time of ejection was used in the computations. The second set was called POTENTIAL. In these tests, potential ejection altitudes were

*Two cases were SAR-designated aircraft.

used. These potential altitudes were calculated based on the following: All of the previously listed information was used to determine what altitude (up to 20,000 feet) could have been reached had the pilot, at the time of initial combat damage, made maximum use of his aircraft to gain altitude. Some general rules that were used included:

- Of the time that the pilot had available between damage and ejection, the initial 5 seconds were used only to assess the damage and overcome shock.
- The pilot had no injuries that would prohibit his control of the aircraft. If his injuries were severe, the actual ejection altitude was also used for this test.
- Climb rates of 45° at 400 KIAS, which is a vertical climb rate of 414 ft/sec, or 30° at 293 ft/sec, were used, depending on aircraft speed at time of damage and degree of damage. If the aircraft could not climb, actual ejection altitudes were used.
- Once the aircraft reached 12,000 feet, the assumption was made that the pilot would eject before going below this altitude.

The SAR rescue craft was assumed to be a fixed-wing jet type having at least the performance characteristics of the Navy's S-3 (Viking) aircraft. The hypothetical SAR aircraft was equipped with an electronic locator system of the type described earlier, which provided immediate and continuous range and bearing data to the ejected survivor as well as continuous readings on his altitude. This SAR aircraft was in orbit at an altitude of approximately 16,000 feet and approached the air rescue site at a speed of 400 KIAS. The aircraft would proceed inbound immediately on notice of ejection or intention to eject. Once the SAR aircraft was in the vicinity of the aircrewman, it would take two additional minutes to line up for the pickup pass. For this study, no final passes were made below 1,000 feet above ground level.

For these tests, two sets of SAR aircraft orbits were used. The first was an orbit (Figure 14, Line A) approximately one to two miles offshore directly in line with the strike or egress route. The second orbit (Figure 14, Line B) was considered to be in the vicinity of the strike group, e.g., within five miles of the stricken craft. In both cases, the SAR aircraft was assumed to have headed for the ejected survivor either upon receipt of a communication of intent to eject or at the time of actual ejection. Time prior to ejection that could have been used to close the distance between the stricken aircraft and the SAR craft was not used in these calculations.

Parachute opening was always assumed to occur at ejection altitude. The parachute was of the Ram Air type, capable of a descent rate of 8 feet per second. Horizontal movement was ignored for these tests.

3. ***Test Results.*** These tests were run under assumed ideal conditions. Hostile fire, weather, and in-parachute losses were not considered. The primary objective of the tests was to

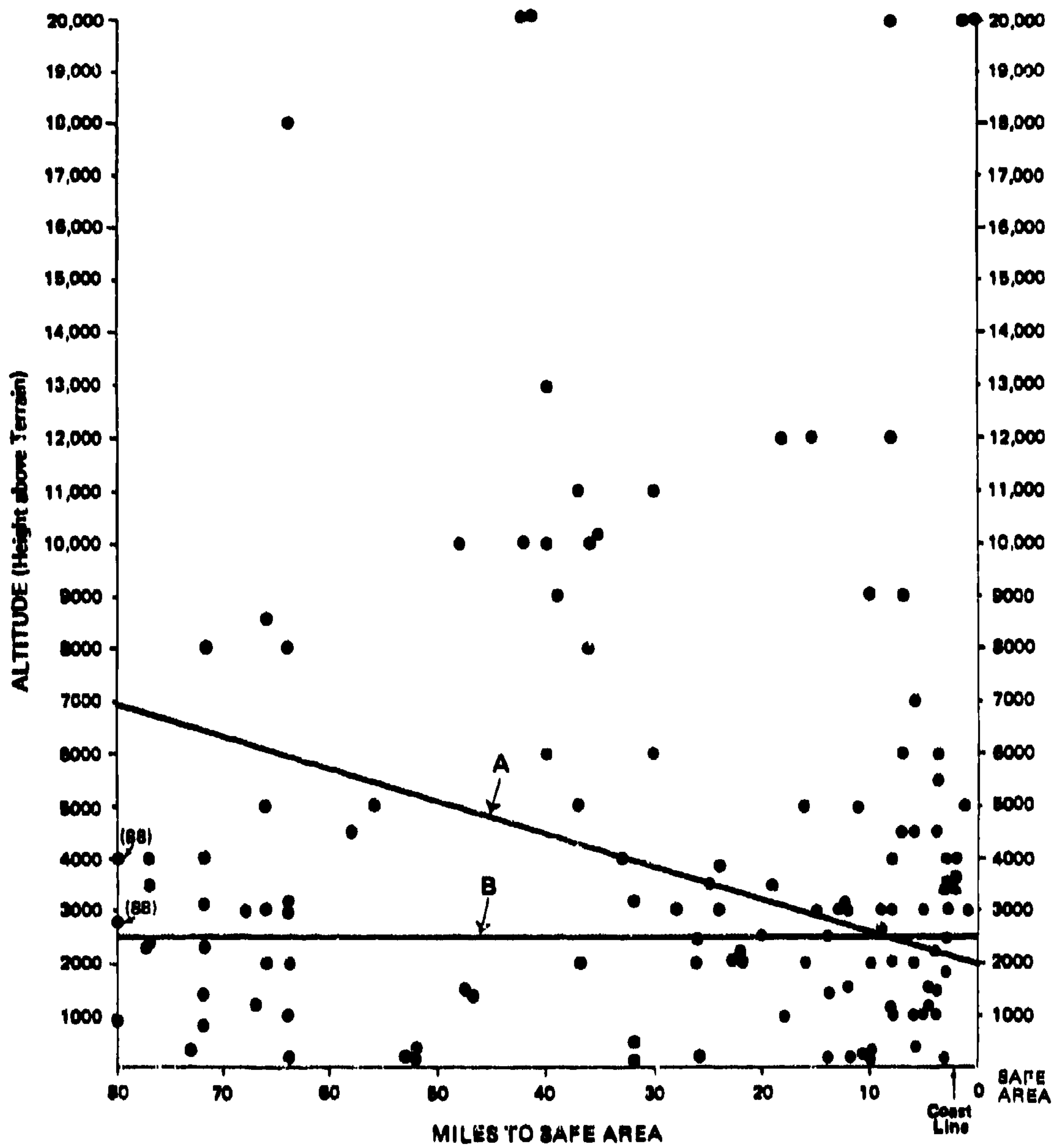

Figure 14. Actual ejection altitudes and distances from "feet wet" SAFE area for Navy aircrewmen who became prisoners of war. (Distances beyond 80 miles are in parentheses.)

determine how many aviators would have had a chance at rescue based on the model conditions. Figure 14 presents the actual ejection altitudes for the POWs. Line A on this figure represents the altitude above which it is calculated that aircrewmen would have had a chance at air rescue by a SAR rescue craft coming in from the coastal orbit as described above. Line B represents the minimum ejection altitude considered necessary in order to be rescued by a SAR craft that remains within three miles of the ejection location. A summary from this figure shows that under actual ejection conditions, *45 percent ejected above Line A and 60 percent ejected above Line B.*

Figure 15 presents the distance to safe area versus the potential ejection altitude data points. The data points were established based on the conditions described earlier with Lines A and B representing the same as above. A summary from this figure shows that under potential ejection conditions, *64 percent of the POWs could have ejected above Line A, and 80 percent could have ejected above Line B.* This means that these aircrewmen all might have been rescued and returned safely had an air-to-air pickup been in use at that time.

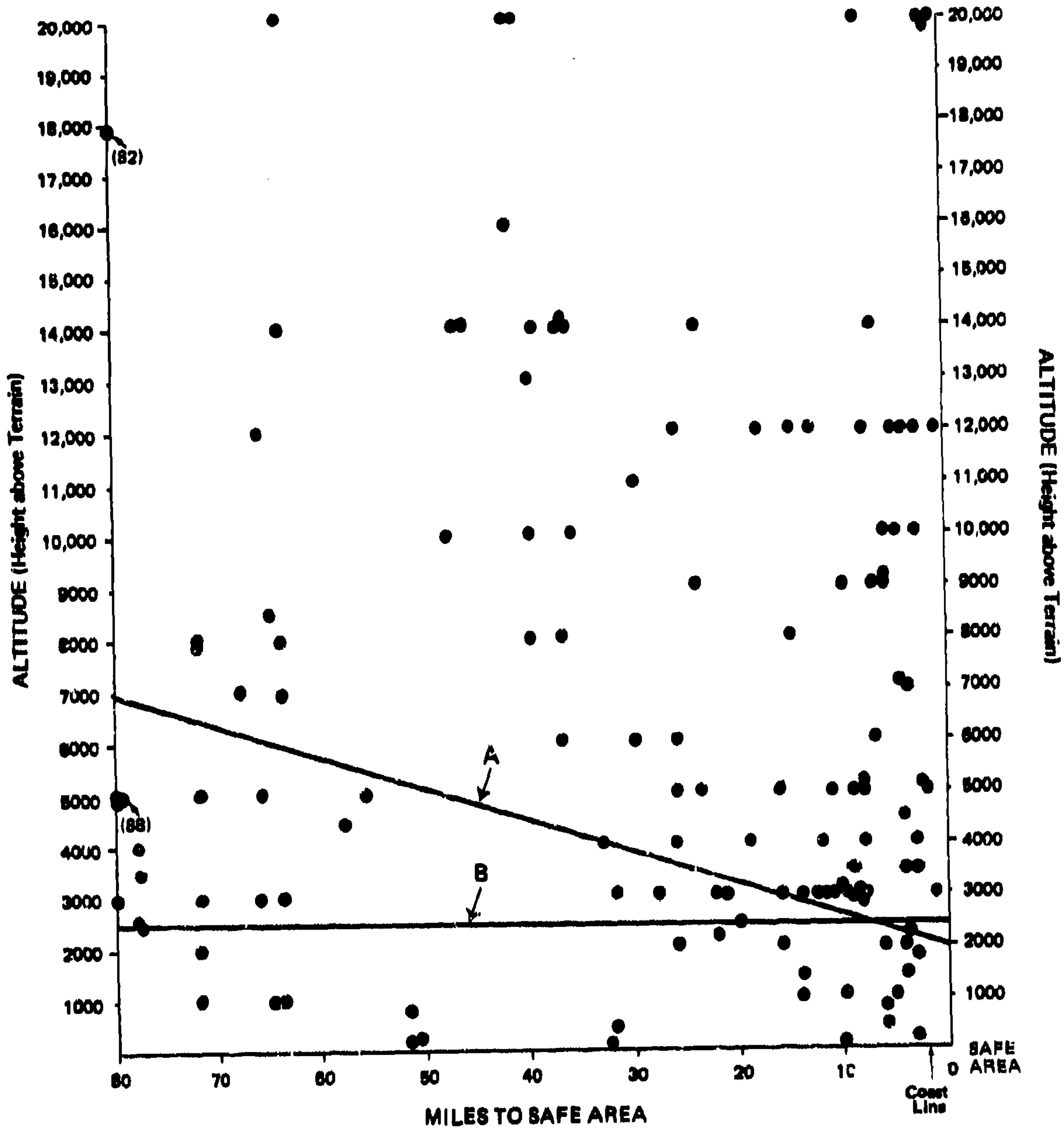

Figure 15. Potenial ejection altitudes and distances from "feet wet" SAFE area for Navy aircrewmen who were listed as prisoners of war. (Distances beyond 80 miles are in parentheses.)

SUMMARY AND CONCLUSIONS

Nine percent of the Navy aircrewmen downed over North Vietnam were rescued – an appalling statistic that in no way reflects on the heroic efforts of the many search and rescue teams who valiantly attempted to retrieve airmen, frequently within sight of the capital of North Vietnam. This statistic points out dramatically that the aircrewman who is forced to eject over hostile territory has very little going for him. In spite of the most advanced aircraft escape systems in the world, and in spite of a comprehensive SAR network, the odds are heavily against his making it. The best bet is that he will not return alive (50 percent). If he does survive, it is very likely that he will spend a long time under most unpleasant prison conditions before being returned (41 percent).

It is apparent that the escape and rescue system used for Navy aircrewmen, which works so well under peacetime training conditions, does not meet the requirements for combat rescue. Very few crewmen are rescued successfully. In addition, heavy losses are encountered by the Navy SAR teams themselves. One SAR aircraft and one SAR crewman were lost in North Vietnam for fewer than every two crewman rescued. These circumstances provide ample justification for a review of escape and rescue equipment and procedures as now used during combat.

This report, one in a series, addresses those problems encountered in the Southeast Asia conflict that had a direct impact on the effectiveness of SAR missions. The principal objective was to examine these problems in relation to potential alternatives to conventional search and rescue. A number of problems have been identified earlier that bear upon rescue success. It was found that, for those aircrewmen who became prisoners of war, the high speed of the aircraft at the time of ejection (averaging 407 knots) caused 53 percent of this group to suffer a major injury during the escape sequence. These injuries, combined with the lack of maneuverability of the parachute and the inability of the aircraft to reach a safe area prior to ejection, resulted in 60 percent of the downed aircrewmen being captured within 10 minutes following parachute landing.

The inability to reach a non-populated area, and the injuries suffered by aircrewmen during the combat ejection, precluded for the most part active evasion efforts, thus making capture a matter of merely a few minutes. Also, when a rescue was attempted, these same injuries prevented the survivor from helping with the rescue effort, thereby reducing chances for success. These problems, as well as a number of others not as prominent but important nonetheless, combine to make combat rescue a risky matter at best.

A number of alternative rescue systems were reviewed in this report. However, because of aircraft design limitations, weight penalties, cost, vulnerability issues, incompatibility with injury status, terrain, or vegetation restrictions on use, most were deemed unacceptable as replacement rescue systems. One system, air-to-air pickup, is promising when systematically matched against the many problems encountered in the combat rescue scenario. Advantages found in air-to-air pickup include:

1. There is no weight increase to the strike aircraft escape system.

2. Most of the key components that would be used in an air-to-air pickup system already have been tested operationally.

3. Air-to-air pickup is particularly suited for combat since it is designed to make a rescue before the possibility of capture.

4. This system would provide severely injured aircrewmen a much improved chance of survival.

5. Eliminating the helicopter search and hover phases of a combat rescue would reduce the losses suffered by SAR forces.

6. Finally, and most important, when the air-to-air pickup system was modeled with Southeast Asia Navy POW ejection data, even using conservative model parameters, between 45 and 80 percent of the North Vietnam POWs would have had a reasonable chance of being rescued prior to parachute landing. This contrasts sharply with the 9 percent actually rescued.

The treatment of captured aircrewmen in North Vietnam was harsh by any standards. However, it might well be better than what one would anticipate if capture occurred in some of the high threat areas now found throughout the world. If Navy aircrewmen flying difficult missions over hostile areas in the future are to be offered a reasonable chance for survival and rescue when forced to abandon their aircraft, a new system for combat rescue must be used. Helicopter search and pickup procedures are not satisfactory under combat conditions. A systematic consideration of all problems found to exist during combat escape and survival circumstances indicates that an air-to-air rescue system offers the best chance for success. Such a system is feasible using the technology of today.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report examines specific problems that affect the rescue of naval aviators downed under combat conditions. It discusses the pros and cons of alternative rescue systems such as air-to-air, flyaway, ground-to-air, etc. The subsystems of an air-to-air rescue system are evaluated as to operational practicability. The air-to-air system is modeled for potential effectiveness utilizing the actual ejection and survival data of the Navy aircrewmen who ejected and became prisoners of war.

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