Combat Search and Rescue: Restoring Promise to a Sacred Assurance

Brandon T. Losacker, Major, USAF

Wright Flyer Papers

Air Command and Staff College

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Foreword

It is my great pleasure to present another issue of The *Wright Flyer Papers*. Through this series, Air Command and Staff College presents a sampling of exemplary research produced by our residence and distance-learning students. This series has long showcased the kind of visionary thinking that drove the aspirations and activities of the earliest aviation pioneers. This year's selection of essays admirably extends that tradition. As the series title indicates, these papers aim to present cutting-edge, actionable knowledge—research that addresses some of the most complex security and defense challenges facing us today.

Recently, The *Wright Flyer Papers* transitioned to an exclusively electronic publication format. It is our hope that our migration from print editions to an electronic-only format will fire even greater intellectual debate among Airmen and fellow members of the profession of arms as the series reaches a growing global audience. By publishing these papers via the Air University Press website, ACSC hopes not only to reach more readers, but also to support Air Force–wide efforts to conserve resources. In this spirit, we invite you to peruse past and current issues of The *Wright Flyer Papers* at https://www.airuniversity.af.edu/AUPress/Wright-Flyers/.

Thank you for supporting The *Wright Flyer Papers* and our efforts to disseminate outstanding ACSC student research for the benefit of our Air Force and war fighters everywhere. We trust that what follows will stimulate thinking, invite debate, and further encourage today's air, space, and cyber war fighters in their continuing search for innovative and improved ways to defend our nation and way of life.

BRIAN HASTINGS
Colonel, USAF
Commandant

Abstract

This research paper analyzes historical data from Southeast Asia, Operation Desert Storm, and Operation Allied Force to identify combat search and rescue (CSAR) helicopter shortfalls that endanger viable personnel recovery in a major theater war. It identifies still-relevant survivability requirements and suggests a helicopter fleet size based on historical asset density ratios. A comparative mission planning analysis reframes the benefit of increased helicopter speed in terms of reduced fighter and tanker requirements for long-range CSAR. This analysis of historical and contemporary issues informs a four-phase proposal to equip and organize the CSAR helicopter force for future relevance.

The phased proposal leverages existing solutions—such as vectored thrust ducted propeller (VTDP) technology—to upgrade the forthcoming HH-60W at a significant cost and time advantage over other potential vertical lift CSAR solutions. Implementing the proposed upgrades to the HH-60W will produce 200-210 knot helicopters well suited for CSAR, Light Attack Support, and Strike Control. This multi-role utilization provides operational value and is aligned with Air Force precedent and existing roles and missions agreements. This paper assumes major war is markedly possible in the next ten years, but absent such a war, it still seeks to posture Air Force combat helicopters as an airpower contributor for lower-intensity conflict.

Viable and effective CSAR is an asymmetric advantage during attritional air warfare; it is also a moral obligation. The current and planned CSAR helicopter fleet is not adequate to fulfill the Air Force's sacred assurance that it will not leave its warriors behind. Change is required, and time may be short.

About the Author

Major Losacker graduated from the USAF Academy with an undergraduate degree in general engineering. He also holds a graduate degree in aeronautical science from Embry-Riddle Aeronautical University. A career helicopter pilot, he was the aircraft commander on the first HH-60G rescue mission launched from the United Kingdom. He and his crew flew a 10-hour overwater rescue mission to save a critically injured sailor from the pitching deck of a container ship nearly 300 nautical miles west of Ireland in the North Atlantic, at night, and in poor winter weather. Major Losacker was later selected to be the first Air Force pilot to fly the US Marine Corps UH-1Y Venom (aka "Yankee") utility and light attack helicopter. At the time, it was the Marine Corps' newest operational combat aircraft. Major Losacker quickly upgraded to UH-1Y instructor pilot and deployed to Helmand Province Afghanistan during 2011. There he led sections of AH-1W and UH-1Ys in the execution of assault support operations and close air support, resulting in numerous enemy being killed and wounded. He led UH-1Y sections on two special operations heliborne assault missions supporting the destruction of narcotics processing facilities. He has completed several other deployments in the HH-60G; flying medical evacuation missions and supporting CSAR alerts. He has flown over 600 combat hours, logged on over 400 missions in Afghanistan, and is a Distinguished Graduate of the USAF Weapons School.

Dedication

This paper is dedicated to my wife, my sons, and the crewmen I have flown with. My wife has patiently endured the uncertainty and worry long characteristic of the loving Air Force spouse. Countless days she sent her husband off to wrestle his infernal air machine skyward—In garrison and war—never certain of his safe return. Her faith, loyalty, and love are foundational to our family. To the Airmen and Marines, I have flown and fought with; your courage and loyalty always gave me a reason to do better. To my young sons: I am so proud to see you growing in integrity, courage, kindness, and faith. If statistics are predictive, some, or all of you will one day take up arms for your people. I cannot abide by an organization that would send you off to do violence on our behalf without a viable way to bring you home, whether that be on your shield or with it. You are the reason I write, and I fight.

> *"Whom shall I send? And who will go for us?" And I said, "Here am I. Send me!"*
>
> *Isaiah 6:8*

Acknowledgments

I wish to thank my wife for her enduring patience as I worked to complete this paper, without her this would not have been possible; her journalist's eye in the review and editing process was a great help. I also need to thank Dr. John G. Terino of Air Command and Staff College for his encouragement and many hours spent reviewing drafts of this paper. The personnel at the Air Force Historical Research Agency were accommodating as I sorted through thousands of archival documents in my quest to compile the necessary data from the war in Southeast Asia. Lastly, I would like to thank Col Darrel Whitcomb, USAF retired, for his thoughtful review and suggestions.

Code of an Air Rescue Man

It is my duty, as a member of the Air Rescue Service, to save life and aid the injured. I will be prepared at all times to perform my assigned duties quickly and efficiently, placing these duties before personal desires and comforts. These things I do THAT OTHERS MAY LIVE.

- Brig Gen Richard Kight
Commander Air Rescue Service,
1 Dec 1946 – 8 Jul 1952

"When the history of the war [Vietnam] is written, the story of the USAF helicopter will become one of the most outstanding human dramas in the history of the USAF."

- The Honorable Harold Brown
Eighth Secretary of the Air Force and 14th Secretary of Defense

"No tradition is worth having in a fighting force except a tradition of success."

- Marshall of the Royal Air Force, Sir Arthur Harris

Prologue

"F-ing heroic." Crisply delivered and unvarnished—as one would expect from a salty Marine Lieutenant Colonel and attack pilot—his words caught me off guard. Not because I was some delicate flower, but by the depth of his sincerity. His comment was not about anything I had done, but it spoke volumes about his admiration for the combat exploits of a small but determined group of Air Force aviators.

In the spring of 2012, I was stationed at Camp Pendleton, California, as an Air Force exchange officer flying UH-1Y helicopter gunships. Normally assigned to HMLA-267, on this particular day, I was assisting another squadron with a functional check flight (FCF) for a UH-1Y that had recently received some maintenance action. While I stood at the operations desk at Marine Light Attack Helicopter Training Squadron 303 (HMLA/T-303), receiving a step-brief from the day's duty lieutenant, a Lt Col walked up to the desk. Noticing the rank sewn onto my flight suit, (Marines do not wear shoulder rank on their flight suits) he paused to look me over; he leaned ever so slightly to see the HMLA-267 squadron patch on my right shoulder and then examined my black leather name tag which clearly labeled me as "Captain . . . USAF." Satisfied with his nonverbal inquisition, he asked me "Why are you here?" I figured this was not an existential question and replied, "I'm down here to FCF one of your birds, Sir." "Hmm, what do you fly?" Fair question, "Yankees." I answered, assuming he did not know I was a UH-1Y pilot and wanted to know which of their unit's three different types of helicopters I was going to FCF. He replied, "No, what do you fly in the Air Force?" "I fly 60s, Sir." Pause. "Were you a Pedro pilot?" His question implied a lot. It meant he spent time in Afghanistan. All Air Force HH-60G rescue helicopters flew under the "Pedro" radio call sign in Afghanistan and had for years. Having just spent seven months in Helmand, Afghanistan, with HMLA-267, I also understood the likely experience he had had with the Pedros. During my unit's deployment, our UH-1Y and AH-1W frequently provided armed escort for the medical evacuation missions the Pedros flew into hot landing zones. I flew several of these escort missions myself. Understanding all of this, I answered his question with a very flat "Yes, Sir." This answer gave him another noticeable pause as if to ensure the precision and weight of his next words, then he looked at me very intently, and in a faintly emotional tone, stated "F-ing heroic." He turned and walked away without another word.

****

The heroic reputation of Air Force CSAR is well earned and well known. However, at some point, even the most august group of warriors cannot continue their lifesaving work when all they have to fight with are weapons inadequate to the battle.

Introduction

"These things I do THAT OTHERS MAY LIVE."[1]

Military mottos are as cliché as they are ubiquitous. They always seek to inspire; some through an earnest call to duty and many through a call to violence upon the enemy. It is the rare motto that rises from slogan to ethos. The closing words of Brig Gen Kight's *Code of an Air Rescue Man* form such an ethos. The idea that our nation would send the willing many to save a desperate few defies cold logic. Yet the decades of dangerous service by Air Force Rescue testifies their deep commitment to this very idea. The heroic daring of this force has earned it a reverence among the other services that few, if any, Air Force communities can match. The accounting on their ledger is unbalanced, it always will be. It is this illogical selflessness that epitomizes the best qualities of America and her people. Time and again, in war, or natural calamity, our rescue crews charge unhesitatingly into the midst of death's rage to save the desperate few. It is this quiet devotion that underwrites the Air Force's promise to the combat aircrew it sends into harm's way: *We will not leave you*. There is great power in this promise.

Unfortunately, the Air Force's current and planned rotary-wing rescue force is ill-equipped to fulfill this solemn assurance. The service has failed to provide these warriors the tools necessary for relevance. Instead, the Air Force seems to expect future combat rescue success without having applied the grave —and still relevant—lessons from the air war in Southeast Asia. Therefore, the baseline survivability of the current and planned HH-60 helicopter fleet is inadequate to the demands of a major attritional air war. This paper analyzes historical lessons from Southeast Asia, Operation Desert Storm, and Operation Allied Force to identify important Combat Search and Rescue (CSAR) helicopter survivability requirements, asset density ratios, and the contemporary need to expand the rescue helicopter's speed envelope to account for reduced fighter aircraft inventories. This historical analysis informs a Four-Phase Proposal to change the way the Air Force equips and organizes its CSAR helicopter force in order to restore the life-saving promise of CSAR. Implementing these changes will provide an innovative opportunity to multi-role these assets for higher threat CSAR, lower threat light attack support, and strike control. While this proposal defies current Air Force dogma, it is a compelling value proposition that builds upon historic Air Force rotary-wing employment and established roles and mission agreements. The uncertain nature of future war necessitates a CSAR force well-prepared for its primary mission during a major war. It is also useful across a broad range of airpower operations.

Several assumptions provide the cognitive context of this paper:

- The rescue of isolated American combat personnel is a moral imperative and is a strategic necessity. This is especially true in any attritional air war in which long-term victory depends on returning experienced tactical aviators back to the fight.
- The Air Force (AF) CSAR community exists to rescue aircrew shot down near or behind enemy lines in a major war against an advanced enemy force. Low-intensity combat does not require a dedicated rescue force. The risk of aircrew loss in these less-intense conflicts is low and personnel recovery can be conducted by general purpose helicopters.
- A major war with a peer adversary(ies) in the next five to 10 years is a significant possibility. The most dangerous potential adversaries are China and Russia, however, Iran or North Korea are relevant as well. This means proposed survivability improvements must be executable in short order.
- Absent an intervening major war, the US will continue to fight a global counterterrorism fight for several more decades. This means a single-mission solution useful only for high-end conflict is a budgetary nonstarter.
- Using expensive jet fighters and bombers to target insurgent fighters is cost-ineffective. It wears out high-end aircraft to kill low-end terrorists. This cost disparity warrants multi-role application of a revitalized CSAR force for light attack in a counterinsurgency fight.
- The operating environment of the next major war will most likely be characterized by all or some of the following characteristics:
  - *Rapid tempo of execution*
    - The war may still last for an extended period, however, the pace of actions within the conflict will be rapid. *Air superiority will be localized and fleeting.*
  - *Denied position, navigation, and timing (PNT) data*; this will hinder employment of Global Positioning System guided munitions from helicopter-escorting fighter aircraft. It will also inhibit employment of autonomous recovery aircraft.
  - *Contested/degraded communications*: satellite, voice, data link, and remotely-piloted aircraft command links. This makes manned aircraft relevant in the next major war.

- *Advanced air defense systems* will partly or wholly negate the advantage of stealth, thereby increasing the risk of fighter shoot downs.
- *Prolific use of electro-optically aimed air defense artillery*; these systems will maintain their relevance as threats to a CSAR Task Force, specifically the helicopters.
- *Contested/denied transoceanic logistics lines of communication*; this necessitates increasing the permanent forward presence of CSAR aircraft.

Important Terms

Several terms useful to the discussion:

Airborne Forward Air Controller (FAC[A]). The FAC(A) is a specifically trained and qualified aviation officer who exercises control from the air of aircraft engaged in Close Air Support (CAS) of ground troops. The FAC(A) is normally an airborne extension of the Tactical Air Control Party. The FAC(A) also provides coordination and terminal attack control for CAS missions, as well as locating, marking, and attacking ground targets using other fire support assets.[2]

From Joint Publication 3-50, Personnel Recovery: The FAC(A) can provide the recovery force with significant tactical advantages. Either a planned or diverted FAC(A) can locate and authenticate isolated personnel before the arrival of the recovery force, and provide a current threat assessment near the objective area. Initial on-scene coordination of the Personnel Recovery (PR) effort may be assumed by the FAC(A) when dedicated Rescue Escort (RESCORT), or other (i.e., wingman) assets are not available, or until the RESCORT arrives. The FAC(A) is trained in terminal attack control and can provide a link between the recovery vehicles and other threat suppression assets. *Fast-strike aircraft may require FAC(A) assistance to effectively support the recovery force.* {emphasis added} FAC(A) requests or diversions should be considered to provide an On-scene Commander (OSC) capability before recovery force arrival, or when threats in the objective area require extensive suppression.[3]

Casualty evacuation (CASEVAC), nonmedical units use this to refer to the movement of casualties aboard nonmedical vehicles or aircraft without enroute medical care.[4]

CAS is air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and requires detailed integration of each air mission with the fire and movement of those forces.[5]

CSAR is the AF's preferred mechanism for the recovery of isolated personnel.[6] (Not a definition, however, relevant to this discussion)

Medical evacuation (MEDEVAC) is performed by dedicated, standardized medical evacuation platforms, with medical professionals who provide the timely, efficient movement and enroute care of the wounded, injured, or ill persons from the battlefield or other locations, or both to medical treatment facilities.[7]

PR is the sum of military, diplomatic, and civil efforts to affect the recovery and reintegration of isolated personnel.[8]

Rescue Mission Commander (RMC). The RMC is the individual designated to control recovery efforts in the objective area, as opposed to an OSC who may be first on-scene, and is not necessarily best-qualified to lead and coordinate the recovery execution. The RMC is designated through the Joint Personnel Recovery Center, or by the component commander through the Personnel Recovery Coordination Center. The RMC initial actions are to collect essential information in the objective area that is threatening to the isolated personnel or recovery force. The RMC will have to balance the need for more accurate information with the possibility of compromising the safety of the isolated personnel. The RMC and the lead recovery vehicle commander should plan and coordinate closely to select ingress and egress routes and objective area tactics. All recovery force participants must contact the RMC before entering the objective area or communicating with the isolated personnel. The call sign 'Sandy' may represent an individual (typically an A-10, F-16C/D, or F/A-18 pilot) specifically trained to conduct RMC duties in support of PR missions.[9]

History's Introduction

"What has been is what will be, and what has been done is what will be done; there is nothing new under the sun."[10] This poetic caution speaks to foolishness—the proclivity to ignore the lessons of the past and believe that *today is different*. This dangerous idea thinks our modernity graces us with knowledge and technology that sets us above and apart from our ignorant predecessors. Combat quickly lays bare the siren song of modernity's arrogance. Failure to learn history's warfighting lessons can prove a profound hindrance to future success. AF CSAR embodies a failure to apply history's instruction and puts US airpower at strategic risk as it faces renewed potential for a hard and bloody fight.

An important historical touchstone for this paper is the war in Southeast Asia. It provides a useful surrogate for major combat against a near-peer adversary. This conflict is especially useful given the available data on recovery statistics and rescue helicopter losses. Operation Desert Storm and Operation Allied Force also constituted challenging threat environments to the air campaigns—some information from them is leveraged appropriately—however, their relevant combat rescue data is limited. In terms of absolute military capability, the United States enjoyed a marked technological edge over its foes in Southeast Asia and some may chafe at the notion the war was akin to fighting a major peer adversary. However, geopolitical constraints and vacuous US strategic vision created an operating environment of relative parity between the US and its communist enemies. It certainly proved costly and dangerous to the airmen fighting them. Frequently referred to as the Vietnam War, it was actually several intertwined conflicts. In Laos there was a civil war between three distinct forces: the communist Pathet Lao, Neutralists, and Rightists.[11] There was a counterinsurgency campaign against the Viet Cong being fought in South Vietnam, formally known as the Republic of Vietnam (RVN). Communist North Vietnam (NVN) supplied the Viet Cong via supply routes through Laos and Cambodia; this logistics line of communication was the infamous Ho Chi Minh Trail. Much air effort was devoted to interdiction of this supply route. After 1970, the US conducted operations against the communist forces in Cambodia known as the Khmer Rouge.[12] The USAF, along with the other services, provided air support to ground forces in Laos, South Vietnam, and Cambodia. However, the war effort against North Vietnam was purely an air campaign conducted by the USAF and US Navy.

The bombing against NVN started in August 1964. Early NVN air defenses were poorly developed. They possessed only a few antiaircraft artillery (AAA) pieces, and were without jet aircraft, surface-to-air missile (SAM) systems, and had poor early warning (EW) radar systems.[13] By 1967, the communists had fielded and integrated a formidable air defense system which included EW radars, ground control intercept radars, extensive SA-2 SAM systems, 115 Fire Can AAA radar control systems, and countless AAA pieces.[14] In July of 1965, NVN fired their first SA-2 missile; from that point until the bombing-halt of NVN in March of 1968, the communists launched as many as 6,000 SAMs at US aircraft.[15] Despite this prolific threat, the North Vietnamese succeeded in downing only 106 USAF aircraft with their SAM systems. [16] More devastating than the SAMs themselves was the way they forced USAF and Navy aircraft to operate at lower altitudes, contributing to the 1,443 AF aircraft lost to ground fire. [17] All told, the AF suffered 1,736 aircraft combat losses during the Vietnam War–with 1,735 men killed, captured, or missing. [18] Despite the attention given after the war to improving air-to-air combat skills, only 67 USAF aircraft were lost in MiG engagements, less than the number lost to base attacks. [19] This war cost the AF's Aerospace and Rescue and Recovery Service (ARRS) 29 helicopters lost to combat.

After the Korean War, the wartime combat rescue requirement was removed from the Air Rescue Service mission.[20] The AF viewed Korea as an anomaly and believed with an unfortunate certainty that any future war would be nuclear. As a result, the first Air Rescue Service HH-43s Huskies—designed for peacetime local base rescue and firefighting—arrived in Southeast Asia in the summer of 1964 without formalized concepts of *combat* rescue or use of armed aircraft to escort them.[21] By 1965, the T-28 Trojan was in regular use as an armed RESCORT of the slow-moving HH-43s (call sign "Pedro").[22]

Later that same year, and up until 1972, the A-1 Skyraider (call sign "Sandy") assumed this RESCORT duty from the T-28s.[23] As the air refuelable HH-3E Jolly Green Giants, and later the HH-53B/C Super Jolly Green Giants (call sign "Jolly Green"), were fielded in Southeast Asia. The Search and Rescue Task Force (CSARTF) expanded to include the HC-130P Combat King (call sign "King") for aerial refueling and command and coordination. Constant was the presence of the intractably heroic pararescuemen (PJs). The current USAF doctrine for CSAR is still based on the SARTF concept developed early in the Vietnam War.[24]

Figure 1: Early SARTF in Southeast Asia (SEA) HH-3[25]

If the construct of the combat SARTF (CSARTF in modern AF parlance) is still largely unchanged from the Vietnam War—we have since substituted in the HH-60G helicopter, A-10C attack plane, and the HC-130J—one would assume a compelling degree of rescue success underpins the model. Is 32.6 percent compelling? This was the percentage of AF aircrew rescued from North Vietnam during the war, as seen in Figure 2.[26] From all locations, including South Vietnam, Laos, and Cambodia, the percentage was a bit higher at 41.4 percent.[27]

TABLE 13. FATE OF CREW IN COMBAT LOSSES BY COUNTRY (1962-1972) (U)

		FATE OF CREW									
	NUMBER OF	RESCUED		KILLED		MISSING		CAPTURED		TOTALS	
COUNTRY	AIRCRAFT	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
NVN	623	346	32.6	48	4.5	375	35.4	292	27.5	1061	100
Laos	419	397	49.2	132	16.4	269	33.4	8	1.0	806	100
SVN	649	462	44.5	499	48.0	77	7.4	1	0.1	1039	100
Thailand	3	1	8.9	6	54.6	4	36.5	0	0	11	100
Cambodia	29	20	45.4	19	43.2	5	11.4	0	0	44	100
TOTALS	1723	1226	41.4	704	23.8	730	24.6	301	10.2	2961	100

Figure 2: USAF Aircrew Losses in SEA[28]

Importantly, 23.8 percent of all downed aircrew were killed while 34.8 percent were either captured or were listed as missing. [29] In other words, an aviator downed during the Vietnam War had almost the same likelihood of rescue as going missing/captured. Whether this likelihood of rescue is "good" or "bad" is certainly open for inconclusive debate, however, it is the historical benchmark with which we work. More important to preparedness for the next major war are two questions: What force disposition enabled USAF rescue to achieve the success it did and how does it compare to other conflicts? What were some poignant combat lessons from Rescue losses in SEA and how well have we applied them to equipping our forces today? The answers to both will highlight the inadequacy of our current and planned combat rescue helicopter force.

Historical Rescue Aircraft Densities

A goal of this work is to provide historical lessons for evaluating the preparedness of the current AF rescue helicopter force to fulfill its mission during a major war with a peer adversary. The first step toward this goal is developing some comparative data that is informative, however, not so specific to Vietnam that it loses value in contemporary application. The density of rescue forces in a combat theater is a good place to start.

There are a number of variables specific to any past or prospective conflict impossible to predict in detail. The optimum distribution of assets is one of these variables. A geometrically perfect distribution of assets—based on adjoining range rings—is a misapplication of forces. It denies the intuitive need to concentrate rescue assets in areas that likely see the greatest aircraft losses. Additionally, some areas will prove more suitable for basing than others, and logistics support is an unceasing consideration. As a result, rescue forces will necessarily be more concentrated in some areas than others. Nonetheless, these USAF rescue forces must still provide PR over a large geographic swath, even those areas less likely to produce downed aircrew. Some aircraft will suffer noncombat mechanical failure; some will fly for a while with battle damage before succumbing like stubborn warriors to their mortal injuries. Considering these imprecise influences, one useful metric is *rescue asset density*.

Force Density—Southeast Asia

From AF records, the number of combat aircrew recoveries peaked from 1967 through 1969—at 192, 263, and 214 respectively—before slowly dropping off in the later years of the war.[30] This roughly corresponded with a growth in deployed USAF rescue aircraft to a highpoint of 71 in 1969, this number remained steady through 1970 and is broken down by aircraft type in Table 1.[31]

Table 1: USAF Rescue Forces—SEA 1969—1970[32]

Assigned	Aircraft Type
20	HH-3E
25	HH-43B
6	HH-43F
5	HH-53B
4	HH-53C
11	HC-130P
71	Total

The AF distributed these aircraft at 15 main operating locations and three forward operating locations—18 daily helicopters alert sites—supported by four operational Aerospace Rescue and Recovery Squadrons (ARRS):

- 37th ARRS—(HH-3E)
  - Da Nang Air Base (AB), Republic of Vietnam (RVN)
    - Also maintained two HH-3Es on alert at Quang Tri Combat Base near the demilitarized zone (DMZ).
- 38th ARRS—(HH-43B/F)
  - Detachment (Det) 1—Phan Rang AB, RVN
  - Det 2—Takhli Royal Thai AF Base (RTAFB)
  - Det 3—Ubon RTAFB
  - Det 4—Korat RTAFB
  - Det 5—Udorn RTAFB
  - Det 6—Bien Hoa AB, RVN
  - Det 7—Da Nang AB, RVN
  - Det 8—Cam Ranh Bay AB, RVN
  - Det 9—Pleiku AB, RVN
  - Det 10—Binh Thuy AB, RVN
  - Det 11—Tuy Hoa AB, RVN
  - Det 12—U-Tapao RTAFB
  - Det 13—Phu Cat AB, RVN
  - Det 14—Tan Son Nhut AB, RVN

- 39th ARRS—(HC-130P)
    - Tuy Hoa AB, RVN
        - Some strike missions would require an airborne alert posture from various search and rescue (SAR) orbits in SEA.
- 40th ARRS—(HH-53B/C)
    - Udorn RTAFB
        - Also maintained two HH-53s on alert at Lima Site 98 in Laos. Some strike missions would require an airborne alert posture from various SAR orbits in SEA.
- 40th ARRS—Detachment 1—(HH-3E)
    - Nakhon Phanom RTAFB
        - Also maintained two HH-3E on alert at Lima Site 36 in northern Laos. As the HH-53 was fielded it largely replaced the outdated HH-3E in SEA. Some strike missions would require an airborne alert posture from various SAR orbits in SEA.

The entire SAR area for US forces in SEA covered 1.1 million square miles; this included Burma, the Gulf of Tonkin, and large portions of the South China Sea and Indian Ocean.[33] However, a more realistic number is 367,518 square nautical miles.[34] This is the geographic area of Vietnam, Thailand, Cambodia, and Laos; the places where need for USAF rescue coverage was far more tangible than say, Burma. Dividing this effective combat SAR area by the 60 rescue helicopters present during the peak years gives a raw rescue asset density of one rescue helicopter per 6,125 square nautical miles.

Another comparative ratio that informs rescue force disposition is the probe-to-drogue ratio. This information is included in this paper because it is potentially useful for planning staffs. The HC-130 fleet provides essential support for long distance rescue missions, so while the focus of this paper is on vertical lift rescue capability, aerial refueling capability and support is a necessary consideration. In 1969 in SEA there were 11 HC-130Ps, each with two drogues, and 29 rescue helicopters equipped with refueling probes. This produced a 1.32 probe-to-drogue ratio.

In 1969, the total worldwide inventory of the USAF Aerospace Rescue and Recovery Service tallied 186 rotary-wing assets and 57 fixed-wing assets.[35] A comparison of the table USAF ARRS Force—Worldwide 1969 with the earlier table USAF Rescue Forces—SEA 1969 shows that 73 percent of the AF's air-refuelable combat rescue helicopters, and what appears to be all of its HH-53s, were deployed to SEA. Perhaps what made this possible was the ready pool of experienced helicopter pilots available in the 137 HH-43 cockpits.

In total, about one-third of all ARRS helicopter assets—and presumably talent—was devoted to sustaining the war effort in SEA. Understanding SEA's rescue demand on total ARRS capacity is a valuable insight into long-term sustainability of a force and speaks to the benefit of larger fleet sizes. The AF today has 97 HH-60G rescue helicopters.[36] It is worth noting that one-third of the current rescue helicopter inventory amounts to only about 33 helicopters, about half of the number deployed to SEA in 1969.

Table 2: USAF ARRS Forces—Worldwide 1969[37]

Assigned	Aircraft Type[38]
32	HH-3E
137	HH-43B/F
8	HH-53B/C
11	Unspecified—assigned to training
52	HC-130P
243	Total

Force Densities—Operations Desert Storm and Allied Force

One data point does not make a trend; therefore, it is necessary to look at other combat operations—each incorporated brief air campaigns against a credible enemy threat—to glean additional rescue data to evaluate the veracity of the force ratios from SEA.

Operation Desert Storm was the American led effort to liberate Kuwait from Iraqi occupation in 1991. On 24 February, coalition forces launched a ground invasion that lasted 100 hours and ultimately succeeded in freeing Kuwait from its northern aggressor. This ground invasion was proceeded by a five-week air campaign that started on 17 January 1991. Throughout the course of the operation, the coalition suffered 43 fixed-wing combat losses, amounting to 87 coalition airmen shot down.[39] Of these 87 airmen, 47 were killed, one was listed as missing (US Navy Captain Scott Speicher, his body later recovered in 2009), and 24 were immediately captured due to their proximity to Iraqi ground forces.[40] That left 16 airmen isolated in enemy territory; of these, eight were rescued successfully.[41] As a raw percentage that meant only 9.2 percent of the total number of downed airmen were recovered.[42] This lower rescue rate, as compared to SEA, probably resulted from several factors. The desert environment, unlike the jungles of SEA, is a hard place to hide; a downed airman in Iraq had little opportunity to evade enemy in close proximity. This same open desert environment, combined with the Iraqi air defenses and troop concentrations, inhibited easy employment of low and slow flying helicopters. Difficulties in ascertaining timely and accurate survivor locations also impeded recovery operations. The threat environment was not exactly favorable for prolonged visual searches over vast expanses of desert. A final complication was the lack of unity of command in the control and tasking of the special operations units charged with the CSAR mission in Desert Storm.[43] Colonel Darrel Whitcomb examines these issues in his book, *Combat Search and Rescue in Desert Storm.* Of particular interest, he discusses the AF mismanagement that kept the service from deploying any of its conventional combat rescue helicopters for the war, relying instead on special operation helicopters to support this moral imperative. These shortcomings aside, the "rescue" forces in Desert Storm saved 50 percent of the airmen not killed or immediately captured. Is rescuing 9.2 percent of the total downed airmen "bad" or is saving 50 percent of "rescuable" downed airmen "good?" Notwithstanding this debate, it seems reasonable to state, as a nation, we would not want the rescue rates in a major war to be any lower than Desert Storm. While there can never be guarantees of success in a future war, it is useful to understand the Desert Storm "rescue" force distribution that enabled the successes achieved.

Col Whitcomb's research shows the United States fielded a dedicated rescue force of 37 special operations helicopters and eight MC/HC-130 tankers.[44] This force was composed of USAF Reserve special operations MH-3s, USAF Special Operations Command (AFSOC) MH-53Js and MH-60Gs, US Navy SH-60Hs (drawn from units specifically trained for CSAR and special operations), and part of a company of US Army special operations MH-60Ls.[45] Conspicuously absent were any of the AF's conventional Air Rescue Service HH-3s or HH-60Gs. Piecing together specifics about these aircraft, it seems 28 of them were air-refuelable. This excludes four SH-60Fs and five MH-60Ls (details about when these Army helicopters received certain upgrades is unclear, however, it appears they were modified for air refueling after Desert Storm). Eight HC/MC-130 tankers, each with two drogues, makes for a 1.75 probe-to-drogue ratio.

The practical SAR coverage area for Desert Storm covered Iraq, Kuwait, and the portion of Saudi Arabia that encompassed the coalition operating bases. This portion generally starts at the Syrian-Saudi-Iraq tri-border then runs southeast, passing just west of Rafha, then goes south to pass just west of Buraydah, then due east to the Persian Gulf, passing just south of Riyadh, then up along the coast and along the northern Saudi Arabian border back to the tri-border. The Google Earth calculated surface area of this portion of Saudi Arabia is roughly 86,100 square nautical miles. Added to the areas of Iraq and Kuwait, 127,792 and 17,818 square nautical miles respectively, the total CSAR area for Desert Storm was approximately 231,710 square nautical miles.[46] Dividing this CSAR area by 37 rescue helicopters gives a rescue asset density of *one rescue helicopter per 6,262 square nautical miles*. This is only 2 percent different from the asset density ratio from SEA.

Operation Allied Force, as titled by the North Atlantic Treaty Organization, was an air campaign to drive Federal Republic of Yugoslavia forces from Kosovo in order to protect ethnic Albanians from persecution. The campaign ran from 24 March to 10 June 1999; during which the US had two AF fighters shot down—an F-117 (Vega 31—then-Lt Col Dale Zelko) on 27 March 1999 and an F-16 (Hammer 34—then-Lt Col David Goldfein) on 2 May 1999.[47] AF special operations helicopters rescued both pilots. According to Colonel Whitcomb's book *On a Steel Horse I Ride: The History of the MH-53 Pave Low in War and Peace,* there were nine MH-53 and four MH-60G helicopters assigned CSAR responsibility for Allied Force.[48] The combat SAR area for Operation Allied Force included Serbia, Kosovo, and Montenegro for a total area of 77,152 square nautical miles.[49] This gives a rescue asset density of *one rescue helicopter per 5,935 square nautical miles*. Additionally, it appears three MC-130s were deployed for Allied Force, making the *probe-to-drogue ratio 2.17:1*. This data is in Table 3.

Table 3: USAF Rescue Asset Densities and Probe-to-Drogue Ratios

	Combat SAR Area (Square Nautical Miles (NM))	Number of Rescue Helos	Rescue Asset Density (# Helo : Square NM)	Probe-to-Drogue Ratio
SEA 1968-1970	367,518	60	1 : 6,125	1.32 : 1
Desert Storm 1991	231,710	37	1 : 6,262	1.75 : 1
Allied Force 1999	77,152	12	1 : 5,935	2.17 : 1
Average			1 : 6,107	1.75 : 1

Force Density—Discussion

The rescue asset densities from SEA, Desert Storm, and Allied Force are unerringly similar. Therefore, while ratios of asset density and probe-to-drogue numbers appear simplistic, this quality most likely hides an applicability that should not be ignored. Combat rescue forces are unique from an air planning perspective because they must provide some level of coverage for a wide geographic area. Their combat utilization is difficult to predict with certainty, and the frequency of their employment is unknowable.

This ambiguous planning environment begs for a historically informed method, or planning assumption, to estimate the number of rotary-wing rescue assets for a major combat operation.

Importantly, *this average density ratio inherently incorporates variances in aircraft speeds, maintenance availability, combat attrition, and aircraft capability*. Each of the three conflicts—SEA, Desert Storm, and Allied Force—leveraged different aircraft for this rescue role; all different in their specific limitations and capabilities. For example, the HH-53C was nearly twice as fast as the HH-43. Furthermore, this ratio does not preclude concentration of assets in high-need areas—it seems to assume such. Consider Figure 3, it shows the unrefueled combat radii of the rescue helicopters deployed in SEA. There is a high concentration of coverage in some areas versus others. Bearing in mind these considerations, the average rescue asset density of 1: 6,107 square nautical miles seems a compelling assumption to plan rescue helicopter fleet size. Also important, however, seemingly less precise, is the average probe-to-drogue.

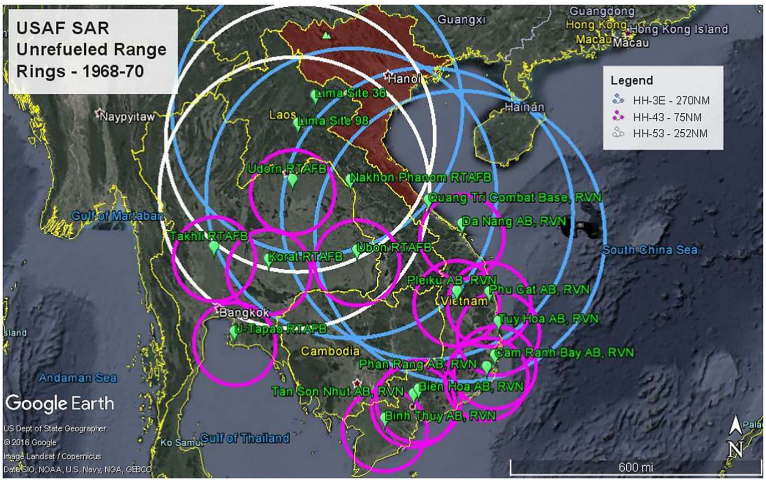


Figure 3: USAF SAR—Unrefueled Helicopter Ranges—1968-1970[50]

Rescue Helicopter Capabilities

The AF suffered 29 rescue helicopter combat losses in SEA from 1964 through 1972.[51] To the best of the author's knowledge, there has never been a comprehensive analysis of rescue combat losses incurred during the Vietnam War in terms of flight profile and enemy weapons system. This is deeply concerning. Combat rescue operations were one of the most dangerous missions in the AF during the Vietnam War. Up through 1967 the HH-3E Jolly Green

Giant had the highest loss rate in North Vietnam at.0088.[52] During the air war in SEA, the USAF's premiere CSAR helicopter, the HH-53, endured the fourth highest loss rate in North Vietnam at 0.0041, and the highest loss rate in South Vietnam at 0.0017.[53] If the service has failed to understand and apply the lessons from the last major war, how can a current or future rescue helicopter force expect success in the next? It cannot.

Rescue Helicopter Shoot Downs—Flight Profile

Increasing an aircraft's combat survivability begins by understanding the nature of the enemy threat and the portion of the mission flight profile posing the gravest danger. During a combat rescue mission, this is the *terminal area*. [For the CSAR community, the term *terminal area* is a historically common term synonymous with *objective area*. This paper will use the terms interchangeably.] The objective area is that area surrounding the location of the isolated person. It is best characterized by the preparations that take place for the final extraction of the isolated individual(s). It is analogous to the *merge* in air combat—combat identification, pre-merge maneuvering, communication, geometries, and weapons systems must all be ready for the "dynamic and lethal ballet of aerial doom" about to ensue.[54] The objective area is where the decisive action takes place and the concentration of recovery effort is expended in pursuit of the "save." It is the Clausewitzian culminating point of a combat rescue "battle." As one might expect, it is also the most dangerous portion of a CSAR mission. Of the 28 helicopters lost during Vietnam—there were technically 29, however, one intentionally crashed into the Son Tay Prison Camp as part of the Son Tay Raid plan—all but four of them were shot down as a result of enemy action in and around the terminal area. Figure 4 graphical presents this information.

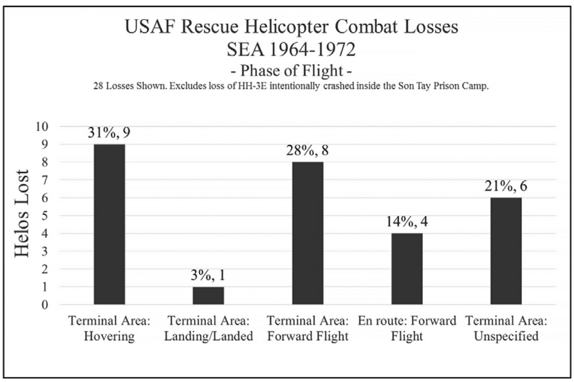


Figure 4: Rescue Helicopter Combat Losses—Phase of Flight[55]

This data requires interpretation. While it affirms what most helicopter pilots would intuitively expect—the objective area is dangerous—the specific values in the chart might lead to imprecise conclusions. The loss of only one helicopter during "landing/landed" probably derives from the mountainous jungle terrain forcing most recovery operations to a hoist/hover. An absence of data regarding the dangers of a landing does not positively affirm an absence of danger. Nonetheless, it is likely that landing to pick up a survivor is inherently safer than a hover. A landing is quicker and affords more opportunity for terrain/foliage masking of the helicopter. Also notable are the number of helicopters downed while in forward flight. Details on exact speeds and altitude were not always contained in the available historical records so conclusions cannot be formed. Drawing meaningful conclusions for historically informed survivability requirements means looking also at the enemy weapon systems responsible for these rescue helicopter shoot downs.

Rescue Helicopter Shoot Downs—Enemy Weapons Systems

It is essential to understand from empirical data the most dangerous portion of a combat rescue mission. This understanding precipitates general schemes for reducing that danger. It also sets the stage for the next, deeper, level of inquiry; what enemy weapon systems proved deadliest to the combat rescue helicopters of SEA? By far, the overwhelming answer is ground fire. This data is presented in Figure 5. The robust air defense system in North Vietnam forced US air operations into lower operating altitudes and into the weapons engagement zones of countless AAA systems. This certainly impacted rescue operations in North Vietnam, however, even in the other operating areas of SEA absent a SAM threat, the very nature of combat rescue still necessitated operating close to the ground, at least in the objective area. Therefore, regardless of the overall assessment of the threat environment for the larger air campaign—low, moderate, or high—the objective area always has the potential to be "contested" if there is proliferation of small arms or automatic weapons among the enemy.

The data displayed in Figure 5 is for all shoot downs, regardless of where in the flight profile a particular enemy weapon systems was used. Of the 28 shoot downs displayed, only four occurred outside the objective area:

1. Enroute—cruise at approximately 7,500' Above Ground Level (AGL)—37 millimeter (mm)
2. Enroute—orbiting at approximately 6,000' AGL—MiG-21 air-to-air missile
3. Enroute—cruise at approximately 100' AGL—Small Arms
4. Enroute—cruise at approximately 9,000' AGL—37mm

Exempting these four enroute shoot downs still leaves 20 of 24 helicopters—83 percent—downed by 37mm or smaller caliber weapons systems in the terminal area. (Four losses were due to "unspecified" ground fire).

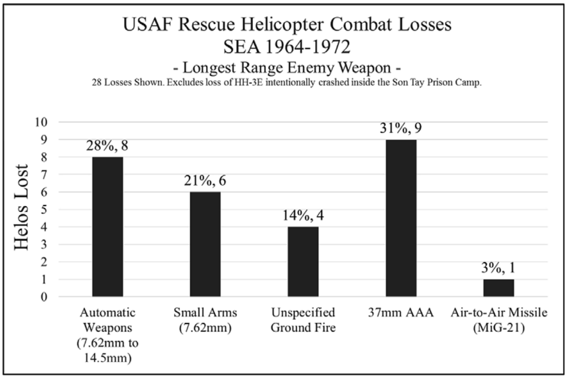


Figure 5: USAF Rescue Helicopter Combat Losses—Enemy Weapon System[56]

Helicopters frequently operate at low-level; this is particularly true near the objective area or in a radar threat environment. Therefore, the horizontal ranges of enemy defensive systems are most pertinent to discussion of lethality. The rough maximum horizontal range of a 37mm AAA system is about 8,000 meters (m), or around 4.3 NM.[57] The 37mm weapon system, along with the other systems responsible for so many downed rescue helicopters, are still widely used throughout the world today. However, the 37mm threat has been somewhat replaced by newer antiaircraft gun systems based on 23mm and 30mm caliber projectiles. These systems have maximum horizontal ranges of approximately 7,000m and 9,500m respectively (or 3.8 NM and 5.0NM).[58] Additionally, the last 45 years has seen widespread fielding of man portable air defense systems (MANPADS) designed to provide lightweight air defense against low-flying aircraft. Broadly speaking, these shoulder-fired SAMs have a typical engagement range of around four statute miles, or 3.5 NM.[59]

In light of the experiences in SEA, not to mention more contemporary conflicts, it seems realistic to assume future hostilities—whether counterinsurgency or major war—will impose an objective area threat formed from some combination of automatic weapons, AAA, or MANPADS. Improving survivability in the objective area requires a rescue helicopter be equipped with some mechanism to build situational awareness of the objective area from a tactically viable stand-off distance. It must also be able to kinetically mitigate identified threats to the survivor or helicopter from this same stand-off distance. Considering the maximum horizontal engagement ranges of historically lethal AAA systems and contemporary MANPADS, a tactically viable stand-off distance is probably about 4.5 NM, or a bit over 8,000m. In practice, this means equipping the rescue helicopter with a targeting sensor and lightweight munitions capable of precisely engaging identified enemy troops and chassis mounted gun systems. Combat identification and target engagement capability, from stand-off, is obviously not a panacea for all enemy threats. Stand-off is historically vindicated and complimentary to current efforts to improve the rescue aircraft's self-protection against radar and infrared threats. Taken together, these improvements promise to increase basic survivability and decrease risk to the CSAR mission.

Enabling the helicopter crew to organically build situational awareness of the enemy threat and identify the survivor location while remaining outside the maximum range of likely objective area threats is self-evidently beneficial. Readers should be shocked to know our rescue crews still, at base, must execute Vietnam era tactics. Namely, they must rely on fighter and attack aircraft to spot all threats in the objective area, find the survivor, neutralize the threats, and then verbally describe this over the radio to the helicopter crews. The helicopter crews must then fly into the objective area—into the weapons engagement zone (WEZ) of every possible enemy weapons system—hoping their mental picture of the objective area is accurate and all the enemy were struck. Any missed enemy position will be identified once it starts shooting at the helicopter. In response, best case, the crews can use side-firing 50 caliber machine guns to shoot back. This is akin to a modern fighter pilot going into aerial combat without intercept radar, without beyond-visual range missiles, without infrared short range air-to-missiles, and only the machine guns adapted from a P-51 Mustang. It is absurd. Such is the case with a rescue helicopter ill-equipped to account for the lessons of hard combat from over 45 years ago.

Less emotionally compelling, however, just as poignant, is the more practical benefit of increasing the capability of the rescue helicopter crew to operate in the objective area with *less* reliance on supporting fighter assets. Doing this increases the availability of these assets for other missions. From a strictly functional perspective, CSAR is necessary during a major war because it preserves human capital. The AF is in the business of aerial delivered violence; the demand for this type of combat power requires men and women skilled in its employment. Such expertise and skill takes years to develop. Recovering isolated personnel and returning them back to the fight is a necessity of attritional air warfare. The hard truth in this type of peer conflict is that the war will not stop just because aircraft get shot down. The air component commander must continue the execution of air operations against the enemy in order to seize and maintain initiative. Therefore, reducing the number of aircraft required to support the execution of a PR mission leaves these assets available for other air operations. The unknowns of combat make it impossible to quantify, however, its truth is intuitive. Even if, in some circumstances, the number of supporting fighters remains relatively unchanged, increasing the inherent survivability of the rescue helicopter still reduces mission risk. In aggregate, addressing the historically proven threats encountered in the objective area promises to increase the viability of PR during a major war.

Rescue Helicopter Speed—Vital, But Not Why You May Think . . .

An analysis conducted by the 3rd Aerospace Rescue and Recovery Group (ARRG)—the parent command of the ARRSs of SEA—determined that if a rescue helicopter could reach a downed aviator inside of 15 minutes his chances of successful rescue were very good.[60] After 30 minutes, his chance of recovery dropped off dramatically.[61] In this study, the 3rd ARRG also noted that 47 percent of all failed rescue attempts were due to the slow speed of the rescue helicopter.[62]

As a result of Air Rescue's experiences in SEA, in the late 1960s the AF drafted a proposal for a Combat Aircrew Recovery Aircraft (CARA) to bolster the effectiveness of combat rescue. Despite the rapid combat fielding of the HH-53 Super Jolly Green Giant, the 3rd ARRG deemed "the helicopter [HH-53] . . . too large and too slow."[63] The 3rd ARRG believed the replacement CARA should be smaller than the HH-53, have a minimum cruise speed of 400 knots, have hostile ground fire detection capability, an electronic countermeasure suite, and be equipped with a terrain following/terrain avoidance radar for all-weather operations.[64] A 400 knot cruise speed may be technologically unlikely for a vertical lift aircraft. The V-22 Osprey only cruises at 270 knots, and 240 knots at low-level.[65] Therefore, while 400 knots may not be easily attainable, it does not justify the complete abandonment of attempts to increase the rescue helicopter's speed. Sadly though, the HH-60G—and its planned replacement the HH-60W—are even slower than the Vietnam era HH-53 and do not have terrain following/terrain avoidance system for all-weather operations.[66] The HH-60 is smaller though, so there is that.

Table 4: USAF Rescue Helicopters—1964 to Present[67]

	HH-43	HH-3E	HH-53C	HH-60G
Crew	4	4	5	6
Speed	75 kts	110kts	140kts	120kts
Unrefueled Radius	75 NM	270 NM	252 NM	195 NM
Armament	None	2 x 7.62 M-60 Guns	3 x 7.62 Mini-guns	2 x 7.62 Mini-guns or 2 x.50cal Guns

AF interest in increasing the speed of its recovery aircraft has always seemed to be relative to the survivor. A recent study by the Research and Development (RAND) Corporation reinforces the original 3rd ARRG analysis. Their 2015 report aimed to determine a relationship between aircrew "rescuability" and time in order to ascertain any benefit of adding the faster, however, markedly more expensive, V-22 Osprey to the CSAR fleet.[68] RAND examined CSAR data from 1968 in SEA and from 1991-2014. Figure 6 is taken from their report and shows the relationship between rescuability and time for PR missions.

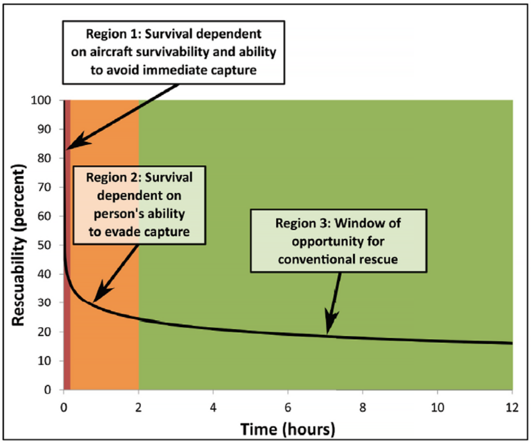


Figure 6: RAND Corporation's—Rescuability by Temporal Region[69]

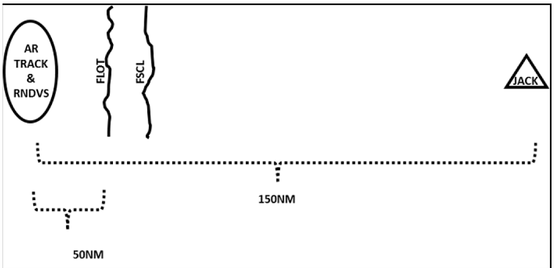
Taking RAND's analysis into account, it seems to temper justification for greater speed. It does not make a strong case for spending the money and resources on the technological advancements necessary for increasing speed to the degree necessary to achieve appreciable increases in rescuability. The futility of increasing the rescue helicopter's speed is true *only* if the justification for increasing speed is solely referenced to the survivor with helicopters executing unilaterally. This myopic perspective on CSAR misses the larger operational context in which increased rescue helicopter speed is hugely vital.

CSAR missions do not happen in a vacuum. When executed in a major war a CSAR effort must necessarily include a number of other assets to locate, support, and recover the survivor. Many of these airborne assets; command and control (C2), intelligence surveillance, and reconnaissance, fighters, and aerial refuelers are crucial contributors to an ongoing air campaign. By diverting these assets from ongoing air operations to support a CSAR Task Force the air component commander incurs a capability deficit.

While CSAR may be a moral, strategic, and operational imperative, it still drains the bench of key players. During the Vietnam War, this was probably not a pressing concern. Today however, it must be. Increasing the speed of our rescue helicopters may have only slight direct benefit to the rescuability of a downed aviator, however, it has significant benefit in reducing the number of supporting combat aircraft necessary to execute a CSARTF. Table 5 is a comparative mission analysis for a notional 150 nautical mile CSAR mission in a threat environment requiring the listed force packaging [support asset] requirements. It compellingly shows the benefit of increasing the speed of the rescue helicopter.

Table 5: Benefit of Increased Helicopter Speed—Comparative CSARTF Mission Planning[70]

Notional 150 NM CSAR Mission:



Notional CSARTF Force Packaging Requirements:

4-ship F-16s—RESCORT
4-ship F-16s—Suppression of Enemy Air Defense (SEAD)
4-ship F-15Cs—Offensive counterair attack (OCA)

This force packaging assumes continuous 4-ship coverage for mission duration.

Total CSARTF Requirements:

Role (Aircraft)	HH-60G/W (120 KGS)	HH-60 X (180 KGS)	HH-60 XX 200 KGS	CV-22 240 KGS	FY17 DoD Rates (Cost/Hour)
RESCORT (F-16)	**12**	8	**8**	8	$8,205.00
SEAD (F-16)	**12**	8	**8**	8	$8,205.00
OCA (F-15C)	**12**	12	**8**	8	$21,506.00
TANKER (KC-135)	**3**	2	**2**	2	$10,654.00
Mission Duration (hour)	**2.75**	1.92	**1.75**	1.50	
CSARTF Fuel Total	331,200	244,533	227,200	201,200	
Total CSARTF Flying Hour Costs	**$1,339,123.50**	**$787,098.33**	**$568,113.00**	**$486,954.00**	

For this mission scenario, increasing the speed of the rescue helicopter to 200 knots cuts one hour from the mission, cuts the flying hour costs in half, reduces the number of supporting fighter assets by nearly 40 percent, and perhaps most importantly, reduces the required number of KC-135s from three to two. In an age of reduced fighter inventories and aging refuelers, this is a huge operational benefit.

If less supporting aircraft are required to execute a CSARTF—without corresponding increase in risk—the more likely an air component commander can form one and launch it. Increasing the speed of the rescue helicopter correspondingly decreases the time the CSARTF is exposed to enemy action. This is operationally vital in any conflict where air supremacy is in contest and a CSARTF must execute within localized air superiority. The less time this window is kept open, the less chance of additional shoot downs. Furthermore, greater rescue helicopter speed gives the air component commander more options in the type of supporting aircraft they can devote to the CSARTF.

In a major peer war, the current rescue helicopter fleet will need some type of supporting RESCORT to provide route reconnaissance and engagement of enemy forces threatening the helicopters. Currently, the well-armed and slower-flying A-10 is an ideal aircraft for this role. However, the slow speed of the helicopter inhibits easy employment of fast-fighters to perform this same RESCORT function. Their fuel burn rates and cruise speeds are largely incompatible for attached escort of helicopters. Therefore, employing them in this specific role incurs risk to the helicopters, without current mechanisms or capabilities to compensate. Increasing the speed of the rescue helicopter helps alleviate this disparity between the recovery aircraft and fast fighter RESCORT. It also reduces the vulnerability time of the helicopter to enroute enemy threats. Consider the following table showing the exposure times of different helicopters to the WEZs of different enemy air defense artillery systems.

Table 6: Time in Various Weapons Engagement Zones (seconds)[71]

AAA millimeters	Max Effective Horizontal Range Miles	HH-3E 90 knots (kt)	HH-53 140kt	HH-60G 120kt	HH-60W 125kt	H-60 XX 210kt	CV-22 240kt
12.7	1,000	12.9	10.3	11.3	11.0	8.1	7.0
14.5	1,400	16.5	13.4	14.5	14.2	10.8	9.5
23	2,500	25.3	20.6	22.1	21.7	17.3	15.6
30	3,000	29.1	23.5	25.2	24.7	19.9	18.0
37	1,500	17.3	14.2	15.3	15.0	11.5	10.1
57	6,000	51.3	39.2	42.6	41.6	33.1	30.5

The decreased exposure time granted by higher enroute cruise speeds is a worthwhile contributor to increasing recovery aircraft survivability. The V-22 is a good performance benchmark for enroute threat avoidance given the AF's apparent interest in leveraging its speed advantage for the CSAR mission. If the speed of the current HH-60 is increased 70-75 percent, to roughly 210 knots, the difference in exposure times to the V-22 are minor. Markedly increasing the speed of the rescue helicopter would put it in the same class as a V-22 flying a low-level profile, significantly reduce exposure time to enroute threat systems, and close the speed gap with fast-fighters, allowing more easily for their employment in the RESCORT role.

Lessons Now Learned: A Summary

Analysis of the 28 rescue helicopter shot down in SEA reveals several critical lessons and insights from the men who flew those dangerous missions. Twenty-four of 28, or 85 percent, of all rescue helicopter shoot downs occurred in the terminal, or objective area, marking it as the single most dangerous portion of the CSAR mission profile. This high loss rate occurred despite the extensive efforts of accompanying fighters and attack aircraft to identify and neutralize enemy forces. Of the 24 aircraft lost in the objective area, nine were downed while hovering.

The analysis of these 28 shoot downs reveals several other crucial insights. First among them is the danger of ground-based air defense artillery and automatic weapons to the rescue helicopter. Aside from one rescue helicopter lost in an air engagement to a MiG-21, the remaining 27 helicopters were lost to ground fire. Four losses are unspecified in the historical records, however, the remaining 22 aircraft were lost to 37mm and smaller caliber systems. The contemporary proliferation of automatic weapons, 23mm and 30mm gun systems, and lightweight MANPADS creates a particularly dangerous threat combination in the CSAR objective area. Expecting CSAR mission success in a major war without accounting for these blood-bought experiences of the past is dangerous and foolhardy.

Importantly, future CSAR success will require more than just better awareness and armament on a conventional helicopter, it will require a faster helicopter. CSAR missions are executed within a larger operational context. The likely operating environment of any forthcoming major peer war requires a markedly faster recovery aircraft. In this age of decreased fighter fleet sizes and emerging peer competitors, every fighter asset becomes a precious warfighting commodity to the air component commander. A comparative mission planning analysis indicates significant economies of force are achievable by increasing the helicopter's speed by just 50 percent. For example, pushing the rescue helicopter's speed from 120 knots to just 180 knots for a 150NM

CSAR mission will require roughly 40 percent fewer fighters and one less KC-135. Increasing the speed of the rescue helicopter will have a direct impact benefit to both the CSAR mission and the larger war effort.

CSAR Helicopter Requirements

Analysis of the combat loss data from SEA and the requirement for increased operating speed produces several key requirements for a CSAR helicopter. These must be applied to decrease risk to the CSAR force and the CSAR mission. [This is not an exhaustive list, rather one revealed from historical and contemporary analysis.]:

- <u>Improved defensive armament systems and onboard targeting sensor</u>: Given the engagement ranges of historically lethal AAA systems and their replacements, and emergence of MANPADS, the combat rescue helicopter must be able to *stand-off from the objective area by over 8,000 m*, conduct combat identification, and engage threats to the survivor or rescue helicopters. To do this, the crews must have a *modern targeting sensor and onboard munitions capable of precisely engaging identified enemy* troops and chassis mounted gun systems.
- <u>Reduced downwash and hover height</u>: Decreasing the time in the objective area, and hence exposure to enemy action, will improve survivability. An aircraft that can increase the speed of its hoist operation will spend less time in the objective area. A way to reduce hoist time is to reduce hover height and downwash. This makes it easier for personnel to operate beneath the aircraft. [Downwash is a function of rotor disk loading, discussed in-depth in Appendix C.]
- <u>Dimensional smaller than an HH-53</u>: A smaller aircraft can hover lower while maintaining proper obstacle clearance. This also reduces silhouetting to enemy gunners. The 3rd ARRG concluded the HH-53 was too large in part because of this reason.
- <u>Equipped with side-firing crew-served weapons</u>: It seems unlikely any CSAR Task Force will be able to achieve complete situational awareness of every threat in an objective area. Improve helicopter sensors and stand-off armament will provide great benefit, however, there will still be a need for side-firing weapons on the rescue helicopter, especially during hoist recoveries from rough terrain or dense foliage. An aerial gunner still provides superior awareness and responsiveness to close-in threats to the helicopter.

- Increased operational speed: In order to reduce demand for supporting fighters and tankers, the rescue helicopter should be able to cruise for long-distances at not less than 180 knots. This is a 50 percent increase over the HH-60G/W. Ideally, cruise speed will be higher for further reductions in asset requirements.

The next section discusses ways to use technology to apply history's lessons to the equipping and organizing of the combat rescue helicopter fleet; and in so doing, restore validity to the sacred assurance that we will not abandon our warriors to the cold whims of evil men.

Equipping and Organizing

There are several vital ingredients to a credible CSAR capability, key among them are equipping and organizing. A dedicated CSAR force primarily exists to recover personnel in a major war. It is unreasonable to assume future combat success in the next major war if past failures and lessons are unapplied. This logic underpins the idea of baseline survivability. It is "baseline" because it resolves historical—and still relevant—vulnerabilities, however, does not go so far as to fully address contemporary threats like advanced SAM systems. These additional threats are serious and require technological and force packaging solutions to mitigate them, however, the specifics are difficult to usefully discuss in an unclassified paper. As a result, this section applies the lessons distilled from historical analysis and proposes material and organizational solutions to create a CSAR force able to fulfill the institutional promise of PR.

Comparing the HH-60G and HH-60W

The HH-60W Combat Rescue Helicopter will provide some necessary improvement over the HH-60G. It will be new, which should increase safety of operation as well as decrease maintenance cost. The avionics package should be well integrated and the self-protection suite will, ideally, provide enhanced survivability against newer radio frequency threats and MANPADS. However, a comparison of the HH-60G Pave Hawk to the expected capabilities of the HH-60W Combat Rescue Helicopter shows a dangerous lack of improvement in areas of relevant historical importance: armament, awareness, and speed.

Table 7: HH-60G vs HH-60W Combat Rescue Helicopter (CRH)

Capability	HH-60G	HH-60W
Range (NM) (inc. 10 min in objective area)	185 NM radius	190-200 NM radius
Cruise Airspeed	120 kts	120 -130 kts
Mission Avionics	Limited Integration	Fully integrated; "glass" cockpit
Self-Protection	Chaff/Flares	Integrated Radio Frequency/ Infrared/Hostile-Fire
Armament	7.62mm mini-gun or .50cal machine gun	7.62mm mini-gun or .50cal machine gun
Electro-Optical Sensor*	Navigation Use Only	Expected: Navigation Use Only
Hover Performance (out-of-ground effect, mid-mission gross wt)	3000′ Pressure Altitude, 35oC	4000′ Pressure Altitude, 35oC
Mission Capability	73.4percent	≥ 83percent
Aircraft Availability	57.1percent	≥ 67.4percent

The word *dangerous* is intentional. It pointedly highlights the risk inherent in fielding an aircraft fleet in quantities, and with capabilities, inadequate to the demands and circumstances of its primary mission. Enabling the requirements identified from the historical analysis will not be a panacea for operations in a contested environment. Rather, they are technical requirements that must be incorporated in the HH-60W in order to provide a baseline survivability and decrease the operational liability of actually executing a CSARTF in a major war.

What to Do?

Relevant CSAR history validates the need for key capabilities in a rescue helicopter. History reveals the AF's cycles of need and neglect toward its CSAR forces (read Appendix B) and hints at the difficulty in getting the HH-60W acquisition program approved. Assuming a relevant CSAR force is imminently necessary due to emerging peer threats, however, a new acquisition program is unlikely due to time, organizational interest, and political restraints, what is the AF to do? The answer must necessarily apply historical lessons while also accounting for the key assumptions listed earlier in the paper.

Equipping for Baseline Survivability and Speed[72]

Stand-off

Altitude, speed, and poor weather can greatly impede escorting fighter pilots from identifying enemy personnel or vehicles posing a threat within the objective area. Poor weather or high threat can negate high altitude employment of targeting sensors from fast-fighters. Additionally, enemy personnel may seek cover and concealment to shield them from overhead view. Enemy communication jamming and contention of the electromagnetic spectrum may preclude use of tactical data links or transmission of full-motion video from supporting fighters to the rescue helicopters. Any of these factors will leave the HH-60 crew to organically derive their own situational awareness and provide their own fire support. This stand-off distance should be at least 8,000 meters. The rescue of Vega 31 in Operation Allied Force is a real-world example of poor weather adversely impacting the ability of RESCORT to provide fire support for the recovery helicopters in the objective area.[73] The most obvious and immediately available way to improve survivability is to equip AF HH-60s with a modern targeting sensor and lightweight precision rocket and missile systems.

Improving Survivability—Electro-Optical Sensor

The HH-60G currently has an AN/AAQ-29 forward looking infrared (FLIR) system used primarily for enroute navigation. The system does not have practical capability to accurately slave-to/look at a user defined location and elevation. It does not have an infrared pointer for target/hazard marking, does not have a laser rangefinder for deriving accurate location and elevation of a point of interest, and does not have the capability to laser designate a target.[74] The limitations of this system severely degrade an HH-60 crew from conducting combat identification of isolated personnel and enemy threats in the objective area from viable stand-off distances. Excepting verbal talk-on by the HH-60G crew, there is currently not a way for an HH-60G crew to derive a targetable coordinate of a threat, from stand-off, or to facilitate a timely hand-off of a target to supporting assets. This elevates risk to the survivor, the HH-60s, and the entire mission.

An advanced electro-optical/infrared (EO/IR) targeting sensor with high fidelity thermal and color imaging, laser target designator, laser range finder, infrared pointer, and laser spot tracker will provide necessary organic crew situational awareness. Helicopter targeting sensors have two important benefits: The lower relative speed of a helicopter makes sensor-employment from lower altitudes a feasible method to build awareness of the objective area. Additionally, the lower flying altitude and perspective of the helicopter gives it a greater freedom to operate beneath weather that would otherwise obscure the EO/IR sensors on a fast fighter. Given the modularity of such systems, they can be transferred to the new HH-60W Combat Rescue Helicopters as they enter service. In a GPS-denied environment, the laser target designator and laser spot tracker will provide residual capability for fires-coordination and precision target engagement.

Air Combat Command (ACC) has a *Form 1067 Modification Proposal* on file specifying this requirement for an advanced electro-optical targeting sensor under Control Number: *ACC 14-296*.[75] The HH-60G is expected to remain in service until 2029. Upgrading its legacy AN/AAQ-29 sensor to meet the threshold key performance parameters outlined in the Form 1067 is possibly the fastest way to field this urgent capability. It seems reasonable the original equipment manufacturer (OEM)—which is Raytheon—could combine parts from their existing sensor products into a situational awareness component kit for the AAQ-29. Contracting with an existing OEM to upgrade a fielded product could offer time and cost efficiencies. Raytheon certainly has market incentive to competitively price and produce such a component kit given the number of potential competitors.

The likely upside to such an upgrade program is reduced time-to-field and reduced cost. Upgrading the AN/AAQ-29 to the minimum capability requirements for a targeting sensor may be sacrificing opportunity to realize a greater technological leap in capability. This is a downside should this conjecture prove correct. However, assuming geopolitics continues to increase the probability of major state-on-state war, it is better to get an adequate sensor solution sooner than an ideal solution later.

The HH-60W is different. The initial low-rate production (ILRP) HH-60W aircraft—totaling 18 airframes—will arrive between 2019 and 2021.[76] Full rate production (FRP) will run from 2023 through 2029.[77] If the HH-60Gs get upgraded sensors, the AF has opportunity to work with Sikorsky and optimize the sensor for the HH-60W. These changes are probably best suited for the FRP aircraft to avoid delays in delivery of the ILRP aircraft. The HH-60W program is considering the L3 Wescam MX-10 sensor for the CRH.[78] The MX-10 offers improvement in long-range electro-optical fidelity and image quality, relative to the AN/AAQ-29, however, the MX-10 does not provide all identified sensor capabilities.[79] A better solution for the HH-60W is to equip the FRP aircraft with the most advanced nondevelopmental rotary-wing targeting sensor available and then retroactively modify the ILRP helicopters. This assumes a change of sensor would delay ILRP delivery, if it does not then equip all the new HH-60Ws with a proper sensor. Underpinning this approach to the HH-60W is a rapid upgrade to the HH-60G. This buys the AF some operational viability while the HH-60W is fielded. Importantly, upgrading the HH-60G's sensor now gives HH-60 pilots opportunity to develop the new tactics and competencies needed to best employ them.

Improving Survivability—Armament

HH-60G's current weapons, and those planned for the HH-60W, do not offer a stand-off engagement capability against enemy threats in the objective area. In order to engage a threat to the isolated personnel or HH-60 formation, an HH-60 crew must close with the enemy and engage them from ranges under 1,800 m with the GAU-18 (.50 caliber machine gun), or far less if the aircraft is equipped with the GAU-2 7.62mm mini-gun. This puts the HH-60 within the effective range of nearly all prospective threat systems.

Equipping the HH-60 with an EO/IR targeting sensor will provide crews situational awareness of the objective area from more survivable stand-off range. This awareness will reduce risk to the helicopter crews by reducing exposure to enemy action. However, in order to advance mission accomplishment, the crew must also be able to shape the objective area to their tactical advantage. Equipping the HH-60 with onboard armament to precisely engage enemy threats from outside the objective area is a needed game changer. It complements the capabilities of accompanying escort fighters—should they be available. However, it also offers the air component commander CSAR options, even if he must devote most of his escort fighters to other missions

The HH-60G is capable of carrying external weapons with little structural modification. The external gun mount system (EGMS) on the HH-60G was designed to carry weapons stores, specifically missile rails or a rocket launcher, outboard of the gun mount.

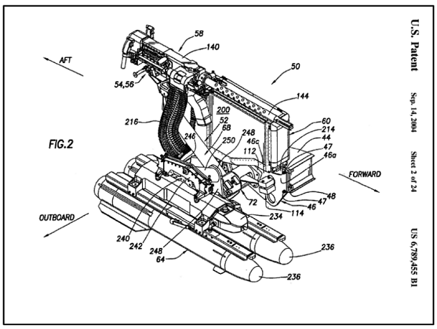


Figure 7: HH-60 External Gun Mount Patent Submission[80]

In the 1990s the AF conducted some testing of this EGMS system with rocket launchers installed as evidenced by the photographs provided by the 88th Test and Evaluation Squadron in Figure 8. The HH-60G

today does not have rocket pods. When the EGMS was tested and fielded, over 15 years ago, the value proposition of unguided 2.75” folding-fin aerial rockets (aka Hydra 70 rockets) for the HH-60G was pretty poor. The typical employment distances for 2.75” high-explosive rockets is not markedly different than HH-60G fixed-forward.50cal employment, which the EGMS currently enables.[81] Unguided rockets do provide excellent target marking and reactive area suppression, especially flechette against enemy ground troops. Nevertheless, they do not provide appreciable stand-off.

Figure 8: HH-60G Fitted with Rocket Launchers[82]

The AGM-114 is a very capable stand-off weapon, however, is also relatively heavy (depending on variant, around 100 pounds per missile) and would have required a laser designator the HH-60G does not have. Furthermore, in the AF of the late 1990’s had roughly 2,500 total fighter and attack aircraft. [83] This fighter capacity likely perpetuated the Vietnam era CSAR doctrine—and its heavy reliance on escort fighters—to prevail.[84]

However, times have changed and so has the value proposition of equipping the HH-60 with an EO/IR targeting sensor and improved defensive armament. Today’s AF only has about 2,000 fighter and attack aircraft in inventory.[85] The CSAR experiences of Vietnam highlight the need to increase aircrew awareness and organic stand-off weapons capability. Even assuming the Vietnam era doctrine relying on escort fighters is adequate, the number of available fighters has dropped dramatically. This somewhat negates argument for continued reliance on fighter support that does not exist now. The fighter shortage pushes the need for other survivability solutions for the rescue helicopter, however, it is recent advancements in lightweight precision munitions that enables the solution. Systems like the AGM-176 Griffin missile or laser-guided 2.75" rockets like the Advanced Precision Kill Weapon System potentially offer the survivability enhancements the HH-60 requires. These lighter weight precision missile and rockets, and others like them, are nondevelopmental armament solutions that are structurally supportable by the HH-60G's EGMS.

Adding improved armament to the HH-60—understanding there will also be wiring and control modifications—seems fairly low risk from a technical stand-point. There will undoubtedly be additional cost to carry and employ this type of ordnance, however, the EGMS are already installed requiring only the inclusion of mounting brackets and standard rotary-wing bomb rack units (BRUs).

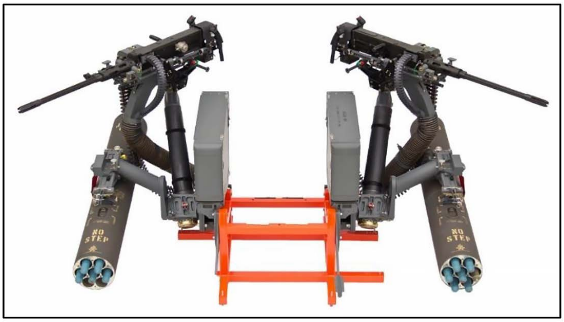


Figure 9: CFD International's H-60 EGMS with 7-shot Rocket Pods[86]

There will be some nonrecurring engineering expense to design the wiring and control harness for the aircraft. However, shooting rockets and missiles off a helicopter is not rocket science, pun intended.

Absent improvements in aircraft speed and power, discussed later, this armament upgrade will require trade-offs in the accounting between weight, power, and speed. External stores increase drag and weight, requiring either more power to achieve the same speed or by acceptance of slower speed for a given power. Well-armed rescue helicopters could partly negate the need for escort fighters on some missions, threat dependent. Adding necessary aircraft armament cuts into the limited trade space on weight. It may be that some threat and environmental conditions will drive a formation construct whereby one "slick" HH-60—equipped only with crew-served machine guns and the pararescue team—is escorted by one or two "gunship" HH-60s. There is still some inherent redundancy for the recovery mission in this construct. If a contingency arises, requiring the pickup of more personnel, the "gun" bird can jettison its stores, freeing up the weight and power margin to lift several passengers. Ideally both rescue helicopters would be similarly well-armed, however, if commanders must make trade-offs to meet mission demands they can look to AF history for relevant insight.

The war in SEA provides more than just lessons about CSAR helicopter survivability shortfalls. It also offers historical precedent for part of the solution. In early 1967, AF UH-1F helicopter gunships—like those in Figure 10—conducted their first combat missions providing CAS to Military Assistance Command Studies and Observation Group (MACSOG) forces.[87] A normal MACSOG mission involved seven UH-1F aircraft: four gunships and three slicks; one of the slicks served as command and control, one carried the infiltration team, and the third slick served as the medical recovery vehicle.[88] The four gunship UH-1F's were armed with 2.75in rockets and 7.62mm miniguns and the slick UH-1F's were armed with only 7.62mm M-60 machine guns.[89] However, operational commanders at the time indicated most operations really only required two gunships to support a mission.[90] As of July 1968, the loss rate of UH-1Fs was low, having lost only one UH-1F in performing missions for MACSOG infiltration/exfiltration operations.[91] This low loss rate was attributable in large part to excellent crew training and flexibility.[92]

While a CSAR differs in purpose from these Vietnam era special air warfare (SAW) missions, the threat environment shares some important similarities. The same enemy weapons that threatened these early special operations helicopters also threated the CSAR helicopters in SEA. Furthermore, both a CSAR and a special operations infiltration/exfiltration require conditions favorable to operating helicopters at low energy states in the objective area. The construct of these AF UH-1F missions' points to the validity of using HH-60 "gunships" to cover a "slick" pick up HH-60. In a modern HH-60 formation the flight lead is also the recovery vehicle package commander, performing the command and control functions once attributed to a dedicated aircraft. Medical capability is inherent within an HH-60 formation. The UH-1F commander assessed that two UH-1F gunships were adequate for most missions, this means one to two HH-60 "gunships" with improved weapons effectiveness—by virtue of precision targeting—could support a "slick" HH-60. In total, it is reasonable to think one or two HH-60 gunships could effectively escort a slick HH-60 in roughly analogous combat circumstances. While the parallels between these two missions are not exacting and perfect, they do provide useful precedent that points to the viability of a mixed formation, should the operating environment preclude arming both aircraft with stand-off weapons.

Figure 10: USAF UH-1F Helicopter Gunships in Southeast Asia[93]

Arming AF helicopters for greater survivability invites discussion of roles and missions agreements. The use of AF helicopter gunships in combat is not a new idea, it was of great interest to senior AF leadership in the late 1960s. In a reply teletype message to the Chief of Staff of the AF, dated February 1967, the Commander in Chief of Pacific AFs provided this:

> Ref is [Chief of Staff of the AF] (CSAF) guidance on arming SAW] helicopter for use in SAW role and indicated strong initial support for project from COMUSMACV [Commander US Military Assistance Command Vietnam] fundamental to successful implementation of program. 7AF [7th Air Force] has advised close contact with MACV (MACSOG), and has so far indicated there is not any resistance to use of AF gunships support [to] SAW operations . . . 7AF is pressing with AF MACSOG personnel [to] use these helicopters as gunships. Rationale in urging immediate employment is to cite 'accomplished fact' should opposition to using AF helicopters as gunships [in] SAW operations arise later.[94]

AF leadership was keen to establish helicopter gunships as another service instrument of airpower, an instrument particularly well suited to conduct light attack and CAS in counterinsurgency warfare. The timing of this message, and the combat introduction of the AF helicopter gunship, is important. The *McConnell-Johnson Agreement of 6 April 1966* released the AF's earlier claims to rotary-wing aviation, with three important exemptions revealed in the excerpt. By using AF helicopter gunships in the SAW role within one year of the agreement the service set precedent for their later use.

"Agreement Between Chief of Staff, US Army, and Chief of Staff, US Air Force"

... b. The Chief of Staff, U.S. Air Force agrees:

(1) *To relinquish all claims for helicopters and follow-on rotary-wing aircraft which are designed and operated for the intra-theater movement, fire support, supply and resupply of Army forces and this Air Force Control elements assigned to DASC and subject thereto.* ***(CSA and CSAF agree that this does not include rotary-wing employed by Air Force SAW [special air warfare] and SAR forces and rotary-wing administrative mission support aircraft)****. {emphasis added}*

"Addendum to the Agreement of 6 April 1966 Between Chief of Staff, US Army, and Chief of Staff, US Air Force" 19 May 1967

The Chief of Staff US Army and Chief of Staff, US Air Force agree to amend their agreement of 6 April 1966 concerning the control and employment of certain types of fixed and rotary wing aircraft by adding the following clarifying sentence to paragraph b (1):

"SAW rotary wing aircraft—armed if required—will be employed to train foreign air forces in the operation and employment of helicopters and to support US Air Force forces, other government agencies, and indigenous forces only when operating ***without*** *{emphasis added} US Army advisors or not under US Army control"*

Figure 11: Excerpts from McConnell-Johnson Agreement of 6 April 1966[95]

The AF eventually upgraded from the single-engine UH-1F to the twin-engine UH-1N (shown in Figure 12) equipping them with XM-94 40mm grenade launchers in addition to the seven-shot 2.75 inch rocket launchers.[96] These UH-1N gunships remained in use until around 1985.[97] The exemptions in the *McConnell-Johnson Agreement* also encompassed SAR. It logically comes to SAW and SAR. In fact, both the Vega 31 and Hammer 34 rescue mission during Allied Force used an analogous formation construct in which two MH-53s acted as attached escort "gunships" for the single MH-60G "pick-up" helicopter.[98] Equipping CSAR helicopters with improved armament will correct a survivability shortfall, improve operational flexibility in air operations, and is in accordance with roles and missions agreements and historical service precedent.

Figure 12: USAF UH-1N Helicopter Gunship[99]

Improving Operational Viability—Speed

The attritional air warfare that makes CSAR so challenging is also the very type of conflict that makes CSAR so necessary. A peer adversary will undoubtedly try to deny useful access to the electromagnetic spectrum and PNT upon which our unmanned systems and command and control systems rely. At least in the foreseeable future the AF will need pilots in cockpits to problem-solve these challenges and continue the fight despite these challenges. An air war characterized by high attrition will require a heavy emphasis on recovering downed aircrew and returning them back to the fight. The experience of the German *Luftwaffe* offers poignant testimony to the importance of preserving human capital—well-trained combat pilots—during the conduct of a major war. The *Luftwaffe* entered World War II as the world's most capable AF, however, by 1944 was left an impotent shell by their inability to replace skilled pilots lost to wartime attrition. As one *Luftwaffe* general commented:

> During aerial combat, the unit's cohesion was quickly lost, and it had to reassemble and take up a new position. This was hardly ever accomplished, as such maneuvers presupposed a superior state of training, which was particularly lacking. The Jagdgruppen Kommandeure often stated that they would rather attack a superior enemy with four or six of their best pilots than take an entire Gruppe of 25-30 aircraft into the air because most pilots were too poorly trained to maintain contact… [100]

A properly sized and modernized CSAR force is more than moral necessity, it is an asymmetric advantage during attritional air warfare. A CSAR force inadequate to the demands of major war against a committed and capable enemy directly undermines the long-term sustainability of American airpower.

Prolonged attritional warfare is normally associated with conflicts like World War I or II. The next war may similarly last for an extended period as each side vies for decisive victory. However, specific actions and operations will likely unfold with a rapidity and violence unique to modern weaponry, computing speeds, and the technological parity of our adversaries. It is conceivable US air supremacy will be unachievable, at least initially, and that opportunities for decisive tactical action will be fleeting, relying on narrow windows of localized air superiority. A rescue helicopter traveling at two nautical miles a minute (120 knots) is wholly inadequate to this environment of brief localized air superiority. It is unlikely a future air component commander, faced with high air attrition, will be able to hold open the window of opportunity necessary to shepherd a slow helicopter during a CSAR mission. Improving crew awareness and armament will correct survivability shortfalls still unresolved from the war in SEA. However, these survivability enhancements are just long-overdue evolution from the CSAR paradigm of the late-

60s. If the AF wants to avoid a fate analogous to that of 1944-*Luftwaffe*, it must enable its HH-60G and HH-60W with the greater flying speed necessary to operate within narrow windows of localized air superiority with the greatest economy of force in the CSARTF. Failure to do this risks much.

Increasing the speed envelope of the AF rescue helicopters is both necessary and viable, however, guided by certain assumptions. The first assumption is that a major peer war is uncomfortably possible within the next ten years. This drives a preference for a "pretty good" speed solution sooner rather than the "perfect" solution at some point decades from now. This desire for "pretty good" informs the second assumption; political and time restraints favor upgrading the HH-60 versus a clean-sheet aircraft design program. The AF could pursue a clean-sheet design, or even join the joint Future Vertical Lift (FVL) program. However, at best, FVL aims for LRIP in 2030 for its first capability set, which will not include CSAR capability.[101] The AF could participate in FVL, however, holding out for the "ideal" solution of FVL in place of relevance today is a poor readiness strategy. The third assumption is that 180—210 knots is a "good" target airspeed based on the comparative mission planning data provided earlier. These three assumptions solicit a technological solution that must be cost-effective, technologically feasible, and push the rescue helicopter's speed envelope out to 180-210 knots cruise, which is about a 50-75 percent increase over the HH-60G. There may be a number of available technological solutions that could achieve this speed increase at minimized cost and in a relatively short period of, however, the author only knows of one: Vectored Thrust Ducted Propeller (VTDP) compounding.

Vectored Thrust Ducted Propeller—VTDP Compound Helicopter

In June 2007, Piasecki Aircraft Corporation (PiAC) first flew an advanced VTDP compound helicopter technology demonstrator, the X-49A Speed Hawk.[102] Since then the X-49A has flown 86.6 flight hours and 79 flight events in which it achieved 180 knots indicated air speed (KIAS) in level flight and saw on average a 50 percent reduction in vibration and fatigue loads versus a base Navy SH-60.[103] This initial X-49A Phase I configuration's envelope was limited to the baseline SH-60 NATOPS (naval air training and operating procedures standardization) limits and excluded critical drag reduction and additional power features. Nonetheless, it validated the technology's potential to improve speed by 42 percent at equivalent power/fuel flow, using just the original T700-401C engines and not a supplementary power unit. At the same time, the X-49A demonstrated reduced vibration and fatigue loads relative to the same helicopter test data before modification into VTDP compound. [104]

These initial test results indicate are a compelling potential solution to the HH-60's significant speed deficit.

To investigate this technology further, the author traveled on temporary duty orders to PiAC headquarters in Essington, Pennsylvania in December 2016 to meet with and interview company representatives. This academic investigation was to better understand and discuss the merits and feasibility of incorporating VTDP compound technology into the HH-60W. All parties understood this interview was for academic purposes only and the author did not represent the AF or US Government in any official capacity beyond that of an Air Command and Staff College student. [The PiAC information discussed herein is approved for release by PiAC.] The representatives interviewed included the President and CEO, John Piasecki, the Chief Technology Officer, Fred Piasecki, the test pilots Christopher Sullivan and Grey Hagwood, and their director of military requirements and programs, Jimmy Hayes. This interview answered several key questions that indicate the potential of this technology to provide the solution to AF rescue needs: How does a VTDP compound work? What are the operational implications? What is the cost and timeline to field this solution?

How Does a VTDP Compound Work?

To understand the benefit of a VTDP compound, it helps to establish a very basic appreciation for the limitations inherent to a conventional single-rotor helicopter like the HH-60. (this discussion is tailored to an audience unfamiliar with rotorcraft operations). The main rotor system must provide the lift to keep the aircraft aloft in both a hover and in forward flight. To achieve forward flight from a hover the rotor disc must be tilted forward (this is a simplification) to translate some of its vertical lift component to horizontal lift, or thrust. This requires the main rotor system, and then the main rotor transmission mounting structure of the aircraft, to support the weight of the aircraft.

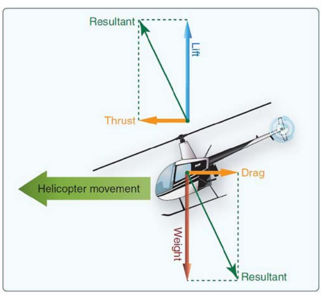


Figure 13: Conventional Helicopter Lift and Thrust[105]

Originally designed in the early 1970s, the UH-60A Black Hawk was designed with a load factor of 3.5g utilizing a design mission weight of 16,825lb.[106] This means the structural design rotor thrust limit is 58,888lb.[107] Therefore, the HH-60 rotor system's 58,888lb thrust limit—conventionally applied through the main transmission mounting structure—constitutes an important limitation.

On US-manufactured helicopters the rotor blades spin counterclockwise when viewed from above. As an "equal and opposite reaction" the airframe wants to spin right with a nose left-to-right movement. The tail rotor provides yaw control to the helicopter by providing the anti-torque necessary to counteract this yawing tendency induced by rotation of the main rotor blades. The tail rotor driveshaft is driven by the main transmission, which itself is driven by the aircraft's main engines. This tail rotor driveshaft routes through two gearboxes where the rotational speed is increased and direction changed, such that the tail rotor spins at a proportionally higher rotational speed than the main rotor and approximately 90 degrees out of plane to it. The main engines of the helicopter have finite power output, so the more anti-torque demanded from the tail rotor, the less power is available to drive the main rotor system. The tail rotor is an important compromise in a single-rotor helicopter. Unfortunately, the power to drive the tail rotor only keeps the nose straight, it does not really help a helicopter fly faster.

Retreating blade stall is a major barrier to increasing the speed envelope on a conventional helicopter. Airframe drag reduction is important to improving helicopter speed, however, following these efforts, the problem of retreating blade stall remains. The Federal Aviation Administration (FAA)'s *Helicopter Flying Handbook* offers a good explanation of retreating blade stall:

> In forward flight, the relative airflow through the main rotor disk is different on the advancing and retreating side. The relative airflow over the advancing side is higher due to the forward speed of the helicopter, while the relative airflow on the retreating side is lower. This dissymmetry of lift increases as forward speed increases. To generate the same amount of lift across the rotor disk, the advancing blade flaps up while the retreating blade flaps down. This causes the AOA [angle of attack] to decrease on the advancing blade, which reduces lift, and increase on the retreating blade, which increases lift. At some point as the forward speed increases, the low blade speed on the retreating blade and its high AOA cause a stall and loss of lift . . . High weight, low rotor rpm, high density altitude, turbulence and/or steep, abrupt turns are all conducive to retreating blade stall at high forward airspeeds. As altitude is increased, higher blade angles are required to maintain lift at a given airspeed.[108]

Although the HH-60 has a structural design rotor thrust limit of 58,888lb, it is unable to make full use of this given other aerodynamic and power limits. The maximum allowable gross weight of the HH-60 is 22,000lb, which gives it a “g” limit of 2.67 when operated at this weight. However, due to the phenomenon of retreating blade stall it is *very* rare an HH-60G can even fly a level 2-g turn at 60o angle of bank in typical operating conditions given aerodynamic and power limits, notwithstanding its excess structural capacity.[109] The implications of this, in concert with the detrimental power demands of the tail rotor, present opportunities to expand the flight envelope of the HH-60. The HH-60 / VTDP compound can pull more “g” before encountering blade stall by holding the load on the main rotor system constant and augmenting the load factor capability with lifting wings and a thrusting tail. This assumes the design rotor thrust limit remains unchanged. This increases tactical maneuverability without exceeding structural limits. Conversely, the wings reduce main rotor load which will reduce vibration and fatigue as well as the amount of power required for anti-torque. Put simply, VTDP compound expands the achievable gross weight and speed envelope of the helicopter within existing structural limits, thereby increasing the combat and cost effectiveness of the aircraft.[110]

PiAC’s initial X-49A tests provided flight validation of their VTDP compounding solution. Their tests proved the viability of increasing a helicopter’s speed envelope in the face of the inherent limitations of a conventional single-rotor helicopter. In broad terms, PiAC achieved this by reducing the loads on the main rotor and delaying retreating blade stall by adding fixed lifting wings and using the VTDP for both anti-torque and thrust. In this early test configuration, the US Navy limited the X-49A to the 180 KIAS operating limit specified in the SH-60F NATOPS, a target it achieved in level flight.[111] This first configuration enabled the X-49A to take off and land vertically while achieving higher forward airspeeds than is achievable with a conventional helicopter design.

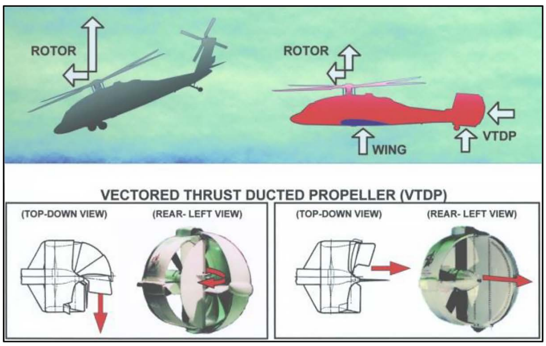


Figure 14: Piasecki Vectored Thrust Ducted Propeller (VTDP)[112]

Figure 15: X-49A Speed Hawk In-Flight[113]

The successful flight testing of the X-49A Speed Hawk demonstrates the viability of this technology, which in the estimation of Piasecki is at a technology readiness level of seven (TRL-7).[114] This means a system has been demonstrated in an operational environment, such as a flight test of prototype technology.[115] [For reference, the highest technology readiness level is TRL-9, or operational deployment.][116]

The mission benefit of this Speed Hawk modification to the HH-60 is significant, with little apparent loss to mission capability. It is important to note the X-49A was a test bed, the real benefit of the Speed Hawk component upgrade lies in the operational configuration PiAC offered during the December 2016 interview and depicted in Figure 16.

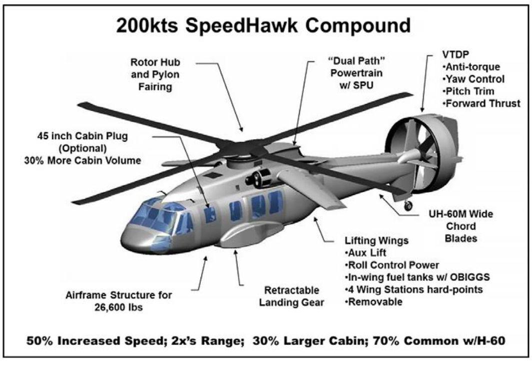


Figure 16: 200kts Operational Speed Hawk Configuration[117]

The operational Speed Hawk components and modifications will add approximately 8–10 percent to the weight empty of the baseline HH-60.[118] However, the net effect, in terms of speed and hover performance is positive.

The Speed Hawk will replace the existing HH-60 auxiliary power unit (APU)—used only for pneumatic power and electric generation—with a supplementary power unit (SPU) that will perform the functions of an APU while also tying into the drive system to contribute an additional 650 shaft horsepower (shp).[119] Adding the SPU-provided power after the main transmission allows the added 650 shp to directly supply the VTDP. This will permit the full power rating of the two main engines to be devoted to the main rotor for lift.[120] This additional power from the SPU and "Dual Path" powertrain allows for a 20 percent increase in hover gross weight to as high as 26,600 pounds.[121] This more than compensates for the added empty weight of the components and provides increased hover useful load at all temperatures and altitudes.

The fixed lifting wings—mounted outboard of the main engines—and the auxiliary thrust from the VTDP increases the speed and efficiency of the aircraft at high gross weight. This assists in greater long-range mission utilization. The high mounted lifting wing permits movement in/out of the cargo door, retains useful fields of fire from crew-served weapons, provides hard mounts for external stores, adds in-wing fuel storage, and relieves over 50 percent of the lifting loads from the main rotor at cruise. Additionally, the flaperons in the fixed-wings provide for redundant roll control and main rotor load alleviation for helicopter maneuvering in forward flight.[122] The allowable maximum gross weight of the Speed Hawk can therefore be increased because the loads on the main rotor system at cruise speed are markedly reduced. For example, if the Speed Hawk is cruising at 25,000 pounds, and the rotor/wing loading ratio is 60 percent/40 percent, the main rotor is only carrying 15,000 pounds. This means, at cruise, even though the Speed Hawk is flying at weights well above the current HH-60G limit of 22,000-pound limit, the rotor is operating below its original 16,825 design gross weight limits. The main rotor achieves peak efficacy and maximum component life at or below 16,825 pounds.[123] As the aircraft slows, the lifting wings become less effective and the main rotor system must support lifting loads as if it were a conventional helicopter. In terms of g-limits, this is not really a problem. Even when the gross weight of the Speed Hawk is increased up to 26,600 pounds, it will still have a 2.2g allowance which is more than the current HH-60G can even sustain at cruise, much less at lower energy states and low speed. An instantaneous g-load could exceed this limit, however, this is true for large portions of the flight profile. As a point of technical comparison, the US Army ADS-29 Structural Design Criteria for rotary-wing aircraft. Rotary-Wing Aircraft allows operation of utility rotorcraft at up to a maximum 2.0g of gross weight for ferry missions; which for the H-60 is a 29,443 pounds limit.[124]

The interference of the lifting wings with the main rotor downwash is of concern when it comes to hover performance. The downwash will create downforce on the wings, making the rotor less efficient and effectively increasing the hovering-weight of the aircraft. This interference is partly negated by the automatic movement of the wing's flaperons to the full trailing-edge down position to streamline with the downwash.[125] The rear stabilator on the current HH-60 does the same thing in a hover.[126] The addition of the SPU also helps compensate for this wing interference in a hover. On the current HH-60, available aircraft power is split between the main rotor system and tail rotor. The Speed Hawk's SPU will essentially enable all the main engines' power to be used for the main rotor system while the SPU powers the VTDP. A general comparison of power-to-weight ratios in Table 8 shows the HH-60 VTDP is on parity with the current and planned HH-60G/W. The US Army's Improved Turbine Engine Program (ITEP) will provide future hover improvement. ITEP will replace the power plants in the Black Hawk and Apache helicopters and should increase power output relative to the General Electric (GE) T700 turbines by 50 percent, while reducing specific fuel consumption by 25 percent. The ITEP power plant in required to be a form-fit replacement for the GE T700 (PiAC estimates the net result of the ITEP's reduced specific fuel consumption will be about 10percent fuel savings over the current configuration).[127] Sikorsky is monitoring the fielding timeline of ITEP for inclusion into later production of the HH-60W, so inclusion of ITEP into the Speed Hawk upgrade is a realistic growth-path for achieving even greater speed and high/hot hover performance.[128] However, even absent ITEP, the Speed Hawk should offer as-good or better hover performance than the HH-60W—owing to the SPU and dual path drive train making greater power available to the main rotor—and a cruise speed around 200 knots with a dash speed of 210 knots.[129]

Table 8: Power-to-Weight Ratios at Maximum Gross Weight[130]

	HH-60G GE T700-701C	**HH-60W GE T700-701D**	**HH-60 VTDP GE T700-701D + SPU**	**HH-60 VTDP ITEP + SPU**
Maximum Gross Weight	22,000 pounds	22,500 pounds	26,600 pounds	26,600 pounds
10-min Engine Power / Total Power	1,890 shp / 3,780 shp	1,994 shp / 3,988 shp	1,994 shp / 4,638 shp	2,991 shp / 6,632 shp
Power-Weight Ratios (shaft horespower (shp) : pounds)	1 : 5.82	1 : 5.64	1 : 5.73	1 : 4.01

What are the Operational Implications?

Aside from expanding the speed envelope, increasing tactical maneuverability, and maintaining or improving hover performance, the Speed Hawk upgrade will provide other important benefits to the CSAR mission. The range of an HH-60 VTDP is likely to double, given greater aerodynamic efficiency, incorporation of fuel storage in the lifting wings, and ability to aerial refuel to much higher gross weights. An onboard inert gas generating system (OBIGGS) will backfill the empty volume of the aircraft fuel tanks to reduce susceptibility to spark-ignition from battle damage. The US Marine Corps' UH-1Y and AH-1Z helicopters utilize a similar OBIGGS system for the same reason.[131] The addition of the VTDP components will move the aircraft center-of-gravity aft relative to the HH-60G/W. The Speed Hawk upgrade will include a 45-inch cabin extension, or "plug," aft of the cockpit and forward of the current cargo compartment to counterbalance the new tail components.[132] This cabin plug will increase the cargo volume by 30 percent, which is significant for an aircraft tasked with combat rescue and other humanitarian missions. The testing on the X-49A also indicates a VTDP upgrade will lend itself to significant vibration reductions, perhaps up to 50 percent.[133] If the operational variant of the Speed Hawk achieves anything approaching this reduction in vibratory loads, the reduction in dynamic component wear, and corresponding reduction in maintenance costs, could be substantial.

Pertinent to earlier discussion of survivability, the Speed Hawk upgrade will provide two hard points on each wing to mount armament, such as laser-guided rockets or small-yield precision guided missiles while retaining side-firing crew-served weapons. [134] The high speed of an HH-60 VTDP will preclude permanent mounting of crew-served weapons on the exterior of the aircraft. During enroute cruise flight the crewed guns will need to be retracted inside the cabin using a mechanism similar to that in Figure 17.[135] As the HH-60 VTDP slows for landing or hoist operations, the aerial gunner would extend the side-firing gun to provide reactive point defense of the aircraft and pararescuemen. An HH-60 Speed Hawk retains all the survivability characteristics identified from analysis of CSAR helicopter losses in SEA:

- The Speed Hawk will support a sensor turret and will carry improved armament to engage targets from tactical stand-off.
- Similar to the conventional HH-60, the Speed Hawk variant will exhibit less disruptive downwash and achieve lower hover heights with better obstacle clearance relative to other potential rescue vehicles like a V-22 or CH-53. These characteristics are vital to survivability in the objective area.

Lower hovers reduce aircraft silhouetting and reduce exposure time to potential enemy action. Faster hover operations make best use of the loiter time from supporting CSARTF assets.

- In addition, unlike a V-22, the Speed Hawk has crew-served side-firing weapons for accurate and responsive threat suppression when the aircraft is most vulnerable, during low and slow operations in the objective area.

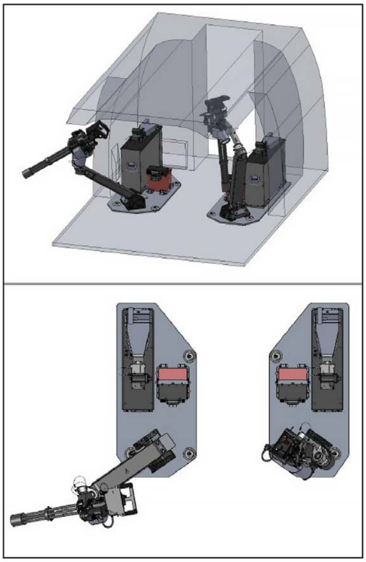


Figure 17: Dillon Aero Retractable Cabin Gun Mount[136]

In summary, the Speed Hawk—or some other technological solution similar to it—solves significant operational challenges for the AF's CSAR mission. It provides the speed necessary to operate within the current constraints of supporting fighter assets. Survivability is markedly advanced by incorporating key situational awareness and armament systems in addition to improved tactical maneuverability and reduced exposure time inside the WEZ of enemy threat systems. These mission benefits incur little mission penalty, if any. The additional monetary cost to restore lost relevance to the CSAR helicopter fleet is relatively low, somewhere on the order of $957 million above the current cost for 112 HH-60Ws.

What is the Cost and Timeline to Field this Solution?

During the PiAC interview a cost estimate was offered to help scope academic discussion of a Speed Hawk upgrade program. If the Speed Hawk upgrade is "cut in" to the production line of the new HH-60W, the estimated cost increase is 10 percent of the "base" price of the new HH-60W.[137] If the upgrade is conducted post-production at depot, the cost increase is roughly 50 percent the base price of a new HH-60W.[138] Applying these estimates requires a discussion of the "base" price of the HH-60W.

The new HH-60W has a program acquisition unit cost (PAUC) of $73.13 million in base year (BY) 2014 dollars.[139] PAUC is the cost of the acquisition program divided by the program's acquisition quantity.[140] The CRH program cost is $8.19 billion, divided by the planned quantity of 112 HH-60W, gives a PAUC of $73.13 million. In fairness, the CRH program is unique in that the prime contractor, Sikorsky, is also responsible for providing aircrew training devices and extended maintenance support not normally embedded in an aircraft acquisition program.[141] Contracting with the prime to provide these extras may provide benefit to the end-user, however, they do artificially inflate the PAUC. A better basis for Speed Hawk estimation is the flyaway cost, which is the "cost related to the production of a usable end item of military hardware. [it] Includes the cost of creating the basic unit (airframe, hull, chassis, etc.), an allowance for changes, propulsion equipment, electronics, armament, other installed Government-Furnished Equipment, and nonrecurring start-up production costs."[142] The flyaway cost of the HH-60W is $40.6 million [for comparison, the flyaway cost of the MH-60R is BY06 $30.9 million, new build AH-64Es are BY10 $36.68 million, and a basic V-22 is BY05 $68.77 million].[143] Interestingly, the HH-60W is 85percent common to the UH-60M, which has a flyaway cost of only BY14 $22.00 million (UH-60M cost adjusted for inflation to a BY14 value).[144] As the author understands it, the HH-60W shares most of its major structural, flight control, and dynamic components with the UH-60M. There are expensive and substantial additional costs for the CSAR-specific mission equipment, avionics, and cargo compartment and fuel system which makes the flyaway cost of the HH-60W higher relative to the UH-60M. Nonetheless, the Speed Hawk will modify UH-60M-common components and it seems appropriate to use a "base" price of $22.0 million.

The next consideration for building a general cost estimate is time, or specifically, when in the HH-60W production schedule—shown in Table 9—the Speed Hawk modification could actually be "cut in." PiAC estimates 36 months, from funding to flight, for a production representative Speed Hawk.[145] They also estimate a manufacturing readiness level for their components as correspondingly high relative to their TRL, which means the industrial and manufacturing base exists to support production of these upgrade components.[146] Assuming funding became available in FY19 and it took four years to develop the production model, flight test it, and develop the kit components, production "cut in" could begin in FY23's Lot four production. It cost $40 million for PiAC to conduct the X-49A, which was 80 percent cheaper than Naval Air Systems Command (NAVAIR)'s original estimate of $200 million.[147] PiAC's estimates RDT&E (research, development, testing, and evaluation) cost of between $287 million to $424 million.[148] This range of estimates comes separate analysis by Sikorsky and Georgia Tech, which preceded the X-49 test program.[149] PiAC is now in a position to leverage existing X-49 flight test results to reduce the military flight review costs embedded within these RDT&E estimates. Ideally, this will move RDT&E to the lower end of the cost range. Nonetheless, it seems prudent to estimate overall program cost from some average of the two estimates, which is about $350 million.

Table 9: HH-60W Production Schedule[150]

	FY18–19 RDT&E	FY20 LRIP 1	FY21 LRIP 2	FY22 FRP Lot 3	FY23 FRP Lot 4	FY24 FRP Lot 5	FY25 FRP Lot 6	FY26 FRP Lot 7	FY27 FRP Lot 8
Aircraft Planned	9	8	10	14	14	14	14	14	15
Min FY Prod Cap.	0	6	6	10	10	10	10	10	10
Max FY Prod Cap.	9	10	12	19	20	20	20	20	19
Cum. Planned Prod	9	17	27	41	55	69	83	97	112
Cum. Min Qty	8	14	20	30	40	50	60	70	80
Cum. Max Qty	9	19	31	50	70	90	110	112	112

These factors give the following rough estimates for modifying all 112 HH-60Ws at a BY 2014 flyway cost of $40.6 million and an aircraft "base" cost of $22.0 million (the below production estimate includes $350 million for RDT&E):

Production cut in FY23 total: *$957.2 million;* New "Flyaway" Cost: *$49.1 million*

- 41 HH-60Ws for depot-mod at 50 percent base cost = $451 million
- 71 HH-60Ws for production line mod at 10 percent base cost = $156.2 million

As a note, this low cost—at least relative to aerospace defense contracts—probably explains why big prime defense contractors have not pushed a VTDP solution for the DOD's rotorcraft obsolescence challenges. VTDP technology is a pretty good way to improve the speed and range of existing rotary-wing fleets at fairly low cost. However, big prime defense contractors are optimized for larger programs and are not well suited for smaller upgrade programs to existing aircraft. Pursuing a more cost-effective and quicker upgrade program fits the AF's pressing requirement to increase the speed and cost effectiveness of its small rescue helicopter fleet in time for the next major war.

Importantly, the above figures are rough order of magnitude estimates to upgrade 112 HH-60Ws to Speed Hawk configuration. A significant variable is when the Speed Hawk components get introduced into the production schedule. From an acquisition perspective, there are some useful factors playing in favor of the AF that can quicken the acquisition timeline and help control cost—should the service decide to pursue the VTDP solution offered by PiAC. The first is that PiAC is an Small Business Innovation Research Program (SBIR) Phase-3.[151] According to the *SBIR/Small Business Technology Transfer (STTR) Reauthorization Act of 2011,* "To the greatest extent practicable, Federal agencies and Federal prime contractors shall issue Phase III awards relating to technology, including sole-source awards, to the SBIR and STTR award recipients that developed the technology."[152] In other words, the AF can sole-source contract PiAC for their intellectual property to guide another contractor's modification of the HH-60W to the Speed Hawk configuration. Provided the Speed Hawk kit satisfies due diligence review, the AF only needs to find a company or partnership to do the actual upgrade work.

Discounting the V-22 as a Dedicated CSAR Aircraft

Before moving on to a discussion of organizing and utilization, it is probably worth noting the unsuitability of the V-22 Osprey as a full-time solution for CSAR. Almost any cargo or utility-based vertical lift aircraft is potentially useful as a recovery vehicle during a PR mission. However, the only real advantage the CV-22 has over the HH-60W is speed, 240 knots versus 120 knots. In terms of all other considerations, it is inadequate. It is too big, its downwash is excessive, it does not have side-firing, crew-served guns, it is extremely expensive to operate, and does not offer stand-off weapons capability. While the Osprey's speed advantage is significant, an HH-60 modified with VTDP technology promises to be hugely cheaper to purchase and operate while mostly negating the V-22's speed margin and meeting almost all other requirements important for CSAR mission effectiveness. In comparison to an HH-60W upgraded with VTDP components, the CV-22 is a poor value. Appendix C contains a more in-depth examination of this issue.

Organizing for Relevance

Inadequacy in the AF's CSAR helicopter force, in terms of fleet size, creates significant risk across multiple domains in the event of a major war. AF doctrine holds air superiority as the guarantor of all other combat operations: "Air superiority …. ensures that the advantages of the other AF core missions, as well as the formidable capabilities of our sister services, are broadly available to combatant commanders."[153] War against a peer could see friendly air losses, from all services and allies, on a scale not seen since the Vietnam War. America's technological edge and numerical superiority has eroded, leaving the various US air arms vulnerable to aerial attrition. Preserving or achieving airpower superiority in the face of high air losses will require a robust and dependable means to recover and return skilled aviators and other isolated personnel back to the fight. The effectiveness of the other main warfighting domains, land and maritime, will suffer the consequences of aerial attrition when AF CSAR is ill-prepared. Organizing and equipping AF CSAR with the asset density necessary to prevail in a peer war is foundational to success.

The baseline survivability and speed improvements previously discussed are necessary to meet the demands of modern operating environments. This condemns the HH-60G and new HH-60W to near irrelevancy for any forthcoming major war. Unfortunately, physics provides one last barrier; despite how exquisitely capable a CSAR aircraft, it can still only be in one place at one time. This makes asset coverage density a key element to credible CSAR capability. Deploying the right number of assets for a given CSAR area provides necessary responsiveness and coverage overlap. The asset density ratios in SEA from 1968-1970—the peak of aircrew rescues in that war—along with Operations Desert Storm and Allied Force reveal an average ratio of **one dedicated rescue helicopter for every 6,107 square nautical miles of CSAR coverage area.** This ratio inherently accounts for marked differences in aircraft capabilities, such as speed and range. Its implication as a predictive planning tool are noteworthy. A conflict in Europe would probably have a rough CSAR area of 360,227 square nautical miles [this area *only* includes Estonia, Latvia, Lithuania, Romania, Slovakia, Hungary, Moldova, Bulgaria, Poland, and Iceland and its former Air Defense Identification Zone (ADIZ)][154] Using the average historical ratio predicts a need for 59 dedicated rescue helicopters. Applying the average probe-to-drogue ratio of 1.75:1 would necessitate about 17 HC-130Js to support these 59 rescue helicopters. The AF only has 97 HH-60Gs and a total planned procurement of 37 HC-130Js.[155] It only has five HH-60Gs based in Europe, and none are HC-130Js.[156] Interestingly, if the Balkan Peninsula is added to the combat area at 194,400 square nautical miles, the number of required rescue helicopters jumps to around 91 and the number of HC-130 tankers is 26.

There are only 97 HH-60G CSAR helicopters in inventory and plans to buy only 112 new HH-60W replacement helicopters.[157] It seems likely that at least 12 of these new HH-60W aircraft will go to the HH-60 training squadron and one to the HH-60 flight test squadron. This leaves approximately 99 combat-capable HH-60Ws. If the HH-60W lives up to its planned availability goal of

67.4 percent, only 67 of the 99 combat coded HH-60Ws will actually be accessible for deployment.[158] Assuming the 59-helicopter requirement for a European conflict closely approximates real-world demand, it would take a near maximum effort surge by all active and reserve component units to meet the need for just this one major theater war. Such a surge leaves CSAR capacity unavailable for conflict anywhere else; not for the Middle East, not for homeland defense, almost nothing else save a single squadron in Pacific Command. Fighting near simultaneous conflicts in the Indo-Asian theater—assuming the Pacific theater CSAR area approximates that of a European conflict—would **require a total AF inventory of roughly 200 to 212 HH-60Ws.**

Multi-Role Utilization

CSAR is essential for success in a major peer war. However, such wars have occurred with less frequency in contemporary times than lower intensity conflict and counterinsurgency (COIN). HH-60 Speed Hawks, acquired in the numbers necessary to provide relevant CSAR capability, present a unique opportunity for multi-role utilization. A 200+ aircraft fleet of HH-60 Speed Hawks should have three primary missions: CSAR, light attack, and strike control. This provides an innovative value proposition to justify the purchase of additional HH-60Ws and the cost to upgrade them with VTDP compound helicopter technology. This will likely lower the per-unit-cost of the new HH-60W aircraft while increasing utilization; improving overall value and benefit to both the combatant commander and taxpayer.

An air-refuelable Speed Hawk, equipped with four hard points and capable of 200-210 knots cruise speed, is a viable COIN aircraft. It may not entirely supplant the need for a lower cost light attack aircraft (LAA), however, it is certainly complimentary to such an effort and may reduce the total buy requirement of LAA. For those emotionally opposed to this idea of rescue crews executing CAS, consider that light attack is already an implied task during a CSAR mission. In fact, HH-60 crews must have a working knowledge of close air support procedures in order to execute casualty evacuation (CASEVAC) missions during COIN operations.[159] Bottom line, CAS and light attack are already executed by HH-60G aircrew as implied tasks during a CSAR or CASEVAC. Making light attack a primary mission, and better equipping for it, is simply a natural evolution made necessary by tighter budgets and fighter fleet reductions. Light attack is aligned with the life-saving ethos of AF CSAR, it is a life-preserving mission that helps ensure our soldiers and Marines do not require a helicopter flight to mortuary affairs.

Strike control, primarily as a FAC[A], is a natural mission overlap between major war CSAR and light attack during COIN. A properly equipped and faster HH-60 Speed Hawk is a viable RMC platform. The heuristics of RMC execution during a CSAR are very similar to those of a FAC[A]. An RMC's responsibility to integrate fires in support of a ground element—the survivor –while providing aircraft deconfliction is cognitively synonymous with the mental and procedural discipline of a FAC[A]. FAC[A]s are particularly useful in some hybrid combat environments where operational necessity dictates the provision of CAS for friendly indigenous ground combatants, however, there is little political appetite for putting US "boots on the ground" to coordinate the CAS. A rotary-wing FAC[A] is well suited to this.

Task Organizing

For the AF HH-60G community, a deployable Unit Type Code (UTC) is normally three helicopters and accompanying personnel. This is generally referred to as "3 to make 2" within the community. The idea is that due to maintenance variability, it generally requires three helicopters to produce two mission capable. A two aircraft formation is currently the standard for HH-60 combat operations, whether performing CSAR or an Army mission like CASEVAC or MEDEVAC. UTC flexibility is central to effectively utilizing the multi-mission capability inherent in a restored CSAR helicopter force. Below are suggested HH-60 UTCs, these enable flexible asset employment:

1. Basic UTC—3 aircraft ("3 to make 2")
    - Theater Employment Concept: This mimics the current standard HH-60 UTC for CSAR. CFACC strike control and CASEVAC/MEDEVAC in support of the Army are likely incompatible. E.g., the air tasking order (ATO) could task an HH-60G formation to provide strike control of theater air assets for a specific deliberate ground operation or CASEVAC coverage, however, not both. CSAR alert can be maintained during the execution of CASEVAC or strike control tasks; CSAR's higher priority can always drive a re-role, much like A-10s can be re-rolled from executing CAS support to providing CSAR support.
2. Enhanced UTC—Four aircraft Four to make three for surge; or four to make two for sustained ops)
    - Theater Employment Concept: *retains capability of Basic UTC*, with addition of CSAR surge capacity to provide self-escort organic to a three-ship HH-60 formation. Additionally, a 3-ship of

HH-60s can be tasked for strike control *and* CASEVAC support to a specified ground deliberate operation.

- *CSAR alert*—(surge) 3-ship HH-60 formation required for self-escort due to overall threat level and limited access to traditional fixed-wing rescue escort.
- *Strike Control*—(surge) 3-ship HH-60 formation; can probably surge to provide 6-7 hours of continuous strike control per ATO day followed by two ATO days of two-ship operations. Requires two FAC[A]s per 12-hour period, or four total to enable surge capability at any point during an ATO day. Requires HC/MC/KC-130 tanker support for in-flight refueling.

3. Theater Support UTC—6 aircraft UTC
    - Theater Employment Concept: This UTC provides the combatant commander the most options. The six aircraft can be divided between two forward operating locations (FOLs) to provide wider CSAR/CASEVAC/strike control coverage with limited surge capacity (essentially two Basic UTCs), or consolidated at one FOL to provide greatest employment flexibility. The Theater Support UTC enables the full range of HH-60 operations. Theater CSAR coverage can be maintained by one Basic UTC while the other three aircraft can be tasked for all operations.

The standard squadron size, based on these proposed UTC constructs, should be 12 aircraft. A 12-aircraft squadron has roughly two Theater Support UTCs. Presuming there are some aircraft in varying levels of maintenance availability, a 12-aircraft squadron will likely still produce a 6-ship Theater Support UTC and a Basic UTC. Acquiring 212 HH-60 Speed Hawks enables a 'right-sizing' of most squadrons to 12 aircraft plus the addition of four new squadrons.

The fielding proposal in Table 10 recommends Pacific AFs (PACAF) and United States AFs in Europe (USAFE) each receive an additional "super squadron" of 18 aircraft. 18 aircraft will allow six-helicopter detachments for South Korea and Iceland. (Iceland is strategically vital to maintaining logistic lines of communication to Europe and control of the North Atlantic). These two super squadrons, along with the two existing overseas units, will house roughly half of the required number of CSAR helicopters needed for a major theater war. This will reduce the logistics burden of moving additional CSAR assets into theater for a major theater war and provide operational flexibility to the respective air component commanders.

The Air National Guard will effectively gain two operational squadrons; New Mexico currently does not have assigned aircraft (excepting an RC-26) and another state will get a squadron. The Air Force Reserve Command (AFRC) will gain one squadron. Hill Air Force Base (AFB) seems a logical location, it is close to extensive range facilities and will be co-located with F-35s, providing unique training opportunities. Additionally, the Air Force lacks an AFRC or Air National Guard (ANG) unit in the Mountain West. This is an appealing location for many, and would help capture aircrew that separate early from active duty. Retaining talent in the Total Force is an obvious way to bolster the available pool of skilled combat aviators necessary for CSAR and other missions like light attack and strike control. Furthermore, offering up additional rescue-capable assets within the United States is a smart political move. What state congressional representatives would not want the jobs and inherent disaster response capability that comes from a new Rescue unit?

Table 10: Proposed HH-60 Speed Hawk Fielding Plan—212 Aircraft Fleet

SQUADRON / LOCATION	ACTIVE DUTY	AIR RESERVE	AIR GUARD	Total
*188th Rescue Squadron (RQS)—(New Mexico ANG—currently does not have HH-60 a/c, lost F-16s)	0	0	12	12
41st RQS—Moody AFB, GA	12	0	0	12
55th RQS—Davis-Monthan AFB, AZ	12	0	0	12
66th RQS—Nellis AFB, NV	12	0	0	12
*34th WPS—Nellis (Weapons School training squadron)	5	0	0	5
*88th TES—Nellis (Flight test squadron)	2	0	0	2
305th RQS—Davis-Monthan AFB, AZ (AF Reserve)	0	12	0	12
56th RQS—USAFE	12	0	0	12
33rd RQS—PACAF	12	0	0	12
129th RQS—Moffett Field, CA (CA ANG)	0	0	12	12
101st RQS—Long Island, NY (NY ANG)	0	0	12	12
210th RQS—JBER, Anchorage, AK (AK ANG)	0	0	12	12
301st RQS—Patrick AFB, FL (AF Reserve)	0	12	0	12
*ANG AFR Command Test Center (AATC)—Tucson, AZ	0	1	0	1
*512th RQS—Kirtland AFB, NM (training squadron)	12	0	0	12
New USAFE (recommend UK or Germany with 6-ship Det in Iceland)	18	0	0	18
New PACAF (recommend Darwin, AUS with 6-ship Det in Korea)	18	0	0	18
New Air Reserve Component (ARC) (recommend Hill AFB, next to Utah Test and Training Range (UTTR) and F-35s)	0	12	0	12
New ANG	0	0	12	12
Total	115	37	60	**212**

(*)—Existing, not-normally-deployable Rescue unit

Thoughts on Personnel Growth and Training

A thorough analysis and discussion of the best way to increase the number of CSAR aircrew in a manner that preserves and grows expertise is beyond the scope of this paper. Nonetheless, here are some opinions informed by the author's experience that should spur debate, discussion, and more productive analysis.

Growing the Community

The AF should limit interservice transfers into the rotary-wing CSAR community to US Marine Corps AH/UH-1, US Army AH-64, and fighter pilots from any branch. A USAF HH-60 is a relatively easy aircraft to fly, however, very difficult to tactically employ in a larger airpower construct. Pilots from these specified platforms—in the author's assessment— "get" airpower employment in a way that will advance the CSAR community and align it with the larger AF's culture and tradition of aviation excellence.

Additionally, the USAF should consider replacing the HH-60 copilot with a Weapons System Officer (WSO) for some higher end missions. In practice, a pilot and copilot would still fly an HH-60 crew designated as the "pick-up aircraft." However, for more cognitively demanding missions such as RMC or strike control, it would make sense to put a WSO in the cockpit instead of a young copilot. This probably means about one-third of the rated officers in an HH-60 squadron would be WSOs. The HH-60 community uses new copilots much like WSOs already. For those concerned with survivability, the author is confident a WSO can be taught basic maneuvers to a proficiency level that would allow them to take over for a wounded pilot and safely land the helicopter. A beta test is probably required to validate or discount this idea.

Lastly, the Air Force should encourage personnel management policies that allows aviators—officer and enlisted—to retire from active duty and then continue serving in an ANG or AFRC unit. If this conflicts with current organizational norms, creating "rank-heavy" units, perhaps the answer is to allow these "retired" officers to continue collecting retirement pay, but de-frock them back to Captain and pay them at that rate for their additional service in the ANG or AFRC. That is not a bad deal for the individual officer or the AF.

Training and Readiness

The AF should tie unit readiness to aircrew qualifications. This works best when unit-size and upgrade syllabi are standardized. For example, an X-aircraft helicopter squadron might be considered fully combat-capable if they had four RMCs, six FAC[A]s, 10 Flight Leads, and 14 mission-qualified aircraft commanders. By standardizing these in-unit upgrade mission qualification syllabi across HH-60 force a squadron operations officer could structure a flying hour program (FHP) based on sortie requirements (i.e., range time, ordnance, flying hours, etc.). Continuation training would constitute the remaining percentage of the FHP. This methodology is analogous to the Sortie Based Training Plan produced in a United States Marine Corps (USMC) flying unit. The AF HH-60 community recently fielded a common upgrade syllabus for its pilots that trains them up through flight lead. This community-wide HH-60 pilot training plan contains standardized in-unit syllabi intentionally crafted with a building-block architecture to allow later additions for FAC[A] and RMC training blocks.[160] Transitioning the HH-60 community to sortie based training is the evolution originally envisioned the HH-60 pilot training plan's authors.[161]

The Four-Phase Proposal

This paper's previous analysis and discussion prompts a general proposal for achieving the change necessary to restore viability to AF PR capability and capacity. Figure 18 offers a Four-Phase Proposal to do just this. Few things worth having are purchased without cost. Fielding a relevant and necessary CSAR capability is not an exception. Implementing all portions of this four-phase program will cost approximately $5,500 million above the current CRH program cost (cost by phase is broken out below).

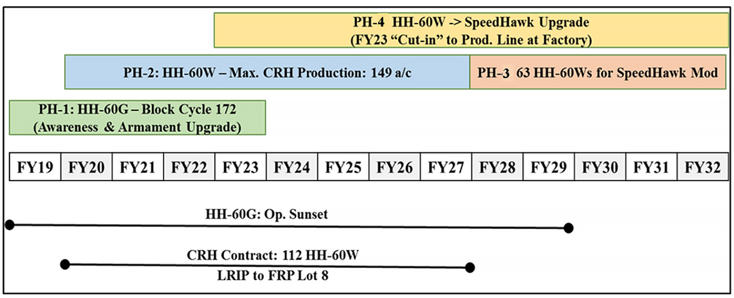


Figure 18: Four-Phase Plan to Revitalize Rescue

However, amortized over 14 years, from FY19–FY31, the additional cost is less than FY14 $400 million per year. This expense is not inconsequential, however, it is an excellent value for the capability it provides. There will be some monetary personnel costs to increase the size of this CSAR community. The author cannot offer an informed estimate for this cost.

Phase-1: HH-60G Block Cycle 172 Upgrade

Cost: $65 million +

- Upgrade ~65 HH-60Gs with an advanced targeting sensor and improved armament.
  - The ANG and AFRC units will operate them longest. ~ 65 upgraded aircraft will cover these ARC units, Test, the Weapons School, and two active duty overseas units.
- 65 EO/IR sensors at approximately $1,000,000/unit plus = $65 million
- 65 Rocket/Missile Rail kits for existing HH-60G EGMS = $ unknown
  - The existing EGMS on the HH-60G is designed to accommodate the structural brackets and BRUs for a rocket pod or missile rail on each side of the fuselage. Costs will include these brackets, standard helicopter BRUs, and cost to design, build, and install the weapons control wiring harness.

Phase-2: Max HH-60W Production Capacity—Total 149 HH-60Ws

Cost: $1,502.2 million

- Current contract is 112 HH-60Ws at ~ $8,190 million. Sikorsky can produce 149 HH-60Ws by the end of FY27
- 37 HH-60Ws at $40.6 million/unit flyaway cost = $1,502.2 million

Phase-3: Purchase 63 HH-60W—Total 212 HH-60Ws

Cost: $2,558 million

- 63 HH-60Ws at $40.6 million/unit flyaway cost = $2,557.8 million

Phase-4: HH-60W to Speed Hawk Upgrade—212 Speed Hawks

Cost: $1,177 million

- Speed Hawk components are "cut in," on HH-60W production line starting in FY23
- RDT&E of production Speed Hawk components = $350 million
- 41 HH-60Ws, upgraded in depot at 50percent base cost = $451million
- 71 HH-60Ws, upgraded on production line at 10percent base cost = $156.2 million
- 37 HH-60Ws, from Phase 2, upgraded on line at 10percent base cost = $81.4 million
- 63 HH-60Ws from Phase 3, upgraded on line at 10percent cost = $138.6 million

This phased plan to acquire relevant CSAR capability and capacity accomplishes several key ends. It right-sizes the CSAR helicopter inventory to support two major regional conflicts based on historic asset-ratio densities. The portion of the HH-60G fleet that will remain in service the longest will undergo a block cycle upgrade to improve survivability while new rescue aircraft are fielded. Most importantly, the plan provides a path to a revitalized and relevant CSAR capability through the conversion of 212 HH-60Ws to the 200 knot Speed Hawk configuration. By design, the Speed Hawk components will inherently support improved sensor and armament capability while retaining the mission benefits of a helicopter in the most dangerous portion of a CSAR mission profile: the objective area.

The current CRH program will field only 112 slow and poorly armed HH-60Ws for $8,190 million. For 70 percent more the AF will receive 212 Speed Hawks with the asset depth and capability to more capably operate in a major war. These assets can also perform other airpower roles like light attack and strike control, providing operational flexibility and value that 112 un-modified HH-60Ws could never match.

Closing Thoughts

Analysis of CSAR during the Vietnam War poignantly highlights the HH-60G's survivability shortcomings in terms of situational awareness and armament. The aircraft and crews cannot conduct combat identification of the objective area, and precisely engage threats to the survivor and helicopter, from a tactically viable stand-off distance. Relying solely on crew-served machine guns and doctrinal CSARTF constructs to compensate for these deficiencies ignores still relevant lessons from SEA and the reality of reduced AF fighter inventories. Furthermore, the slow speed of a conventional helicopter demands a high number of supporting fighter aircraft to provide continuous escort coverage of poorly armed HH-60s while also holding open a prolonged window of opportunity in which to execute a CSAR. Lastly, in the event of a major theater war (the reason CSAR exists) there are far too few CSAR helicopters to meet historic asset density ratios used in Vietnam, Desert Storm, and Allied Force. In summary, the HH-60G fleet is too slow, inadequately armed, and too few in number to fulfill its PR mission in a major peer war.

Sadly, the planned fleet of 112 new CRHs will do little to restore relevant capability or capacity. While the HH-60W should receive important avionics improvements, it will perpetuate existing operational shortfalls. Upgrading the new HH-60Ws with VTDP compound helicopter technology is a cost-effective path to expand the speed envelope of the rescue helicopter.

This technology can push the HH-60 to 200-210 knots cruise at roughly half the cost of CV-22s while still incorporating important objective area survivability requirements unique to CSAR operations.

Failure to ready the CSAR force for a major war invites great strategic risk. Every entity, organic or organizational, has some level of loss tolerance. Business entities can only lose so much money before they become insolvent. The body can only withstand so much blood loss before it dies. In this same way, nations, and the militaries that defend them, have some inherent level of loss tolerance. At its heart, this is what major war is all about; getting the enemy to reach their loss tolerance before you do, and in so doing, convincing them that capitulating to your will is in their best interest. All warfare, in some way, is attributional. Air warfare against a peer enemy is not any different.

The build-time for a well-trained combat pilot is years. The build-time for aircraft is months. From a peer enemy's perspective, any induced pilot shortfall is advantageous. For them, the war planning aim becomes one of aircrew attrition; crafting ways and means by which to inhibit America's ability to keep its cockpits manned with well-trained warriors. Freedom's enemies are not fools. They remember and understand, perhaps better than short-memoried Americans, the devastating impact pilot attrition played in the decline of the German Luftwaffe during World War II. Viable and effective CSAR is more than just moral obligation, it is strategic necessity. Implementing something akin to the proposed four-phase plan to revitalize CSAR is a relatively fast cost-effective way to restore promise to the AF's sacred assurance that it will not leave its warriors behind.

"These things we do, THAT OTHERS MAY LIVE."[162]

Notes

(All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.)

1. Ramon, AF Pararescuemen: 'So Others May Live.'
2. Joint Publication 3–09, II–18.
3. Joint Publication 3–50, 114.
4. US Army Field Manual 4–02.2, 1–7.
5. Joint Publication 3–09.3., 12.
6. Air Force Doctrine Document 3–50, 11.
7. US Army Field Manual 4–02.2, 1–6.
8. Joint Publication 3–50, ix.
9. Joint Publication 3–50, 113.

10. Ecclesiastes 1:9.

11. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 31.

12. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 31.

13. Granville. *Summary of USAF Losses in SEA*, 9.

14. Granville, *Summary of USAF Losses in SEA,* 9.

15. Granville, *Summary of USAF Losses in SEA,* 10.

16. Granville, *Summary of USAF Losses in SEA,* 24.

17. Granville, *Summary of USAF Losses in SEA,* 24.

18. Granville, *Summary of USAF Losses in SEA,* 57.

19. Granville, *Summary of USAF Losses in SEA,* 24.

20. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 16.

21. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 65.

22. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 65.

23. Tiliford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975*, 65.

24. Author's experience and knowledge as an HH–60G Weapons Officer.

25. "Jolly Green Giant" refueling from HC–130 "King," escorted by four A–1 "Sandys" somewhere in Southeast Asia. Photo courtesy of the National Museum of the Air Force.

26. Granville, *Summary of USAF Losses in SEA,* 57.

27. Granville, *Summary of USAF Losses in SEA,* 57.

28. Image taken from Granville. *Summary of USAF Losses in SEA,* 57.

29. Granville, *Summary of USAF Losses in SEA.*

30. Granville, *Summary of USAF Losses in SEA,* 98.

31. Overton, *USAF SAR November 1967–June 1969*, 3.

32. Overton, *USAF SAR November 1967–June 1969*.

33. Durkee, *USAF Search and Rescue: July 1966–November 1967,* 1.

34. The total geographic surface areas, water and land, of Laos, Vietnam, Cambodia, and Thailand as derived from the CIA's online *World Factbook*.

35. *Command Performance: 1 Jul–30 Sep 1969*, 14.

36. Drew, *USAF to Begin Converting L–model Back Hawks into HH–60Gs.*

37. The previous list of Rescue helicopters in SEA tallied nine HH–53s. The discrepancy is likely because this data was taken from ARRS inventories from July–September 1969 and during this time frame the USAF was acquiring additional HH–53s and shipping them to SEA. Data is drawn from an internal MAC staff report, *Command Performance: 1 Jul–30 Sep 1969*, 14–30.

38. *Command Performance: 1 Jul–30 Sep 1969*, 14–30.

39. Whitcomb, *Combat Search and Rescue in Desert Storm*, 47–8.

40. The story of Capt Speicher is widely available from multiple sources, and Whitcomb, *Combat Search and Rescue in Desert Storm*, 259, 272.

41. Whitcomb, *Combat Search and Rescue in Desert Storm*, 259, 272.

42. Whitcomb, *Combat Search and Rescue in Desert Storm*, 259, 272.

43. Whitcomb, *Combat Search and Rescue in Desert Storm*, 272.

44. Whitcomb, *Combat Search and Rescue in Desert Storm*, 75.

45. Whitcomb, *Combat Search and Rescue in Desert Storm*, 52, 64, 75, 85.

46. The total geographic surface areas, water and land, of Iraq and Kuwait as derived from the CIA's online *World Factbook*.

47. Whitcomb. *On a Steel Horse I Ride: The History of the MH–53 Pave Low in War and Peace*, 448–60.

48. Whitcomb. *On a Steel Horse I Ride: The History of the MH–53 Pave Low in War and Peace*, 446–7 and *Operation Allied Force–Order of Battle–June 1999*.

49. The total geographic surface areas, water and land, of Serbia, Kosovo, and Montenegro derived from the CIA's online *World Factbook*.

50. The author used Google Earth to create this image at a ratio of 1.75:1. Enthusiasm for this ratio must be tempered in light of the smaller data sets that generated it, although it seems reasonable that an acceptable number of HC/KC/MC–130 tankers available for rescue helicopter refueling during a major war is probably somewhere between the 1.32:1 and 2.17:1 ratio. A probe–to–drogue ratio of 1.75:1 seems a good planning assumption.

51. Reference the table of information on rescue helicopter losses in SEA in Appendix A. This data was compiled from numerous sources, detailed within the table itself.

52. McLeaish and Silves, *Southeast Asia Operational Analysis of Required Performance Parameters for a Combat Aircrew Recovery Aircraft,* 9.

53. Granville, *Summary of USAF Losses in SEA,* 37–8, 45–8.

54. Credit for this poetic description of air combat maneuvering goes to Lt Col Adam Rudolphi, USAF, as declared during the Air Force HH–60G Weapons Instructor Course 14A.

55. The raw data and its primary sources are in the data table found in Appendix A.

56. The absence of losses due to SA–2 systems indicates little in terms of the danger of SAMs to the current CSAR helicopter. The early SA–2s had a rough minimum engagement altitude of 1,500 feet above ground level; well above the normal low–level flight profile of a helicopter trying to avoid radar detection. The advent of modern mobile tactical SAM systems does pose a significant threat to the CSARTF and rescue helicopters. Addressing this threat is absolutely necessary, but beyond the classification level of this paper. The raw data and its primary sources are in the data table found in Appendix A.

57. Granville, *Summary of USAF Losses in SEA*, 53.

58. Guardia, *Self–Propelled Anti–Aircraft Guns of the Soviet Union*, 20, and Nardulli et al., *Disjointed War: Military Operations in Kosovo, 1999*, 28–9.

59. Bolkom, *Homeland Security: Protecting Airliners from Terrorist Missiles*, 1.

60. Tilford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975,* 82.

61. Tilford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975,* 82.

62. Tilford, *The United States Air Force; Search and Rescue in Southeast Asia, 1961–1975,* 82.

63. Francis and Nelson, *Search and Rescue Operations in SEA*, 51.

64. Francis and Nelson, *Search and Rescue Operations in SEA*, 51, and McLeaish and Silves, *Southeast Asia Operational Analysis of Required Performance Parameters for a Combat Aircrew Recovery Aircraft*, 8,12,13.

65. Boeing: V–22.

66. Author's experience and knowledge as an HH–60G Weapons Officer.

67. HH–60G information is based on author's professional insight as an HH–60G instructor pilot. Unrefueled radius information for the HH–60G assumes 20 minutes in the objective area, appropriate fuel reserves, and two 185gal internal auxiliary fuel tanks. Underlying assumptions for t HH–43, HH–3E, and HH–53 information is unknown; it was drawn from *Project CHECO Southeast Asia Report: USAF SAR November 1967–June 1969*, 18, 20.

68. Mouton et al, *Rescuing Downed Aircrews: Value of Time,* xv.

69. *Rescuing Downed Aircrews: Value of Time*, xiv.

70. This table excludes flying hour costs associated with the recovery vehicles or C–130 tankers or Airborne Early Warning and Control System. The F–16 RESCORT data assumes a CAS mission configuration (5,000lb/hour burn with a 14lb/NM configuration bill), one threat reaction, and roughly 11,800 pounds' fuel capacity with drop tanks. The F–16 SEAD data assumes a SEAD mission configuration (6,000lb/hour burn with a 12lb/NM configuration bill), one threat reaction, and roughly 11,800 pounds' fuel capacity with drop tanks. The F–15C OCA data assumes 15,000lb/hour burn with a built–in configuration bill, one threat reaction, one merge, and roughly 22,800 pounds' fuel capacity with a drop tank. It is assumed aircraft depart the rendezvous with full tanks and will swap out as whole 4–ships and that swap out occurs after the aircraft have consumed 70 percent of total fuel capacity to allow for flight to air refueling (AR) track and reserves. KC–135 fuel transfer capacity is assumed as 150,000 lb. Source: Mission planning data was collected and provided by Maj Brough McDonald of the 34th Weapons Squadron, USAF Weapons School.

71. The calculations assume the aircraft are flying at low–level, then get engaged by the described weapons system – at two–thirds the gun's maximum effective range–from one clock position left or right of the aircraft's flight path. The aircraft breaks into a 30o bank turn and then rolls out at a point to most quickly escape the maximum effective range of the gun system. The decreases in exposure time are not linear because the turn radius, and therefore the arc length of the aircraft's turn, increases with the square of its speed. Ranges derived from Major John C. Pratt. Air Tactics Against NVN Air Ground Defenses: 1 December 1966–1 November 1968.

(*Project CHECO Southeast Asia Reports*, xi. and Guardia, *Self–Propelled Anti–Aircraft Guns of the Soviet Union*, 20.

72. This section discusses currently available technological solutions to meet the requirements derived from the analysis conducted earlier in the paper. This is not a personal endorsement of any company or corporation, but an attempt to make known what is possible and feasible in a short acquisition timeline. There may be other solutions that are cheaper, faster, and better for the Air Force.

73. Whitcomb, *On a Steel Horse I Ride*, 448–55.

74. Author's firsthand knowledge and experience using the AN/AAQ–29 FLIR.

75. This Form, 1067 Modification Proposal, Control Number: ACC 14–296, is unclassified. Submitted by author.

76. *HH–60W Combat Rescue Helicopter (CRH).*

77. *HH–60W Combat Rescue Helicopter (CRH).*

78. Colucci, *Pedro's Progress.*

79. MX–10. L–3 Wescam Brochure.

80. Figure 7 is from the patent submission by CFD International, manufacturer of the HH–60G's EGMS, and depicts two AGM–114 Hellfire missiles mounted with a.50 caliber machine gun. Image derived from US Patent #: US 6,789,455 B1.

81. Author's experience employing 2.75 inch rockets as a UH–1Y utility and light attack helicopter pilot assigned to HMLA–267 and as a fixed–forward employment instructor in the HH–60G.

82. HH–60G with 2.75-inch rocket launcher fitted for testing. Capt Geragosian (name on the door in the first picture) was killed in a C–130 mishap in December 1999; which helps date the picture to the late 1990s. Photos are unclassified, provided by 88th Test and Evaluation Squadron, Nellis AFB, NV.

83. Ruehrmund and Bowie, *Arsenal of Airpower.*

84. Ruehrmund and Bowie, *Arsenal of Airpower.*

85. *Department of the Air Force Fiscal Year (FY) 2017 Budget Estimates Operation and Maintenance*, *Air Force*.

86. Image is CFD International's H–60 EGMS with optional BRU for M260 rocket launchers. CFD International provides the EGMS for the HH–60G. The HH–60G does not have the optional bolt–on structure for the BRUs. Source: Image from CFD International.

87. Nelson, *USAF Helicopter in Southeast Asia 1968*, 25.

88. Nelson, *USAF Helicopter in Southeast Asia 1968*, 29.

89. Nelson, *USAF Helicopter in Southeast Asia 1968*, 29.

90. Nelson, *USAF Helicopter in Southeast Asia 1968*, 29.

91. Nelson, *USAF Helicopter in Southeast Asia 1968*, 32.

92. Nelson, *USAF Helicopter in Southeast Asia 1968*, 32.

93. USAF UH–1F Huey gunships supporting a special operations infiltration in Cambodia in the late 1960s. Photo courtesy of the National Museum of the Air Force.

94. Nelson, *USAF Helicopter in Southeast Asia 1968*, 26.

95. Excerpts taken from; Wolf, T*he United States Air Force: Basic Documents on Roles and Missions*, 383–4.

96. Mutza, *Green Hornets*, 49.

97. Mutza, *Green Hornets,* 61, 65.

98. Whitcomb, *On a Steel Horse I Ride*, 448–60.

99. USAF UH–1N gunship flying over a stateside range. Photo from Mutza, *Green Hornets*, 61, 65.

100. Caldwell and Muller, *The Luftwaffe over Germany*, 206.

101. *Future Vertical Lift Initiative*.

102. Briefing, Piasecki Aircraft Corporation, subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016 [briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.]

103. Briefing, Piasecki Aircraft Corporation.

104. Briefing, Piasecki Aircraft Corporation.

105. As a conventional helicopter transitions to forward flight, more power is typically required to overcome the forces of weight and drag. As the aircraft translates to forward flight, and smoother air, the main rotor and tail rotor gain aerodynamic efficiency, resulting in decreased power demand. Image from the *Federal Aviation Administration Helicopter Flying Handbook.*

106. Carlson, *"Review of Piasecki Aircraft Corporation Report 4–16–X–114B,"* 7.

107. Carlson, *"Review of Piasecki Aircraft Corporation Report 4–16–X–114B,"* 7.

108. FAA, *Helicopter Flying Handbook*, 11.

109. Discussion of limits was informed by PiAC comments received 18 April 2017 during proprietary release review.

110. This paraphrases a summary of the VTDP benefits as offered in PiAC editorial comments received 18 April 2017.

111. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

112. Image courtesy of Piasecki Aircraft Corporation.

113. Photo courtesy of Piasecki Aircraft Corporation.

114. During this 13 December 2016 interview, the PiAC representatives assessed their VTDP compound technology at a Technology Readiness Level (TRL) of seven. The definition of TRL is taken from *Technology Readiness Assessment (TRA) Guidance*, 2–14.

115. *Technology Readiness Assessment (TRA) Guidance*, 2–14.

116. *Technology Readiness Assessment (TRA) Guidance*, 2–14.

117. Image provided by Piasecki Aircraft Corporation.

118. Carlson. *"Review of Piasecki Aircraft Corporation Report 4–16–X–114B,"* 4 and releasability review comments provided by PiAC, 18 April 2017.

119. Shaft horsepower rating corrected from 600 to 650shp during PiAC proprietary release review, received 18 April 2017.

120. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine, 7 December 2016

[briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.]

121. Discussion of limits was informed by PiAC comments received 18 April 2017 and Briefing Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016 [briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.]

122. Discussion of limits was informed by PiAC comments received 18 April 2017 and Briefing Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016. Briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.

123. Discussion of limits was informed by PiAC comments received 18 April 2017.

124. US Army reference provided by PiAC comments received 18 April 2017.

125. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

126. United States Air Force Flight Manual, *USAF series HH–60G Helicopter, (TO 1H–60(H)G–1) Change 16. September 2014,* 1–80.11.

127. Gareth, *DOD Awards ITEP Advanced Helicopter Engine Contracts* and discussion of fuel savings informed by PiAC comments received 18 April 2017.

128. Drew, *Design Review to Unlock Sikorsky HH–60W Funds*.

129. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine, 7 December 2016. Briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation and John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

130. SPU is expected to produce 650shp and is a nondevelopmental power plant. ITEP is the US Army's effort to increase power plant output turbines by 50percent, while reducing fuel consumption by 25 percent. The ITEP power plant will be a form–fit replacement for the GE T700.

131. Author's experience and knowledge as a UH–1Y pilot.

132. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

133. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016. Briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.

134. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

135. The author flew HH–60G's equipped with the older style window mounts. These window mounts only supported the 7.62 mm Mini–gun and 7.62 mm M240. During a contingency operation the author's unit flew with the mini–guns retracted

inside the aircraft and then deployed them near the destination. This had more to do with the nature of the mission versus a speed consideration, but the idea to do this on the Speed Hawk has precedent.

136. Image depicts a Dillon Aero Inc. retractable GAU–2 / M134 7.62 mini–gun cabin mount. A mount like this may work for employment through a smaller cabin door placed inside the 45–inch cabin "plug" on the Speed Hawk. Image from the Dillon Aero Inc. product catalog, section title "EC725/H225M, AS332 and AS532 Gun Mount Assembly."

137. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

138. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

139. Department of Defense, *Selected Acquisition Report (SAR): Combat Rescue Helicopter (CRH)*, 24.

140. Hagan, *Glossary of Defense Acquisition Acronyms & Terms,* B–144.

141. *Pave Hawks–New Combat Rescue Helicopter*. Defense Industry Daily.

142. Hagan, *Glossary of Defense Acquisition Acronyms & Terms*, B–70.

143. Department of Defense, *Selected Acquisition Report (SAR): Combat Rescue Helicopter (CRH)*, 14, Department of Defense, *Selected Acquisition Report (SAR):MH–60R*, 13, Department of Defense, *Selected Acquisition Report (SAR): AH–64E Apache New Build (AH–64E New Build)*, 13, and Department of Defense, *Selected Acquisition Report (SAR): V–22 Osprey Joint Services Advanced Vertical Lift Aircraft (V–22)*, 19.

144. Department of Defense. *Selected Acquisition Report (SAR): UH–60M Black Hawk Helicopter (UH–60M Black Hawk),* 14.

145. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

146. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

147. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016 [briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.

148. During 18 April 2017 proprietary release review, PiAC noted that "In support of [Vice Chief of Naval Operations] (VCNO) request for Sikorsky estimate for performance and cost for production version of Speed Hawk for FY00 ATD decision, Sikorsky estimated Non Recurring Engineering (NRE) of $200M. Adjusting for Consumer Price Index (CPI) to 2017, this is $287M . . . The GaTech study estimated 53 percent of new H–60 RDT&E. UH–60M was $800M RDT&E, so Speed Hawk might be as high as $424M." This value range is used for RDT&E of a production Speed Hawk.

149. During 18 April 2017 proprietary release review, PiAC noted that "In support of VCNO request for Sikorsky estimate for performance and cost for production version of Speed Hawk for FY00 ATD decision, Sikorsky estimated NRE of $200M. Adjusting for CPI to 2017, this is $287M . . . The GaTech study estimated 53 percent

of new H–60 RDT&E. UH–60M was $800M RDT&E, so Speed Hawk might be as high as $424M." This value range is used for RDT&E of a production Speed Hawk.

150. RDT&E, LRIP (Low–Rate Initial Production), FRP. Importantly, the actual projected manufacturing capacity of the HH–60W production line is 149 aircraft, assuming production capacity is maximized for each fiscal year. However, the total planned production is only 112 aircraft. This data is compiled from Attachment 12 of the original CRH Contract, # FA8629–12–R–2400, dated 9 October 2012, and the DOD *Selected Acquisition Report (SAR): Combat Rescue Helicopter (CRH)* dated May 2016.

151. John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

152. *SBIR/STTR Reauthorization Act of 2011: Division E—SBIR and STTR Reauthorization Title L—Short Title.*

153. United States Air Force, "Global Vigilance, Global Reach, Global Power for America," 4.

154. These countries areas—Estonia, Latvia, Lithuania, Romania, Slovakia, Hungary, Moldova, Bulgaria, Poland, and Iceland and its Air Defense Identification Zone (ADIZ)—were calculated, and included, from searches of the *CIA World Factbook* and from the author's old in–flight Guide from the 85th Group, NAS Keflavik, Iceland.

155. Church, Gallery of USAF Weapons.

156. Arana–Barradas, *Rescue Unit Faces Moving Challenges.*

157. Drew, *ANALYSIS: Pave Hawk Replacement Finally Beckons for US Air Force.*

158. These aircraft availability and mission capable rates, of 67.4 percent and 83 percent respectively, are drawn from: Department of Defense, *Selected Acquisition Report (SAR): Combat Rescue Helicopter (CRH)*, 32.

159. The first half of Chapter five of AFTTP 3–3. HH–60G describes HH–60G CAS tactics, techniques, and procedures during the execution of recovery missions when HH–60 delivered fires require detailed integration with ground forces. The author wrote it.

160. This ACC HH–60 pilot progression training plan was originally written by the author and then–Maj Evan Scaggs. We drafted it with the idea of a future expansion into sortie based training and inclusion of a CAS, FAC[A], and RMC syllabi. In fact, the author's Weapons School paper *HH–60G Flight Leadership Training,* 28 June 2014, was knowingly written as the HH–60G Flight Lead Upgrade syllabus intended for inclusion in the larger ACC HH–60 pilot progression training plan.

161. Losacker and Scaggs.

162. Ramon, AF Pararescuemen: 'So Others May Live.'

Appendix A – SEA CSAR Mission Data

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
2-Jun-65	HH-43	63-9713	Rescue 95	South Vietnam (16 11N—108 08E)	Det 5	Pacific Air Rescue Center (PARC) Det 5, DaNang AB, RVN	37mm AAA	Objective area: Hovering	Hovering over downed USMC O-1E 10 miles north of DaNang. Hit by small arms and 37mm. Weather (WX): unk Assets: unk	Aircraft Mishap Report, 03 June 1965, from: 2nd Air Division (AD) to: RUHLKM/ Commander in Chief, Pacific Air Forces (CINCPACAF) [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to Military Airlift Commander, dated 30 Oct 1972. Subject was General Everest's response to Military Airlift Command (MAC)/Commander (CC) inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project Contemporary Historical Examination of Current Operations (CHECO) Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]
20-Sep-65	HH-43	63-4510	Dutchy 41	North Vietnam (18 07N—105 47E)	38th Air Rescue Service (ARS), Det 1	Nakhom Phanom, RTAFB	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Forward Flight	Crashed while attempting rescue of Essex 04 (F-105D), 38 miles south of Vinh. N approach into zone took heavy automatic weapons fire and burst into flames. WX: unk. Assets: 2 x HC-54, 4 x F-4C, 14 x F-105, 3 x A-1E, 5 x KC-135, 3 x HH-43B, 1 x CH-3C	SAR Opening Report for Mission Number 38ARS-950-20SEP65 from: 38th ARS TSN AFLD RVN to: RUEAHQ/HQ USAF WASH DC 201440z Sep 65 [declassified] and Head, Larry D., 1Lt, Narrative Report Mission #95, 23 Sep 1965 to: HQs PARC, Hickam AFB, Hawaii [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
6-Nov-65	CH-3E	63-09685	Jolly Green	North Vietnam (40 miles south-southwest (SSW) of Hanoi)	38th ARRS	Lima Site 36 (Laos)	37mm AAA	Enroute: Forward Flight	SAR for Sandy 12 (A-1E). Callsign listed simply as "Jolly Green." ~5NM out from terminal area, at 8000MSL, approx 7,500 AGL, CH-3 hit by heavy flak, ruptured fuel lines. All four crewmen bailed out (parachuted). 37mm is inferred from altitude and extent of damage WX: BKN Assets: 1 x HC-54, 8 x A-1E, 2 x CH-3C, 4 x A-1H (USN), 2 x SH-3 (USN), 10 x F-4C, 4 x KC-135, 6 x F-105	RUMSAR Report from: 38th ARS to: RUEAHQ/HQ USAF WASH DC, 08 Nov 65 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
20-Oct-66	HH-3E	65-12778	Jolly Green	North Vietnam (17 08N—105 48E)	38th ARRS, Det 5	Unk	Unspecified Ground Fire	Terminal Area: Unspecified	*Limited information available for this mission.* Callsign listed simply as "Jolly Green.' Downed on SAR mission for F-4C down in Laos. Crewmembers recovered by another HH-3E. Unspecified ground fire. WX: unk Assets: unk	ARRS Log of Combat Saves [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
28-Oct-66	HH-43F	62-4511	Pedro 42	South Vietnam (14 06N—107 33E)	38th ARRS	Pleiku AB, RVN	Unspecified Ground Fire	Terminal Area: Unspecified	*Limited information available for this mission* MEDEVAC for US Army soldiers. 35miles west-northwest (WNW) of Pleiku, Vietnam. Downed by unspecified ground fire. WX: unk Assets: unk	ARRS Log of Combat Saves [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
6-Feb-67	HH-3E	65-12779	Jolly Green 05	North Vietnam (17 46 20N—105 48 00E)	38th ARRS	Nahkom Phanom, RTAFB	Unspecified Ground Fire	Terminal Area: Forward Flight	SAR for O-1F (Nail 65). After hover to successfully pick up Nail 65, helo was flying out of terminal area and hit by unspecified ground fire. One PJ managed to bail out before helo exploded and was later rescued (suspect this was Dwayne Hackney). WX: unk Assets: 2 x HC-130P, 2 x HH-3E, 4 x A-1E	Rescue Suspending Report from: 3ARRGP Udorn RTAFB to: RUEDHQA/HQ USAF WASH DC, 061515z Feb 67 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
8-May-67	HH-43F	63-9715	Pedro 96	South Vietnam (15 57N—108 04E)	38th ARRS, Det 7	DaNang AB, RVN	Small Arms (7.62mm)	Terminal Area: Hovering	MEDEVAC for 4 x WIA USMC (part of larger USMC Company). While in a hover, aircraft hit by small arms fire and forced down. Crew linked up with Marines and was later rescued. WX: 100' ceilings, visibility unk Assets: unk	Joint Operational Reporting System (JOPREP)-3 Pinnacle Report from: 37 ARRS DANANG AB, RVN to: RUEPJS/NMCC 081210z May 67 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
21-May-67	HH-43F	63-9711	Pedro 73	South Vietnam (12 miles north of Bien Hoa)	38th ARRS	Bien Hoa AB, RVN	37mm AAA	Terminal Area: Unspecified	*Limited information available for this mission* Downed at unknown aircraft crash site 12 miles north of Bien Hoa, South Vietnam. Downed by 37mm. (SAR was possibly for Ramrod 02, an F-100D based; on some unverifiable internet search results). WX: unk Assets: unk	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project CHECO Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]
27-Oct-67	HH-3E	66-13283	Jolly Green 30	Laos (70 miles west of DaNang)	37th ARRS	DaNang AB, RVN	Small Arms (7.62mm)	Terminal Area: Hovering	Attempting MEDEVAC of one wounded US Special Forces man 70 miles west of DaNang. Experienced engine failure due to suspected ground fire. Helo was established in a hover over dense jungle canopy. Ground fire was not directly observed, however, the Special Forces (SF) team had been recently engaged in an active firefight just before arrival of the rescue helicopter. WX: unk Assets: 2 x HH-3E, 1 x HC-130P, 2 x O-1, 1 x SF team	Rescue Info Report from: OL-1 3 ARRGP SON TRA RVN to: RUCLMFA/ARSCP ORLANDO AFB, FL 290910Z OCT 67 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
9-Nov-67	HH-3E	66-13279	Jolly Green 26	Laos (16 15N—106 53E)	37th ARRS	DaNang AB, RVN	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Forward Flight	Emergency extraction of 5-man Special Forces team. JG 29 hit by automatic weapons fire after they recovered 3/5 soldiers. JG26 attempted to extract remaining 2 soldiers and hit by Artillery Weapons (AW) fire. Downed while flying out of objective area. Capt Gerald O. Young, Medal of Honor. mission. WX: BKN 015, 3miles Visibility (VIS), Fog Assets: 3 x UH-1 gunships, 2 x A-1, 1 x FAC (type unclear), plus some additional assets unclear from OPREP	JOPREP JIFFY from: OL-1 3 ARRGP SON TRA RVN to: RUCLMFA/ARSCP ORLANDO AFB, FL 8 Nov 67 [declassified] Note: the date discrepancy between the mission date and JOPREP date is due to international dateline. And Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
15-Jan-68	HH-3E	64-14233	Jolly Green	North Vietnam (50 miles east of Lima Site 36)	37th ARRS	Lima Site 36 (Laos)	37mm AAA	Terminal Area: Unspecified	*Limited information available for this mission* Downed on a SAR mission 50 miles east of Lima Site 36 in North Vietnam. Downed by 37mm ground fire. (SAR was possibly for Preview 01 (EB-66C); based on some unverifiable internet search results). WX: unk Assets: unk	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project CHECO Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]
8-Feb-68	HH-43F	62-4525	Pedro 56	South Vietnam (28 miles North-Northeast (NNE) of Pleiku)	38th ARRS, Det 9	Pleiku AB, RVN	37mm AAA	Terminal Area: Forward Flight	*Limited information available for this mission* Downed on a MEDEVAC mission for the US Army, 28 miles NNE of Pleiku. Downed by 37mm ground fire. WX: unk Assets: unk	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project CHECO Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]
9-Jun-68	HH-3E	67-14710	Jolly Green 23	South Vietnam (20 miles South-Southeast (SSE) of Khe Sanh)	37th ARRS	DaNang AB, RVN	37mm AAA	Terminal Area: Hovering	SAR for Hellborne 215 (USMC A-4). JG 23 shot down while in a hover by automatic weapons and possibly by 37mm. A 37mm was active and in vicinity of the recovery point. The helo crashed and burned. Identification of enemy positions made nearly impossible due to enemy use of camouflage, foxholes, and caves. SAR was in Ashau Valley, 20 miles SSE of Khe Sanh. WX: BKN 045, unlimited VIS Assets: 3 x HH-3E, unspecified number of helo gunships, 6 x A-4, unspecified number of F-4s, 8 x A-1Es	Mission Narrative Report to: 3 ARRGP SON TRA RVN, dated 9 Jun 1968 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
5-Oct-68	HH-3E	64-14782	Jolly Green 10	Laos	37th ARRS	DaNang AB, RVN	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Hovering	Emergency extraction mission for 7-man Special Forces team. Helo at 20ft above ground/canopy on short final for a hover over the jungle canopy. Mountainous terrain. Aircraft hit by some combination of automatic weapons, rocket propelled grenades, and mortar fire. WX: 10miles VIS, SKC Assets: 4 x HH-3E, 23 x A-1 (sorties), 4 x F-4, 2 x F-100, 8 x UH-1 gunships, 2 x O-2	OPREP-3, from : OL-1 3 ARRGP SON TRA RVN to: RUCLMFA/ARSCP ORLANDO AFB, FL 7 Oct 68 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
20-Oct-68	HH-3E	66-13282	Jolly Green 29	North Vietnam (20 miles NNE of Dong Ha, 1 mile off-shore from Con Co Island (aka "Tiger Island"))	37th ARRS	DaNang AB, RVN	37mm AAA	Terminal Area: Landing/ Landed	Made open sea landing 20 miles NNE of Dong Ha for pick up of Dover 01 (F-4D). Dover 01 drifted to within 1 mile of Tiger Island and the helo was hit by shore-based mortar and 37mm fire from the island. WX: SCT 020, BKN 080, 6mi VIS, Assets: 3 x HH-3E, 2 x A-1, unspecified number of F-4s, unspecified number for F-105s	Mission Narrative Report to: 3 ARRGP dated 20 Oct 68 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project CHECO Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
18-Jan-69	HH-53B	66-14430	Jolly Green 67	Laos (16 34 35N—106 18 20E)	40th ARRS	Udorn RTAFB	37mm AAA	Terminal Area: Forward Flight	SAR for Sandy 02 (A-1) near Tchepone, Laos. After successfully picking up survivor, aircraft was hit by suspected 37mm fire while exiting objective area. WX: unk Assets: 2 x HH-53B, 6 x A-1E, 1 x HC-130P	Durham, Louis, Capt Mission Narrative Report, 19 Jan 69 [declassified] and JOPREP JIFFY / RESCUE REPORT OL-2 18 Jan 69 [declassified] and also Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in South-east Asia. [declassified]
21-Jan-69	HH-43	unk	Pedro 20	South Vietnam	38th ARRS, Det 12	Nha Trang AB, RVN	Small Arms (7.62mm)	Terminal Area: Hovering	MEDEVAC of wounded Marine via hoist/ Hovering 20ft over canopy. Took small arms to transmission, forced to land 5 miles from objective area. Aircraft later recovered so it is not listed as a combat loss even though it was shot down. A serial number was not discovered in research. Jungle terrain. WX: SKC, 15 miles VIS Assets: 2 x HH-43 and 3 x UH-1 gunships	Mission Narrative Report dated 24 Jan 69 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
26-Jan-69	HH-43F	63-9712	unk	South Vietnam (Pleikuv AB perimeter)	38th ARRS, Det 9	Pleiku AB, RVN	Small Arms (7.62mm)	Terminal Area: Forward Flight	Performing perimeter defense at Pleiku AB. Downed by unspecified ground fire, however, small arms is most likely given the difficulty of Viet Cong forces transport-ing heavier and more cumbersome auto-matic weapon systems close to base perimeter. WX: unk Assets: unk	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
28-Jun-69	HH-43B	59-1590	Pedro 92	South Vietnam (5 miles east of Phan Rang AB)	41st ARRS	Phan Rang AB, RVN	Unspecified Ground Fire	Terminal Area: Unspecified	*Limited information available.* Downed attempting SAR for a downed aircraft 5 miles east of Phan Rang by unspecified ground fire. (unverifiable internet searches indicate this may have been Blade 04 (an F-100D)). WX: unk Assets: unk	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
24-Oct-69	HH-3E	66-13281	Jolly Green 28	Laos (15 51N—106 52E)	37th ARRS	Unkown (reports list launch site as "Channel 77," reference to a Tactical Air Navigation (TACAN) station)	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Hovering	Downed on a SAR mission for Misty 11 (F-100). Hit by "heavy automatic weapons fire" while in a hover. WX: unk Assets: 14 x A-1E, 6 x HH-3E, 2 x HH-53, 3 x HC-130P	Mission Narrative Report dated 24 Oct 69 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
28-Jan-70	HH-53B	66-14434	Jolly Green 71	North Vietnam and Laos Border (055o / 60NM) Nakhom Phanom RTAFB)	40th ARRS	Nakhom Pha-nom RTAFB	Air-to-Air Missile (MiG-21)	Enroute: Forward Flight	JG71 was launched to hold in SAR orbit for possible Seabird 02 (F-105G) rescue. While holding at 10,000 MSL (6,000 AGL) near Laotian and North Vietnamese border it was shot down by a MiG-21 that got past the MiG CAP fighters. WX: unk Assets: unspecified number of A-1, 2 x HC-130Ps, 2 x HH-53	OPREP JIFFY / 432 TRW LOSREP002 29 JAN 70 [declassi-fied] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/ CC inquiry (on 5 October 1972) as to nature of ARRS air-craft and personnel losses in Southeast Asia. [declassified]

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
15-Apr-70	HH-3E	66-13280	Jolly Green	South Vietnam (80 miles South-west (SW) DaNang AB)	37th ARRS	DaNang AB, RVN	Small Arms (7.62mm)	Terminal Area: Unspecified	*Limited information available.* SAR mission for downed aircraft 80 miles SW of DaNang. Downed by small arms fire. A backup HH-3E recovered survivors	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified] and Mr. Walter Lynch, USAF Search and Rescue in Southeast Asia 1 Jul 68—31 Dec 70, (Project CHECO Report, PACAF HQ, Hickam AFB, HI. 23 Apr 71), 98-99 [declassified]
30-Jun-70	HH-53C	68-8283	Jolly Green 54	Laos (44miles west of Quang Tri, RVN)	40th ARRS	Nakhom Pha-nom, RTAFB	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Forward Flight	SAR for Fatcapper 07 (type unspecified in report), in vicinity of and coincident to Nail 44 (OV-10A) SAR. Encountered heavy automatic weapons fire during approach. Shot down while attempting to exit the objective area. SAR area was approximately 44 miles west of Quang tri, RVN. WX: unk Assets: unk	Elkinton, James Z., Major, Mission Narrative Report for Mission Number 1-3-051, 30 June 70 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
21-Nov-70	HH-3E	65-12785	Banana 1	North Vietnam (Son Tay Prison Camp)	37th ARRS				Intentionally crashed into Son Tay Prison Camp during attempted Prisoner of War (POW) rescue mission	Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
22-Jul-71	HH-53C	68-8285	Jolly Green 54	Laos (19 47 15N—102 32 50E)	40th ARRS	Nakhom Pha-nom, RTAFB	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Hovering	Helo in a 50ft hover recovering an AQM-34B drone. Downed by enemy ".51 caliber" fire (this odd descriptor may be a typo and seems to roughly match other mission report references to automatic weapons fire; likely referring to 12.7mm fire). WX: Day Visual Meteorological Conditions (VMC) Assets: unk	OPREP-3 PINNACLE from: 56SOW NAKHOM PHANOM RTAFB to: RUEKJCS/NMCC 211205z JUL 71 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS air-craft and personnel losses in Southeast Asia. [declassified]
25-Nov-71	HH-53C	68-10366	Jolly Green 70	South Vietnam (12 miles South of Tan Son Nhut AB, RVN)	37th ARRS		Small Arms (7.62mm)	Enroute: Forward Flight	Return flight to Tan Son Nhut AB, RVN after dropping off survivors (at Can Tho AB) from a SAR mission for a downed C-7 near Bien Thuy. After encountering rain showers, helo descend to approximately 100ft AGL when pilot was shot in groin with a small caliber round; ground fire. Helo crashed into river 12 miles south of Tan Son Nhut. WX: +SHRA, 1 mile VIS, BKN Assets: 2 x HH-53C	Staffing Form MAC HQ Form 42, Subject: "HH-53C Loss, Vietnam," from: MAC/IGYF, Lt Col Feil, dated 3 Dec 1971 [declassified] and Attachments to letter from Brig Gen Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS air-craft and personnel losses in Southeast Asia. [declassified]
27-Mar-72	HH-53C	68-10359	Jolly Green	Laos (14 36N—106 48E)	40th ARRS	Nakhom Pha-nom RTAFB	37mm AAA	Enroute: Forward Flight	Enroute from Nakhom Phanom for an escort mission over NE Cambodia (what this mission entailed is unspecified). After air refueling helo was shot down by enemy ground fire; suspected 37mm. The previous night Spectre 13 had received 18 rounds of 37mm from the same location as shootdown area. Helo was at 9500MSL, approximately 9000AGL. WX: unk Assets: 2 x HH-53C, 1 x HC-130P	JOPREP JIFFY / LOSREP 007 from: 40 ARRS/56SPOPWG NKP RTAFB to: RUEFHQA?CSAF 291035z MAR 72 [declas-sified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]

Date	Aircraft Type	Serial Number	Callsign	Area of Loss	Unit	Unit/Launch Location	Enemy System	Phase of Flight	Mission Remarks	Source
6-Apr-72	HH-53C	68-10365	Jolly Green 67	South Vietnam (16 49N 107 02E)	37th ARRS	Da Nang AB	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Forward Flight	Downed 2 miles west of Dong Ha. HH-53C maneuvering in terminal area to pick up Bat 21B (BE-66C) and Nail 38B when hit by heavy groundfire. Helo exploded. Enemy weapon system unspecified in JOPREP. Other data from mission reports related to Bat 21B mission indicated heavy automatic weapons fire, if not even higher caliber, is likely culprit. WX: VMC Assets: extensive, see numerous other works about BAT-21 rescue mission	JOPREP JIFFY / RESCUE OPENING REPORT, 070025Z APR 72 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]
27-Dec-72	HH-53C	69-5788	Jolly Green 73 changed mid-mission to Jolly Green 01	North Vietnam (29 49N 105 34E: SAR objective) Laos (19 57N—103 47E: forced landing)	40th ARRS	Nakhom Phanom, RTAFB	Automatic Weapons (7.62mm to 14.5mm)	Terminal Area: Hovering	SAR for Jackal 33B (F-111A), coincident with daytime Linebacker II strikes by Tactical Air Command (TAC) aircraft. (author's note: B-52s primarily executed night strikes.) While established in a 30ft hover over Jackal 33B, helo was severely damaged by automatic weapons fire and had to fly out of objective area. Jackal 33B slipped on some rocks and fell down before getting in the hoist strop. Battle damage caused fuel loss and inability to refuel in air. Helo forced to land in Laos and was destroyed by A-7 Sandys after crew recovered. Jackal 33B was not rescued	Shapiro, Richard D., Capt, Summary of SAR Actions, Mission # 40-133, 27 Dec 72 [declassified] and Attachments to letter from Brigadier General Frank Everest Jr, USAF, Commander of ARRS to MAC/CC, dated 30 Oct 1972. Subject was General Everest's response to MAC/CC inquiry (on 5 October 1972) as to nature of ARRS aircraft and personnel losses in Southeast Asia. [declassified]

Appendix B: Historical Synopsis

Contemporary Perspective[1]

On 26 June 2014 the AF awarded Sikorsky Aircraft Company a contract to manufacturer 112 new CRH; these aircraft will replace the existing fleet of HH-60G Pave Hawks.[2] The contract was valued at $7.9 billion with final delivery of the aircraft not expected until 2029.[3] The AF's stated missions for these new aircraft, designated HH-60Ws, is CSAR CASEVAC, MEDEVAC, noncombatant evacuation operations (NEO), civil SAR, international aid, disaster and humanitarian relief operations, and insertion, extraction or both of combat forces.[4]

This contract award followed an abrupt decision on 4 March 2014 by AF Secretary Deborah James to include funding for it in the AF's FY15 budget.[5] In December of 2013, 74 lawmakers in the House of Representatives signed a letter urging the AF to support acquisition of the CRH.[6] Senators Charles Schumer and Dick Durbin called Secretary James on 4 March 2014 to urge her support for the program; they did this after learning of the following verbiage in the Fiscal Year 2015 Budget Overview Book.[7]

> The FY 2015 President's Budget includes recommendations to terminate or restructure weapons systems acquisition programs that are experiencing significant developmental problems, unsustainable cost growth, and inefficient or ineffective operations, and realign the funding to higher priority national security requirements. This includes . . . the AF's delay of the Combat Rescue Helicopter (CRH) program.[8]

The excerpts from the budget proposal logically followed the service's initial push back to 2013 congressional demand in which the CSAF assessed the program as unaffordable, even while remarking on its criticality.[9] Undoubtedly, General Mark Welsh, the CSAF at the time, did view combat rescue as a very important mission, however, in the context of Bipartisan Control Act spending caps ("Sequestration"), the AF was in a difficult spot as it worked to fund programs and initiatives in line with its historical core mission areas. Secretary James' decision to include CRH funding was welcome by the AF's small community of combat rescue helicopter pilots and crewmen . . . the author included.

The June 2014 contract award provided a cautious sense of relief among the rescue force. Cautious; because a replacement combat rescue vehicle program had been tried and killed two times in the previous decade and there was not a guarantee a new aircraft would actually materialize.[10] Relief was due to the poor overall state of the fleet of HH-60G Pave Hawks that desperately need replacement. The HH-60G Pave Hawk helicopter is based on the UH-60L Black Hawk platform (some early versions were based on the UH-60A), initially modified to perform special operation missions then adapted and further modified to the CSAR role. The intended airframe life for the UH-60 platform is 20 years of service and 8,000 airframe hours, with a normal operating weight of 16,825 pounds[11],[12] The average age of the AF HH-60G is nearly 25 years old and normally operated between 20,000 and 22,000 pounds; at least ten airframes are above 8,000 hours of flight time, with several of the oldest models over 11,000 airframe hours.[13] The HH-60G now struggles to meet a 60 percent maintenance availability rate fleet-wide, has seen a 25 percent increase in the cost per flight hour over the last half-decade, and has suffered from a prolific number of major airframe structural cracks in recent years.[14] The last several years have seen training restrictions on aerial refueling due to dangerous occurrences of divergent probe oscillations.[15] On 14 December 2010 an HH-60G assigned to Kirtland AFB, NM (Tail # 82-23708) had an aerial refueling probe catastrophically fail in-flight, tearing itself off of the airframe; the crew lived only because it broke down and not up into the rotor system.[16] The original acquisition number, and program of record, for the HH-60G was 112 aircraft;, however, combat and training losses have left 97 remaining aircraft.

How Did We Get Here?

US involvement in Vietnam and Southeast Asia grew during the latter part of the 1950s and into the early 1960s.[17] By 1961, USAF aviation training programs to train Vietnamese forces had led to a significant increase in American air combat activity in Vietnam.[18] From this early period in the conflict until June 1964, the AF did not have rescue units assigned to duty in Southeast Asia.[19]

During the Korean War, the ARS had more than 12,000 personnel; after the war the force was drawn down to only 1,465 men and 66 aircraft.[20] Furthermore, during the interwar period between Korea and Vietnam, Headquarters AF (HAF) had withdrawn any wartime mission from Air Rescue activities.[21] This decision created a technological void in PR systems and led to a lack of support and low priority for the Rescue Service and the USAF helicopter fleet.[22] Since the AF had placed highest priority on increasing strike capability, the development and advancement of the rotary-wing fleet had been subordinated to increases in tactical forces during this time frame.[23] The end result of this institutional neglect was a rescue force unable to provide relevant combat deployable assets from 1961-1964; in this period there were

143 casualties due to aircraft crashes with the AF relying solely upon Army, Marine, and Vietnamese AF assets to rescue its downed aircrews.[24]

From August 1964 until July 1965, AF HH-43 Huskies, known by their call sign of "Pedro," originally designed for peacetime local base recovery missions, were tasked with combat rescue efforts in South Vietnam.[25] During this same period, these HH-43 crews were credited with 74 lives saved, earning 16 Silver Stars and 10 Purple Hearts.[26] As the air war progressed and moved into North Vietnam, the AF rescue forces faced a future of increased operational hazard. In July 1965, two CH-3C's arrived at Nakhon Phanom AB Thailand, the first of what would later evolve as the air-refuelable HH-3E "Jolly Green Giant."[27] The HH-3E constituted a breakthrough for combat rescue in Southeast Asia; it had vastly improved range, hover capability, and 1,000 pounds of titanium armor plating around the cockpit and critical aircraft components.[28] The success of the HH-3E in Southeast Asia was aided in large part by A-1E Skyraider pilots operating under the call sign "Sandy" and performing rescue escort duties.[29] The A-1E "Sandys" provided rescue escort as well as on-scene-command for the SAR task force; these propeller driven ground attack planes had a slow cruising speed, short turning radius, extended range and loiter times, and were heavily armed.[30] They effectively provided the "search" in SAR, whether electronically or visually, and then provided fire support in the objective area while the helicopters executed the recovery.[31]

CSAR efforts during the war in Southeast Asia gave birth to the HH-53 Pave Low III program in 1976.[32] During the war, night recovery operations proved to be more survivable for the rescue crews than daylight missions and a special program was initiated under MAC to provide the HH-53 helicopter with full night and adverse weather capability.[33] This suite of systems included a gyro-stabilized FLIR, Doppler navigation, projected map display, terrain following and terrain avoidance (TF/TA) radar, and substantial self-protection equipment.[34] MAC funded seven aircraft after diverting funds from the C-5 fleet and fielded the new HH-53 Pave Low rescue helicopters in 1980.[35]

Following the abject failure of Operation Eagle Claw (the Iranian hostage rescue attempt) in the spring of 1980, the AF Chief of Staff ordered the immediate transfer of the Pave Low HH-53s from the Air Rescue and Recovery Service to the 20th Special Operations Squadron.[36] This left the AF rotary-wing rescue force with nonmodified HH-53s (all eventually transferred to AF special operations) and HH-3s. Neither of which were equipped with viable self-protection equipment; this relegated AF rescue forces to low- or no-threat environments.[37]

After the move of the Pave Low modified HH-53 helicopters to special operations, the Air Staff began work on a plan to replace its aging fleet of HH-

3s.[38] In 1982 the AF received nine UH-60A Black Hawk models, eventually upgraded to the HH-60G, assigned to the 55th ARRS; these aircraft were considered special operations capable and the 55th eventually became a Special Operations Squadron in 1988.[39],[40] As part of this plan, the Air Staff aimed to procure 243 HH-60D helicopters for CSAR; incorporating lessons from the Pave Low program, these HH-60Ds would be fielded with an inertial navigation system (INS), TF/TA radar, and FLIR.[41] Congressional procurement cuts combined with AF Council actions in FY84 scaled the planned procurement of HH-60Ds down to 99 HH-60Ds and 90 HH-60As (the "A" virtually identical to US Army UH-60A Black Hawks).[42] Motivation for this change was purely financial; even though the HH-60D was far superior in capability to the HH-60A, it was to cost $22 million per aircraft compared to the $10 million for the HH-60A.[43] The entire procurement program was terminated in FY85, leaving AF rescue equipped with Vietnam era HH-3 helicopters.[44]

As described in Col Darrel Whitcomb's book, *Combat Search and Rescue in Desert Storm*, the following discussion took place among the AF Council members during a meeting concerning procurement of the HH-60D; this account comes from Colonel Tony Burshnick, then chief of plans for MAC:

> Our case was being presented by a rescue guy from the Air Staff… the Vice Chief [of the Air Force] . . . listened to this pitch and he said, "That [HH-60] is a great, great helicopter." And then, of course, the price tag came up. [The board members] yakked about it around the room and they finally decided that they were going to kill it. It was too expensive. I said, "Wait a minute. You're killing rescue service." And the guy said, "If we put all that money into the H-60, there won't be any money to buy fighters so there won't be any fighter pilots to rescue." . . . So there was no [HH-60].[45]

In the context of the time, the prevailing view was that cataclysmic war in Europe against the Soviet Union would easily overwhelm any rescue force.[46] As a result, aircrew were directed that if they were shot down they were to move to specific recovery points and at designated times special operations helicopters would recover them.[47] Highlighting this in an assessment from the 2nd Air Division (then MAC's subordinate organization responsible for both special operations and rescue) was a statement that special operations helicopters would provide combat recovery on a relative priority basis and that aircrew should plan on an extended evasion period until a rescue effort could be executed.[48]

Finally, in 1989, MAC revitalized the initiative to procure new helicopters and secured funding for 16 UH-60A helicopters to be modified into HH-60Gs that same year.[49] These were to be the first of a recurring purchase of 10 aircraft per year for several years.[50] It should be noted that the HH-60G never reached technological parity with the HH-53 (later redesignated MH-53)

Pave Low despite sharing a similar name. Even today, the currently fielded force of HH-60G aircraft lacks some significant radar self-protection equipment, does not possess an integrated moving map display, and lacks a true all-weather capability due to the absence of a TF/TA system.[51]

In January 1991, just before the start of Operation Desert Storm, the coalition forces fielded and organized to provide CSAR support were extensive.[52] US Army, Marine, British, French, and even Saudi helicopters were available to execute recoveries.[53] The dedicated CSAR helicopters were provided by US Special Operations Command; including the MH-53 Pave Lows.[54] However, as a result of the continued pattern of institutional mismanagement toward its conventional rescue forces, the AF did not deploy rescue helicopters suitable for the combat environment of Operation Desert Storm.

As a result, those aviators isolated on land behind enemy lines during Desert Storm relied on special operations helicopters for their recovery. Overall, when the mission proved feasible (taking into account environmental factors, threat, and proof-of-life of the survivor) special operations forces aircraft proved quite adept at executing CSAR missions. It should be noted that "At no time were [Special Operations Forces] (SOF) aircraft not available for rescue missions."[55] There were issues with the command and control of the CSAR forces that may have precluded additional rescues being accomplished; however, that was a fault of operational control, not a reflection of the CSAR capability of the assigned forces.

From the mid to late 1990s, the conventional AF CSAR force was simultaneously rebuilding its wartime capacity and undertaking the role of providing CSAR coverage in Iraq supporting the no-fly zones.[56] As a result, Special Operations Command (SOCOM) rotary-wing assets and a Marine Expeditionary Unit were tasked with providing PR support in the Balkans; specifically Operation Deny Flight and later Operation Allied Force.[57] In June of 1995 an AF F-16 pilot, Basher 52, was shot down and then rescued from enemy held territory by a Marine Tactical Recovery of Aircraft and Personnel (TRAP) team launched from the United States Ship (USS) *Kearsarge*.[58]

In the spring of 1999, SOCOM assigned AF special operations helicopters twice more proved their ability to conduct CSAR missions. Rescue task forces consisting primarily of MH-53 Pave Lows, MH-60 G Pave Hawks belonging to the 55th Special Operations Squadron, and A-10 Thunderbolt II's in the Sandy role as RMCs, executed the rescue of Hammer 34 and Vega 31.[59] Deployed to provide CSAR coverage for the beginning of Operation Iraqi Freedom, conventional AF CSAR forces finally executed the first traditional CSAR mission since Vietnam in support of a downed F-14 crew, call sign Junker 14.[60]

Air strikes in Libya targeting pro-Qaddafi forces began on 19 March 2011.[61] At the outset of hostilities, AF CSAR assets were not in place to support recovery operations.[62] On 21 March 2011, an F-15E Strike Eagle (call sign Bolar 34) originally based out of Royal AF (RAF) Lakenheath crashed, forcing the crew of two to eject over Libya.[63] The AF CSAR unit tasked with providing PR support for the Libya campaign was the 56th Rescue Squadron, also out of RAF Lakenheath.[64] The 56th Rescue Squadron had just returned from a deployment to Afghanistan where it had been primarily providing MEDEVAC support. This AF unit did not execute the rescue mission for Bolar 34. One of the HH-60G pilots assigned to the 56th Rescue Squadron during this time, who was on both the Afghanistan deployment and deployment in support of the Libyan airstrikes had this to say about their involvement, or lack thereof, in the Bolar 34 recovery:

> . . . we'd just left [Naval Air Station] [NAS] Sigonella and put all of our gear onboard the USS Ponce and gotten everybody qualified on decks that day. We were I think 12-14 hours away [from the survivor's location] so they went with the TRAP who had V-22s and were already in [position]. The USS Ponce had driven north to Italy to pick us up.[65]

Asked to explain why the 56th RQS had not been in place earlier, this was the officer's reply:

> I can't remember the exact date of return from Operation Enduring Freedom (OEF) [Afghanistan], but I think we got to NAS Sigonella 18 Mar or so and it was under a month from the OEF trip as we were calling people on [Commercial Travel Office] (CTO) [post-deployment leave]. *We were an afterthought as always* {emphasis added}, so it was a hurry to get down there because people were already flying combat sorties, then we broke crossing the [English] Channel and made it down there in 2-3 days then picked up the boat after a day or two. Guys rotated in/out fairly routinely after the one month on the USS *Ponce* when we were at NAS Souda Bay and then the Grecian Base Kalamata taking turns on the [Her Majesty's Ship] (HMS) *Ocean*. [66]

It is complete conjecture to speculate what may have transpired differently had the 56th RQS been deployable sooner in the conflict, but the fact remains the Marines Expeditionary Unit (MEU) was there. So on the evening of 21 March 2011 a Marine TRAP team again successfully rescued a downed AF aviator. Launching once more from the USS *Kearsarge*, this TRAP force consisting primarily of MV-22 Ospreys, AV-8B Harriers, and a KC-130J tanker crossed into Libyan territory and saved Bolar 34 Alpha, an F-15E pilot isolated on the ground, who was at risk of capture from pro-Qaddafi forces.[67]

It should be noted the Marine Corps does not maintain dedicated personnel recovery assets, however, they do mandate recurring and comprehensive training to support their TRAP construct that provides a robust organic PR capability. As part of the pre-deployment training of a MEU, the assigned

Marine Air Ground Task Force conducts multiple training scenarios. Below is an email excerpt from a MAWTS-1 (Marine Aviation Weapons and Tactics Squadron One) AH-1Z Weapons and Tactics Instructor (WTI):

> . . . each MEU will be evaluated on TRAP during each of the Pre-deployment Training Program events. These include several at-sea periods as well as RUT (Realistic Urban Training) events. MEUEX (MEU Exercise), PMINT (US Navy Amphibious Squadron and MEU Integration), COMPUTEX (Composite Unit Training Exercise), MARITIME RUT, GROUND RUT, and CERTEX (Certification Exercise) . . . are all workup events at-sea or from places like El Centro or Pt Mugu. The whole workup period for a typical MEU is appx 6 months. They are evaluated by an entity called Expeditionary Operations Training Group (EOTG) (formerly Special Operations Training Group (SOTG)). EOTG along with fleet WTI's evaluate the final workup period CERTEX to put the "stamp of approval" on them prior to sail.[68]

The important thing to take from this email excerpt, even if the litany of exercise acronyms is foreign to the AF reader, is that the Marine Corps very intentionally and seriously trains to conduct PR.

In June of 2014, the United States admitted to flying manned aircraft over Islamic State (ISIS) held territory in Iraq.[69] US and coalition efforts increased as the operation moved from reconnaissance to include strike operations; on 24 December 2014 a Jordanian F-16 pilot ejected over ISIS held territory and was captured.[70] He was horrifically burned to death, the video released in early February 2015.[71] As a result of this capture and execution of the downed Jordanian pilot, another coalition partner, the United Arab Emirates, refused to continue conducting airstrikes until combat rescue forces were in place; importantly, this demand from the United Arab Emirates (UAE) was six months into manned aircraft operations against ISIS.[72]

The AF's recurring pattern of need and neglect of its CSAR forces verges on organizational embarrassment. Continuing this pattern of neglect, in which the service naively thinks that what it has is good enough, is simply setting the stage for future failure. Unfortunately, given the resurgence of peer competitors, this neglect promises much graver consequences than any since the Vietnam War.

Notes

(All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.)

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Appendix C: Discounting the Osprey for CSAR

The CV-22 is unsuitable as a dedicated solution for CSAR. Almost any cargo or utility-based vertical lift aircraft is potentially useful as a recovery vehicle during a PR mission. However, when it comes to aircraft specifically designated to conduct CSAR as a primary mission, the only real advantage the CV-22 has over the HH-60W is speed, 240knots versus 120 knots. That is significant, and absent some real speed improvements to the HH-60W, there is probably an argument for killing the HH-60W program and buying CV-22s., however, compared to an HH-60W upgraded with Speed Hawk components, the CV-22 is a poor choice for CSAR. The CV-22 is too big, its downwash is excessive, it does not have side-firing, crew-served guns (and the nacelles make it unlikely it will ever get them), and it is extremely expensive to operate. While the Osprey's speed advantage is significant, an HH-60 Speed Hawk mostly negates the V-22's speed margin while besting it in almost all other areas important for CSAR mission effectiveness.

Let us assume the combat rescue pilots of the Vietnam War had the expertise and insight to accurately specify requirements for a CRH. It seems a reasonable nod to their depth of actual CSAR experience. Their parent command, the 3rd ARRG, evaluated the HH-53 as too big for the CSAR mission.[1] A dimensionally larger aircraft requires a larger landing zone, it is also a larger target for optically aimed threat systems, and may potentially have to hover higher in order to maintain obstacle clearance. The CV-22 is smaller than the HH-53, however, is markedly larger than the HH-60.

Table C-1: Relative Aircraft Size[2]

	HH-53B/C	HH-60 / Speed Hawk	CV-22
Length	88ft 2in	64ft 10in	57ft 4in
Wingspan	72ft 3in	53ft 8in	84ft 7in
Landing Zone Area	9,978 ft2	6,249 ft2	8,087 ft2

The major appeal of the CV-22 is its speed. It can fly relatively fast for an aircraft that can land and takeoff like a helicopter. However, rescue history has shown the necessity of hover operations. Therefore, while the CV-22 can take off and land like a helicopter, the force of its downwash is a hindrance to objective area survivability. Improving the speed and efficacy of a hoist operation requires reducing the hover height as much as obstacle clearance will allow, and minimizing the adverse effect of rotor downwash. Downwash is a function of disk loading.

Disk loading is calculated:

$$\text{Disk Loading} = \frac{\text{Weight}}{(\pi\ (0.5 \times \text{Rotor Diameter})^2}$$

Lower disk loading means the rotor downwash is weaker and therefore personnel can work underneath the aircraft with greater ease and speed. Lower disk loading also results in less disturbance to foliage, dust, snow, debris, and so forth. The CV-22's disk loading is almost twice that expected from the Speed Hawk. This greater downwash impedes the speed and safety with which personnel can operate beneath the aircraft. One method to mitigate the effect of high disk loading is to hover higher, giving the downwash opportunity to slow and disperse, however, a higher hover prolongs the operations and increases the exposure of the aircraft to enemy action. Not really a good thing during a combat rescue mission.

Table C-2: Rotor Disk Loading[3]

	HH-53B/C	HH-60G/W	Speed Hawk	CV-22
Rotor Diameter	72ft 3in	53ft 8in	53ft 8in	38ft
Maximum Gross Weight	42,000 lb	22,000 lb	26,600 lb	52,870 lb
Rotor Disc Loading	10.25 lb/ft2	9.72 lb/ft2	11.76lb/ft2	23.3 lb/ft2

HH-60 Speed Hawk vs CV-22 Predictive Cost Analysis[4]

A cost comparison of the HH-60 VTDP Speed Hawk to the CV-22 must consider two elements, acquisition cost and operating cost. To provide the best comparison, the flyaway costs will be used as unit acquisition cost and the DOD Comptroller Reimbursement Rates will be used to provide CPFH. The higher of the two previously estimated flyaway costs for the HH-60 Speed Hawk (in BY14 dollars) will be used; $49.1 million. The flyaway cost for the CV-22 in BY05 is $68.77, adjusted for inflation, it becomes FY14 $83.36 million. This analysis assumes a one-for-one comparison of HH-60 Speed Hawk to CV-22, that is, 112 HH-60 Speed Hawks to 112 CSAR-CV-22s.

The CV-22 is currently in service with the USAF, so recent CPFH data is readily available from the Under Secretary of Defense Comptroller's website. However, an estimate for the CPFH for the HH-60 Speed Hawk will be derived from existing data for HH-60G and like models along with an estimated cost increase drawn from a 2003 Georgia Tech assessment of VTDP technology. This report estimated a 10percent increase in operating costs for a VTDP H-60 over a base H-60.[5] It is worth noting Georgia Tech estimated this higher operating cost based on a VTDP's increased gross weight relative to a base H-60.[6] In 2003 Georgia Tech did not have the data showing significant vibratory load reductions achieved by the X-49A, which may have tempered their estimated cost increase. Nonetheless, in the absence of a more compelling assessment, this 10percent increase is used here. A key element to estimating total long-term costs is the growth in CPFH over time that the CV-22 and Speed Hawk are likely to experience. In order to provide a reasonable estimate of this cost growth increase over time, the Microsoft Excel TREND function is used to project CPFH backward to a baseline year of FY97 for the UH-60L and HH-60H (HH-60G CPFH data is available back to FY97). Neither the CV-22 nor MV-22 have been in use long enough, nor have their CPFHs stabilized sufficiently, to use their limited data sets to derive any kind of projected growth in CPFH over time. The Speed Hawk does not even exist, so using a sample of H-60 CPFH data from three separate services to develop a representative CPFH growth rate seems reasonable and fair to the analysis.

Table C-3: Cost Per Flying Hour[7]

Fiscal Year (FY)	HH-60G (USAF)	UH-60L (USA)	HH-60H (USN)	MV-22 (USMC)	CV-22 (USAF)
1997	$1,321	$1,320*	$1,427*		
1998	$1,550	$1,592*	$1,352		
1999	$1,533	$1,742	$1,352		
2000	$1,903	$1,675	$1,554		
2001	$1,842	$1,572	$1,820		
2002	$2,265	$1,749	$2,579		
2003	$2,593	$1,967	$2,970		
2004	$3,887	$2,891	$3,917		
2007	$4,871	$4,150	$4,925		
2008	$5,011	$4,313	$4,943		
2009	$5,132	$4,620	$4,772		
2010	$5,690	$4,543	$4,465	$8,529	$5,500
2011	$5,659	$4,777	$5,261	$13,730	$13,482
2012	$6,250	$4,009	$4,521	$12,747	$26,514
2013	$6,481	$4,042	$5,720	$14,133	$21,321
2014	$7,139	$4,059	$5,543	$13,032	$25,732

In order to distill out the cost growth over time, the CPFH data is normalized to present a dimensionless *factor of increase* for each aircraft's cost growth against the FY97 reference year. The formula used is:

$$\text{Factor of Increase} = \frac{(\text{Reference FY CPFH}-\text{FY97 Baseline CPFH})}{\text{FY97 Baseline CPFH}}$$

Normalizing allows the data set to begin at a Factor of Increase of zero at the FY97 baseline. Table C-4 lists this new normalized data, it is also depicted as a series of scatterplots in Figure C-1.

Table C-4: Normalized Factor of Increase over Baseline FY97 Cost Per Flying Hour[8]

Year Count	HH-60G	UH-60L	HH-60H
1	0.000	0.000	0.000
2	0.173	0.206	-0.053
3	0.160	0.320	-0.053
4	0.441	0.269	0.089
5	0.394	0.191	0.275
6	0.715	0.325	0.807
7	0.963	0.490	1.081
8	1.942	1.190	1.745
9	2.687	2.144	2.451
10	2.793	2.267	2.464
11	2.885	2.500	2.344
12	3.307	2.442	2.129
13	3.284	2.619	2.687
14	3.731	2.037	2.168
15	3.906	2.062	3.008
16	4.404	2.075	2.884

Linear regression modeling is used because it is well suited for analysis and comparison of bivariate data sets like those used here, in which the dependent variable (factor of increase), graphically depicted on the vertical y-axis, is expected to increase against the independent variable (time), depicted on the horizontal x-axis. Each scatterplot shows a best-fit trend line and its corresponding linear equation shown in this format:

$$y= \beta(x)+a$$

In this equation, β is the regression coefficient and is effectively the slope of the trend line, and is the intercept on the y-axis. All the trendlines intercept the zero on the y-axis, so that the regression equations do not display a.

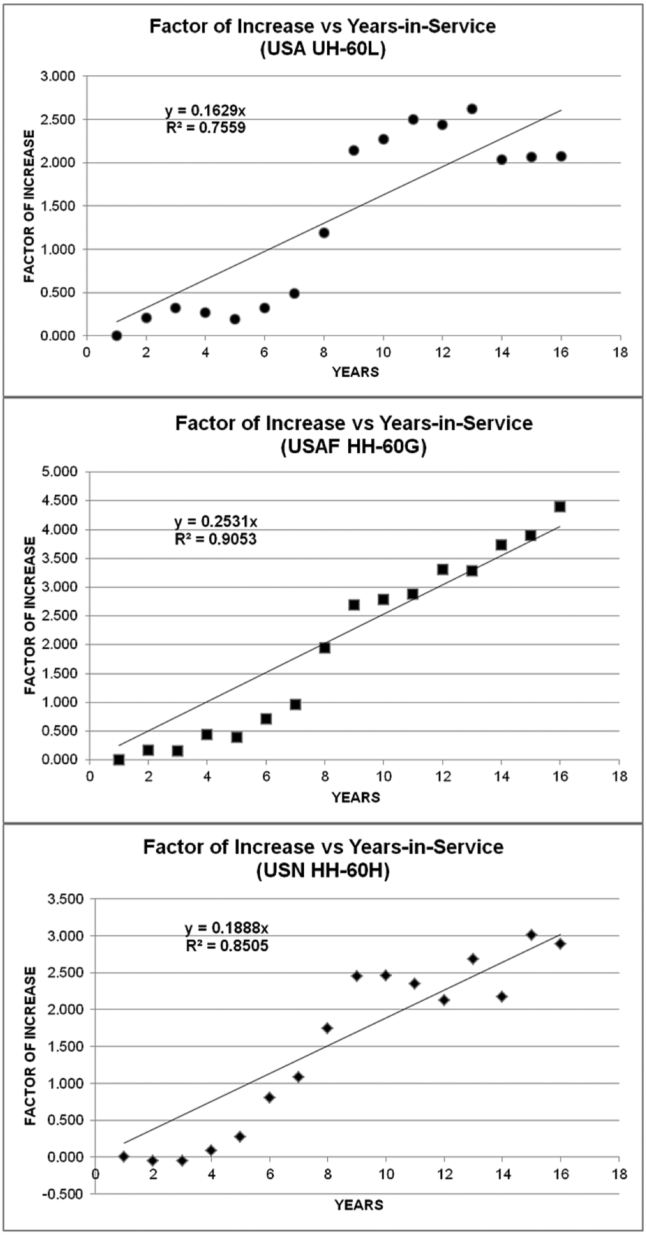

Figure C-1: Scatterplots of Factors of Increase vs Years of Service –UH-60L, HH-60G, HH-60H[9]

A coefficient of determination, displayed as R^2, portrays the "goodness of fit" of the trend line to the available data set; an $R^2 = 1.0$ is a perfect fit, whereas $R^2 = 0.0$ is not a fit.[10] A Defense Acquisition University teaching note discusses cost estimating methodologies; within this paper it specifies an R^2 value of 0.9 as desirable, however, 0.8 as acceptable.[11] Therefore, a minimum R^2 value of 0.8 is the lowest acceptable level of fit for this comparison. An average of the regression coefficients is used to extrapolate the rate of cost growth. Averaging the provides an average R^2 value of 0.8372 for the entire data set of the three aircraft and exceeds the established threshold R^2 value of 0.8.

Table C-5: Regression Coefficients and Coefficients of Determination[12]

Aircraft	Regression Coefficient β	Coefficient of Determination R^2
UH-60L	0.1629	0.7559
HH-60G	0.2531	0.9053
HH-60H	0.1888	0.8505
Average	0.2016	0.8372

For ease of comparison it is assumed that acquisition of all 112 aircraft will take place as a one-time purchase and payment. For the Speed Hawk, the cost of modification is included in the flyaway cost ($49.1 million for FY23 production line cut in). Both "estimated cost" values look only at flyaway cost multiplied by 112. This intentionally excludes other associated costs of simulators, manufacturer support, and so forth. This estimated cost is added later to projected operating costs to give a total expense for each aircraft type.

- Estimated cost for 112 Speed Hawks: **$5,499 million** (112 units × $49.1 million/unit
- Estimated cost for 112 CV-22s: **$9,336 million** (112 units × $83.36 million/unit

In the absence of CPFH data for the Speed Hawk, an average of the CPFH for the HH-60G from FY10-FY17 will be used, with the 10 percent VTDP "penalty" applied per the Georgia Tech report. This seems reasonable. The Speed Hawk will be based on an HH-60W and share 70 percent parts commonality with the H-60 series of helicopters, it seems unlikely the Speed Hawks CPFH will be markedly higher than the aged and maintenance intensive HH-60G plus VTDP penalty. Correspondingly, the analysis will use the CV-22's average CPFH from FY10-FY17. This helps moderate the erratic CPFH rates the CV-22 has experienced since 2010.

Table C-6: Other DOD User Rates (Cost Per Flying Hour)—FY10—FY17[13]

Fiscal Year	HH-60G (USAF)	UH-60L (USA)	HH-60H (USN)	UH-60M (USA)	CV-22 (USAF)	MV-22 (USMC)
2010	$5,690	$4,543	$4,465	$4,577	$5,500	$8,529
2011	$5,659	$4,777	$5,261	$4,615	$13,482	$13,730
2012	$6,250	$4,009	$4,521	$3,648	$26,514	$12,747
2013	$6,481	$4,042	$5,720	$3,506	$21,321	$14,133
2014	$7,139	$4,059	$5,543	$3,292	$25,732	$13,032
2015	$7,474	$4,194	$6,564	$5,045	$25,517	$12,123
2016	$7,310	$4,487		$3,633	$24,005	$12,008
2017	$7,398	$4,378	$7,788	$3,438	$18,785	$12,219
Average	$6,675				$20,107	$12,315

The HH-60W is expected to fly 360 hours per year per aircraft, so this annual utilization rate is be applied to the Speed Hawk and CV-22.[14] Applying 360 hours/year for each aircraft, the total flying hour requirement for a 112 aircraft fleet is 40,320 hours/year. Using the respective average FY10-FY17 CPFH data from Table C-6 as the operating cost baseline for each aircraft, the total estimated fleet operating costs will start at:

- Speed Hawks: $269,136,000 million ($6,675 × 40,320 hours/year)
  - Rounded to: **$269.14 million/year**; add in the 10percent penalty prescribed by the Georgia Tech VTDP report, and a_{SH} is **$322.97 million/year**
- CV-22 Osprey: $810,714,000 million ($20,107 × 40,320 hours/year)
  - Rounded to: **$810.71 million/year**; this will be a_{CV}

These initial operating cost estimates act as the value in the linear regression equation (the y-axis intercept). Combined with the coefficient (0.2016) and the two respective values ($269.14 and $810.71), the linear regression equation is will calculate a single cost point () at a given year. A definite integral will provide the operating expenses over a specific time period:

$$\int_0^x [0.2016(x)+a]\, dx$$

A final assumption is that both aircraft will have 25 years of relevance, meaning 25 years from full operational capability neither the Speed Hawk nor CV-22 will be viable combat solutions. The total 25-year fleet operating cost of the Speed Hawk is approximately $3,563 million and $8,929 million for the CV-22.

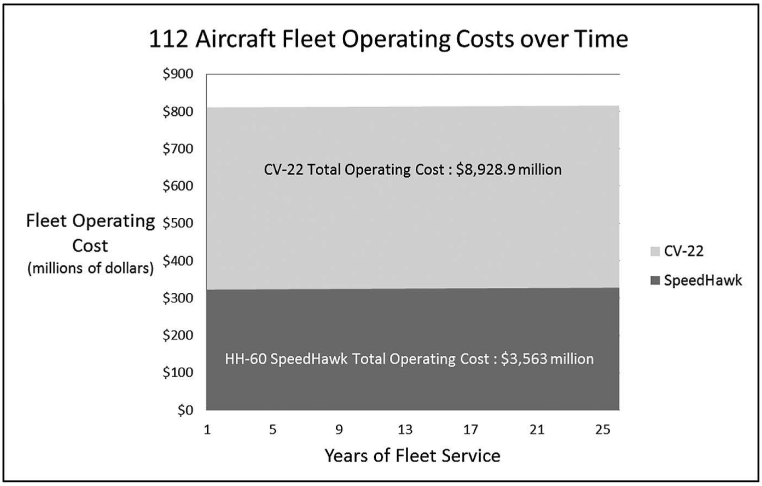

Figure C-2: 112 Aircraft Fleet, Operating Costs over Time

Adding in the initial acquisition cost give a very rough cost comparison of each fleet:

- Speed Hawk: $9,062 million
- CV-22: $18,265 million

These results are very rough estimates. View them as broadly predictive. They are gauges of magnitude, not specificity. Generally speaking, it is probably safe to say the Speed Hawk is going to be much cheaper to buy and operate than the CV-22 and provide more value to the mission. The CV-22 will probably be 15-20 percent faster than the Speed Hawk, however, will cost on the order of 100 percent more. Moreover, the CV-22 is deficient in important characteristics identified earlier. The Speed Hawk accounts for these requirements. Overall, the CV-22 is a poor choice for the CSAR mission when a solution like the HH-60 Speed Hawk is available.

As a parting comment on the CV-22; anyone that proposes purchasing them for CSAR needs to be able to answer a very important question: Who will train the aircrew? While outside the scope of this paper, it is worth mentioning that currently the AF probably does not have much capacity to expand the training pipeline for the CV-22. Anecdotally, based on the author's four years of experience at the 58th Special Operations Wing (the wing responsible for all AF rotary-wing and tilt-rotor training) the AF does not appear to have much CV-22 instructor pilot depth due to poor retention and an inability to season younger pilots because of problematic utilization rates on the CV-22. As of summer 2016—when the author departed the 58th for a new assignment—the AF had to significantly underman its CV-22 training squadron. In contrast, the training burden for transition of conventional HH-60 crews to a Speed Hawk should be much easier since many of the aircraft systems will remain the same and the aircraft controls will remain the same as on a conventional H-60.[15] This would not be the case if the AF were to transition HH-60 pilots to the CV-22.

Notes

1. Francis and Nelson, *Search and Rescue Operations in SEA*, 51 and McLeaish and Silves, *Southeast Asia Operational Analysis of Required Performance Parameters for a Combat Aircrew Recovery Aircraft*, 8,12,13.

2. The landing zone area is calculated as rectangular with 10 feet of clearance from any portion of the aircraft. HH–60 information adapted from TO 1H–60(H)G–1, USAF, 2014, September, CV–22 information from the US Air Force CV–22 Fact Sheet, and HH–53B/C information from 15 March 1967, thisdayinaviation.com. An HH–60 VTDP Speed Hawk variant should have roughly the same dimensional footprint since the main rotor disk dimensions are the same as the HH–60G/W and the ducted tail components appear to require roughly the same obstacle clearance as a conventional H–60 tail rotor and stabilator.

3. HH–60 information adapted from TO 1H–60(H)G–1, USAF, 2014, September, CV–22 information from the US Air Force CV–22 Fact Sheet, and HH–53B/C information from 15 March 1967, thisdayinaviation.com.

4. Most of this analytical methodology, and the relevant data and text, were originally from the author's graduate capstone project "*Enabling Mission Surety: Replacing the USAF UH–1N Fleet*." Significant portions of the text are used verbatim because it provides clarity for the analysis and is applicable to cost comparison between a Speed Hawk and CV–22.

5. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief to Col von Eschenbach and Col Levine. 7 December 2016. Briefing and information are proprietary to Piasecki Aircraft Corporation. Use of information in this unclassified paper has been approved by Piasecki Aircraft Corporation.

6. Briefing. Piasecki Aircraft Corporation. subject: ADAPT & Compound Helicopter Technology Brief and John Piasecki, Fred Piasecki, Christopher Sullivan, Grey Hagwood, and Jimmy Hayes (Piasecki Aircraft Corporation), interview by the author, 13 December 2016.

7. CPFH data after 2014 is not included since the comparison looks at costs in FY2014 equivalent dollars. Adapted from Financial Management Reports by the Under Secretary of Defense Comptroller, 1997–2014. Data in red/asterisked has been projected back to FY97 using the TREND function in Microsoft Excel. Note that data is not available for FY 05 and FY 06. Some of this data and analysis was originally

published in the author's graduate capstone project Enabling Mission Surety: Replacing the USAF UH–1N Fleet, Embry–Riddle Aeronautical University, December 2014.

8. Some of this data and analysis was originally published in the author's graduate capstone project *Enabling Mission Surety: Replacing the USAF UH–1N Fleet*.

9. Each aircraft's scatterplot of factor of increase versus years in service is depicted with a trend line and linear regression equation. Source: This image originally appeared in the author's graduate capstone project *Enabling Mission Surety: Replacing the USAF UH–1N Fleet*.

10. Williams and Barber, *Cost Estimating Methodologies*, B–17.

11. Williams and Barber, *Cost Estimating Methodologies*, B–17.

12. This table shows the calculated and R2 values for each of the three airframes. The UH–60L's R2 value is less than 0.8. Because the UH–60L's R2 value is less than the established threshold the and R2 values from the other two H–60 variants are averaged in with those of the UH–60L to produce a and that is ideally more predictive because of the higher averaged R2 value. Data originally appeared in the author's graduate capstone project *Enabling Mission Surety: Replacing the USAF UH–1N Fleet.*

13. The other cost data is based on FY14; however, this eight-year average will capture changes in the CPFH due to inflation, on either side of 2014, and largely be inconsequential to a like comparison between the two aircraft. All CPFH data is available from the Undersecretary of Defense Comptroller.

14. Department of Defense, *Selected Acquisition Report (SAR): Combat Rescue Helicopter (CRH)*, 32.

15. During the 13 December 2016 interview at Piasecki Aircraft Corporation, the company's representatives discussed their intent to use the H–60's existing flight controls for the VTDP upgrade, with the intent of reducing the training burden for converting aircrew.

Abbreviations

AAA	Antiaircraft Artillery
AATC	Air National Guard Air Force Reserve Command Test Center
AB	Air Base
ACC	Air Combat Command
AD	Air Division
ADZ	Air Defense Identification Zone
AETC	Air Education and Training Command
AF	Air Force
AFB	Air Force Base
AFRC	Air Force Reserve Command
AFSOC	Air Force Special Operations Command
AGL	Above Ground Level
ANG	Air National Guard
AOA	Angle of Attack
APU	Auxiliary Power Unit
AR	Air Refueling
ARC	Air Reserve Component
ARRG	Aerospace Rescue and Recovery Group
ARRS	Aerospace and Rescue and Recovery Service
ARS	Air Rescue Service
ASDR&E	Assistant Secretary of Defense for Research and Engineering
ATO	Air Tasking Order
AW	Artillery Weapons
BRU	Bomb Rack Units
BY	Base Year
CARA	Combat Aircrew Recovery Aircraft
CAS	Close Air Support
CASEVAC	Casualty Evacuation
CERTEX	Certification Exercise

CFACC	Combined Forces Air Component Commander
CHECO	Contemporary Historical Examination of Current Operations
CINCPACAF	Commander in Chief, Pacific Air Forces
COIN	Counterinsurgency
COMPUTEX	Composite Unit Training Exercise
COMUSMACV	Commander US Military Assistance Command Vietnam
CPFH	Cost per Flying Hour
CPI	Consumer Price Index
CRH	Combat Rescue Helicopter
CSAF	Chief of Staff of the Air Force
CSAR	Combat Search and Rescue
CSARTF	Combat Search and Rescue Task Force
CTO	Commercial Travel Office
DMZ	Demilitarized Zone
DOD	Department of Defense
EGMS	External Gun Mount System
EO/IR	Electro-optical / Infrared
EOTG	Expeditionary Operations Training Group
EW	Early Warning
FAA	Federal Aviation Administration
FAC	Forward Air Controller
FCF	Functional Check Flight
FHP	Flying Hour Program
FLIR	Forward Looking Infrared
FOL	Forward Operating Locations
FRP	Full Rate Production
FVL	Future Vertical Lift
FY	Fiscal Year
GE	General Electric
HAF	Headquarters Air Force

HMLA/T-303	Marine Light Attack Helicopter Training Squadron 303
ILRP	Initial Low-rate Production
INS	Inertial Navigation System
ISIS	Islamic State
ITEP	Improved Turbine Engine Program
JOPREP	Joint Operational Reporting System
KGS	Kilograms
KIAS	Knots Indicated Air Speed
KT	Knots
LAA	Light Attack Aircraft
LRIP	Low-Rate Initial Production
M	Miles
MAC	Military Airlift Command
MACSOG	Military Assistance Command Studies and Observation Group
MACV	Military Assistance Command Vietnam
MANPADS	Man Portable Air Defense Systems
MAWTS-1	Marine Aviation Weapons and Tactics Squadron One
MEDEVAC	Medical Evacuation
MEU	Marines Expeditionary Unit
MEUX	Marines Expeditionary Unit Exercise
MM	Millimeter
NAS	Naval Air Station
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
NEO	Noncombatant Evacuation Operations
NM	Nautical Miles
NNE	North-northeast
NRE	Non Recurring Engineering
NVN	North Vietnam
OBIGGS	Onboard Inert Gas Generating System

OCA	Offensive Counterair Attack
OEF	Original Equipment Manufacturer
OSC	On-scene Commander
PACAF	Pacific Air Forces
PARC	Pacific Air Rescue Center
PAUC	Program Acquisition Unit Cost
PiAC	Piasecki Aircraft Corporation
PJ	Pararescuemen
PMINT	US Navy Amphibious Squadron and MEU Integration
PNT	Position, Navigation, and Timing
POW	Prisoner of War
PR	Personnel Recovery
RAF	Royal Air Force
RAND	Research and Development
RDT&E	Research, Development, Testing, and Evaluation
RESCORT	Rescue Escort
RMC	Rescue Mission Commander
RQS	Rescue Squadron
RTAFB	Royal Thai Air Force Base
RUT	Realistic Urban Training
RVN	Republic of Vietnam
SAM	Surface-to-air Missile
SAR	Search and Rescue
SARTF	Search and Rescue Task Force
SAW	Special Air Warfare
SBIR	Small Business Innovation Research Program
SEA CSAR	Southeast Asia Combat Search and Rescue
SEA	Southeast Asia
SEAD	Suppression of Enemy Air Defense
SF	Special Forces
SHP	Shaft Horsepower
SOCOM	Special Operations Command

SOF	Special Operations Forces
SOTG	Special Operations Training Group
SPU	Supplementary Power Unit
SSE	South-southeast
SSW	South-southwest
STTR	Small Business Technology Transfer
SW	Southwest
TAC	Tactical Air Command
TACAN	Tactical Air Navigation
TF/TA	Terrain Following / Terrain Avoidance Radar
TRA	Technology Readiness Assessment
TRAP	Tactical Recovery of Aircraft and Personnel
TRL	Technology Readiness Level
UAE	United Arab Emirates
USAF	United States Air Force
USAFE	United States Air Forces in Europe
USAF SAR	United States Air Force Search and Rescue
USMC	United States Marine Corps
USS	United States Ship
UTC	Unit Type Code
UTTR	Utah Test and Training Range
VCNO	Vice Chief of Naval Operations
VIS	Visibility
VMC	Visual Meteorological Conditions
VTDP	Vectored Thrust Ducted Propeller
WEZ	Weapons Engagement Zone
WNW	West-northwest
WSO	Weapons System Officer
WTI	Weapons and Tactics Instructor
WX	Weather

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