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Final Report

Volume I

ANALYSIS OF FUTURE REQUIREMENTS FOR TRANSPORTATION ROTORCRAFT IN ARMY CS AND CSS MISSION AREAS

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FINAL

Volume I

ANALYSIS OF FUTURE REQUIREMENTS FOR TRANSPORTATION ROTORCRAFT IN ARMY CS AND CSS MISSION AREAS

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The study investigates requirements for Army rotorcraft for future Combat Support (CS) and Combat Service Support (CSS) missions. Factors considered are the threat, the operational fielded fleets, the technology base, and AirLand Battle 2000 operational concepts. The results of this effort define the cost-effective logistics rotorcraft fleet to perform CS and CSS missions and identifies technology programs for rotorcraft system development.

The force structure and the planned rotorcraft fleet size/mix are defined for the 1995-2015 timeframe. Mission requirements, the technology base and the

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Section 1
INTRODUCTION

STUDY OVERVIEW

General

The purpose of this study is to investigate the future (1995-2015) requirements for Army rotorcraft in the Combat Support (CS) and Combat Service Support (CSS) mission areas. The study objectives are to:

- Define cost-effective transportatiaon rotorcraft fleet mixes to perform the CS and CSS missions

- Recommend technology programs for CS and CSS system development

This project; performed for the Advanced Concepts Division, US Army Aviation Systems Command; consists of the accomplishment of four principal research tasks. The objectives of these tasks are:

Task 1. The Definition of Future Transport Aviation Mission Requirements

Task 2. The Description of Advanced Technology Rotorcraft Concepts

Task 3. The Definition of Logistic Rotorcraft Fleet Size/Mix based upon Army 86

Task 4. The Identification of the Characteristics, Quantities, and Mixes of Rotorcraft Systems to

Perform Future Transport Aviation Mission Requirements for the Lowest Life Cycle Cost.

Under subcontract to the McLean Research Center, Inc. (MRC), Burdeshaw Associates, Ltd (BAL) accomplished Tasks 1 and 3 above.

An outline of the approach used to accomplish the objectives of this study is shown in Figure 1-1. This illustration summarizes the flow of the research effort and reflects the relationships between the project tasks.

Mission Definition

The definition of future transport aviation mission requirements reveals that nine missions will be assigned to rotorcraft for accomplishment. The identity of these missions and some of their characteristics are summarized in Table 1.1. These data reflect a typical day of US V Corps operations in Europe and XVIII Airborne Corps operations in Southwest Asia. The information included are the number of missions per day, mission radii and mission durations. Mission accomplishment sequences are discussed in a subsequent section of this report. The mission definition task also identifies payload/radius requirements which occur with sufficient frequency to define design points for the rotorcraft concepts developed in Tasks 2 and 4.

Aviation Structure

The structure of doctrinal Army 86 aviation organizations is summarized in Table 1.2. This information includes only the utility and cargo rotorcraft composition of a Corps Aviation Brigade and the aviation units organic to Army divisions.

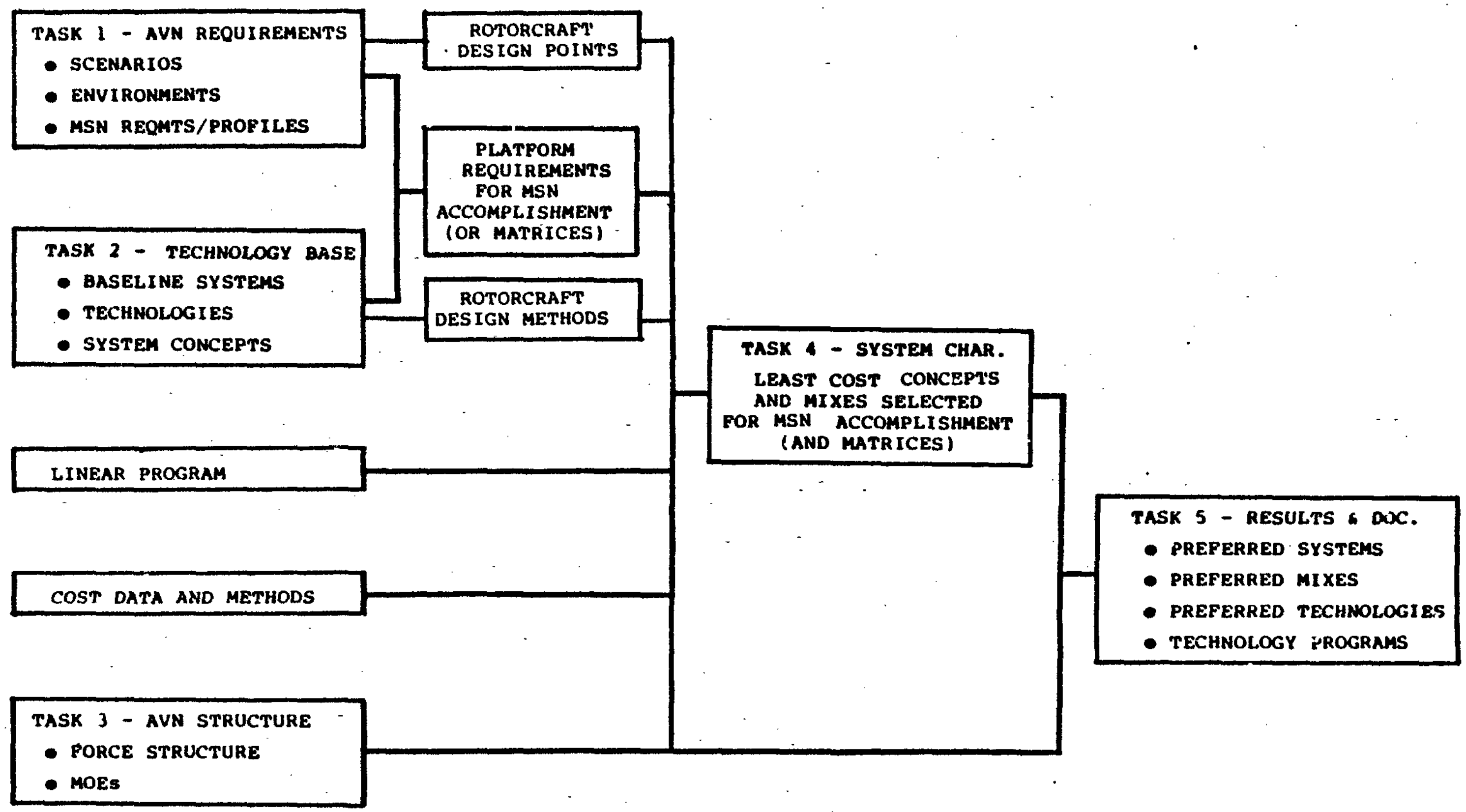

Figure 1.1. Study Approach

TABLE 1.1. SUMMARY OF ROTORCRAFT MISSION REQUIREMENTS

Mission Type	Frequency (Number/Day)		Radius (Km)		Accomplishment Time (Hrs)	
	Europe	Southwest Asia	Europe	Southwest Asia*	Europe	Southwest Asia
Unit Moves	47	42	25-50	75-150	2-4	2-8
Supplies/Equip.	13	5	50-200	100-150	24	24
Special Weapons	10	0	25-200	N/A **	2	N/A**
Engineer Support	7	4	50-75	100-150	2-8	2-8
APOD Clearance	2	1	150-250	150	24	24
MEDEVAC	1	1	50-150	150	2-3	2
SPOD/Lots	4	4	25	25	24	24
Equip Recovery	6	12	50-150	100-150	4	4
Personnel	1	1	200	150	24	24
Total	91	70				

*Mission radii are based on the assumption that Air Force aircraft will deliver Army cargo to the Forward Operating Bases (FOL) which are division areas. Mission radii will be greater if FOB's are not used.

**Is is assumed that nuclear and chemical weapons are not employed in Southwest Asia.

TABLE 1.2. COMPOSITION OF UTILITY AND CARGO ROTORCRAFT IN ARMY AVIATION ORGANIZATIONS

Type Rotorcraft	Number of Rotorcraft					
	Corps Avn Bde	Hvy Div	Inf Div	Abn Div	AA Div	HTMD
UH-1H	30 1/	6	6	6	28	8
UH-60A	45 2/	15	30	45	90	30
CH-47D	48 3/	0	0	0	32	16

1/ 10 per Gen Spt Avn Co
2/ 15 per Combt Spt Avn Co
3/ 16 per Med Helicopter Co

Technology Base

The technology base used to explore and define rotorcraft concepts for transportation mission accomplishment are:

- Conventional shaft driven rotor
  - Advanced composites
  - Engine uprating
  - Twin lift
- Tilt rotor
- Warm cycle propulsion
- Lighter-than-air

This technology base results in the selection of the specific rotorcraft candidates identified in Table 1.3. These specific concepts are used to select the least cost mix of rotorcraft for accomplishing all of the missions allocated to rotorcraft as defined in Task 2.

In addition to the specific candidates identified in Table 1.3, research of the technology base resulted in the evolution of rotorcraft conceptual design and cost estimating techniques. These are used to select and identify preferred rotorcraft technologies and concepts to satisfy high frequency mission design points developed from the mission requirements specified in Task 2.

In both the least cost mix and the least cost concept evaluations, rotorcraft mission accomplishment capability is assessed at 2000 feet pressure altitude and 70 degrees Fahrenheit in the European scenario and at 4000 feet pressure altitude and 95 degrees Fahrenheit in the Southwest Asia (SWA) scenario.

The resulting dimensions of the least cost mix analysis which covers all identified missions are:

- Three Battle Phases in Europe
- Two Battle Phases in Southwest Asia
- 12 specific Rotorcraft Candidates

The dimension of the least cost concept analysis, which is based upon selected high frequency missions are:

- Six design points for Europe
- Seven design points for Southwest Asia
- Four Principal Rotorcraft Technologies (Conventional Shaft Driven Rotor, Tilt Rotor, Warm Cycle Rotor Propulsion and Lighter-Than-Air)

TABLE 1.3. SELECTED ROTORCRAFT CANDIDATES

Rotorcraft Useful Load* (Klbs)	Rotorcraft Representing Design Technology					
	Conventional Shaft Driven Rotor	Tilt Rotor	Composite	Uprated Engine	Lighter Than Air	Warm Cycle
4.4	UH-1H					
9.7	UH-60A					
23.0		JVX				
27.5	CH-47D					
34.4			COMP47			
40.4	CH-53E					
51.2				MOD53		
83.1	HLH					
100.0					HLA	
174.0						HWC

* Useful load. The load-carrying capability of an aircraft, including payload, crew, oil and usable fuel required for the mission. This is the difference between gross and basic weight.

Principal Assumptions

The major simplifying assumptions made to conduct this evaluation within the allocated resources are listed in Table 1.4.

TABLE 1-4. MAJOR STUDY ASSUMPTIONS

- Mission Assumptions
  - Corps Slice
  - Single typical day
  - All tasks are essential

- Environmental Assumptions
  - Europe: 2000'/70 degrees F
  - Southwest Asia: 4000'/95 degrees F

- Assumptions Which Affect Rotorcraft Technologies
  - Rotorcraft Technologies are represented by Single Rotorcraft Candidates for the Least Cost Mix Analyses
  - Principal Rotorcraft Technologies are reflected in Parametric Form for the Least Cost Concept Evaluation based upon selected High Frequency Mission Design Points
  - Payload, radius, speed, procurement cost, operating cost, gross weight and basic weight are the principal Rotorcraft characteristics considered

As indicated above these assumptions are made to accommodate the scope and resources associated with this research effort. The information derived from the least cost mixes of rotorcraft candidates to accomplish all missions and the least cost rotorcraft technologies and concepts to accomplish selected mission are combined to provide the results needed to satisfy the objectives of this study.

REPORT ORGANIZATION

Section 2 of this volume presents the results of the analysis of future transportation mission requirements for Army aviation and summarizes the aviation force structure defined by Army 86 and the Army Aviation Modernization Plan. Section 3 describes the technology base used to evolve the rotorcraft candidates and conceptual designs evaluated in this study. Section 4 presents the least cost mix and the analysis of rotorcraft technologies and concepts based upon mission related design points. Section 5 summarizes the results of these analyses and presents the findings associated with, and resulting from, this effort. Volume II contains the reports generated by Burdeshaw Associates, Ltd in support of this research project and other relevant technical appendices.

Section 2
TRANSPORTATION MISSION REQUIREMENTS

PERSPECTIVE

The transportation mission requirements developed in this section are used to evaluate the performance of U.S.Army rotorcraft candidates, candidate fleet mixes and rotorcraft concepts. The transportation missions on the battlefields of the 21st Century are based upon an examination of future U.S.Army organizations, future concepts for tactics and operations, the threat, and combat service support requirements derived in the context of a Europe-NATO scenario and a Southwest Asia scenario.

The research which provided the necessary data and information includes the review of the U.S.Army Aviation Mission Area Analysis, the Combat Service Support Mission Area Analysis and earlier rotorcraft studies such as HELILOG and the more recent HELILOG Update.

The steps in developing transportation mission requirements are shown in Figure 2.1

1. Review previous rotorcraft studies and analyses
2. Review relevant mission area analyses
3. Examine U.S.Army concepts for future organization and combat operations
4. Consider the future threat
5. Study selected scenarios
6. Determine combat service support requirements
7. Define transportation rotorcraft missions

Figure 2.1. Developing Transportation Mission Requirements

ARMY STRUCTURE AND OPERATIONS

Army Organization

The U.S.Army '86 studies are the basis for the aviation structure used in this study. It is assumed that the U.S.Army force structure will change very slowly and that most divisional and non-divisional organizations projected for 1990 will exist in 2015. Further, it is assumed that the supply consumption (Class I, III etc) factors will not change dramatically and that current NATO and contingency corps scenarios provide an adequate basis for defining transportation missions.

Some trends which are not yet fully accepted or programmed are identified and incorporated into the analysis. One of these is that light infantry divisions will be smaller and lighter than current infantry divisions.

Army Aviation Organization

The Army has implemented a functionally oriented aviation organization based upon a series of Army '86 force structure studies. The key aviation organizations are: The Corps Aviation Brigade, and the divisional Combat Aviation Brigade. The organization of the corps and division aviation brigades are depicted in Figures 2.2 and 2.3.

Army Concept of Operations

The Army's evolutionary concept for fighting a war in the next century is described in the "Airland Battle 2000 Concept" (ALB 2000), now called Army 21, and will be the unifying concept for doctrinal, force, material, and training development and the

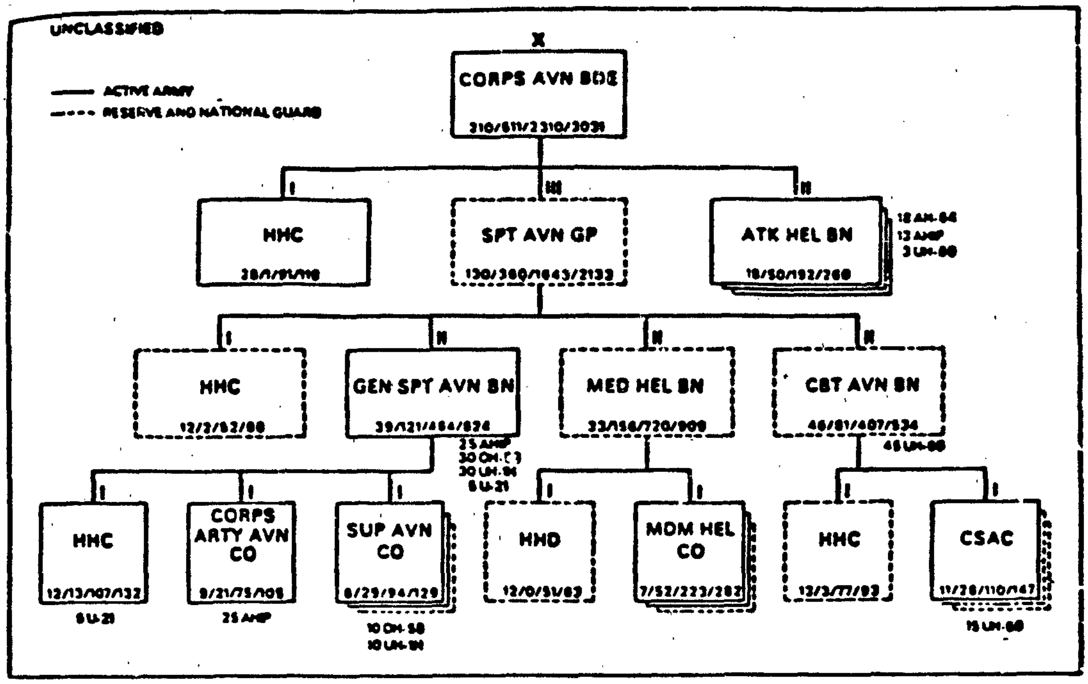

Figure 2.2 Corps Aviation Brigade (U)

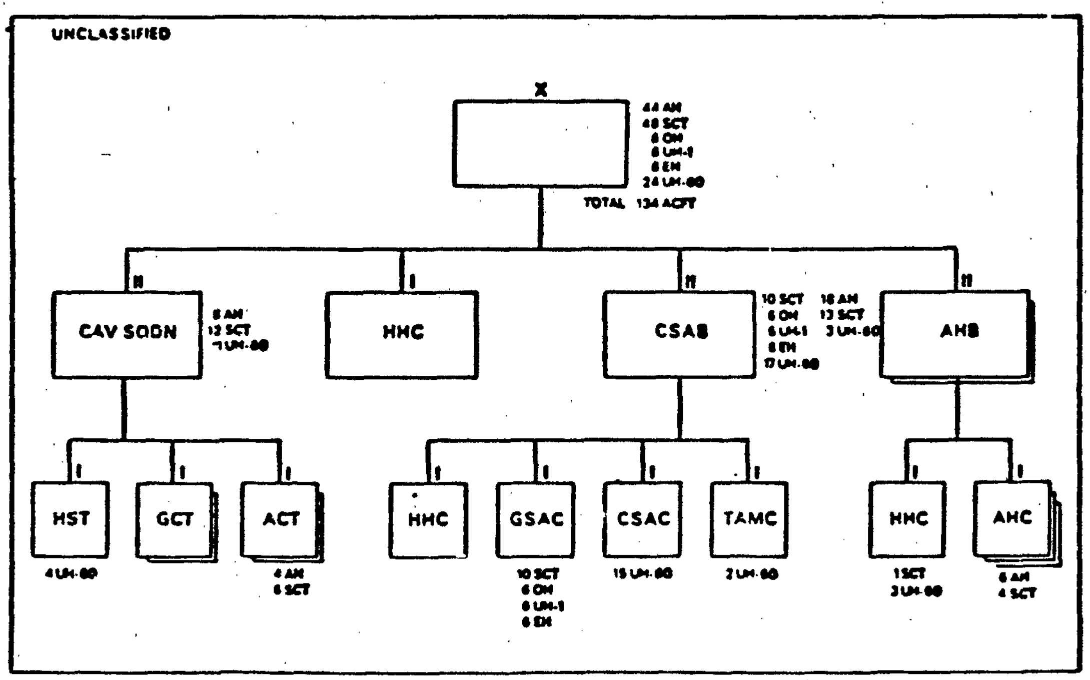

Figure 2.3. Division Combat Aviation Brigade

driving force for joint operations such as rapid deployment. This concept has been integrated into this study. The following is a summary of the principal aspects as they pertain to the transport rotorcraft requirement.

- The essence of the concept is maneuver which enables the commander to place the enemy in a position of disadvantage through the flexible application of combat power.

- The requirement is to see and strike deep.

- At the corps level, the concept stresses decentralized execution by small, self-sufficient units.

- Agility is a pre-requisite.

- The battlefield is extended in depth and oriented on the enemy.

- Army aviation provides the commander the capability to mass rapidly.

- Continuous operations will generate increased logistic demands and require continuous logistic support.

- The integrated battlefield will embrace conventional, nuclear, chemical and biological warfare to include contaminated areas.

SCENARIOS

The transportation mission requirements for rotorcraft used in this study are derived from the analysis of two standard

U.S.Army scenarios. These are the TRADOC SCORES, Europe III, Sequence 2A which provides a high intensity combat environment and the Southwest Asia scenario adapted from SCORES, Middle East III which provides a most difficult contingency operation. The latter scenario has the additional advantage of providing a non-linear combat setting (islands of conflict) as described in the Army 21 Concept.

In each of the two scenarios the transport rotorcraft requirements were drawn from the operations and support demands of a U.S. Corps. The requirements thus derived represent a corps slice (with EAC support) for heavy forces in the Europe-NATO theater and for a rapid deployment force in Southwest Asia. The two scenarios are discussed briefly below; more complete descriptions are provided in Appendix A, Volume II.

The two scenarios provide very different operational environments for U.S.Army rotorcraft. The effects of environmental conditions on rotorcraft are also discussed in Appendix A, Volume II.

Europe - NATO Scenario

A NATO-Warsaw Pact (WP) war remains the most serious threat to U.S.security. While it is not the most likely threat, its magnitude and sophistication, the vital requirement to win the first battle and sustain our forces until final victory, and the very real possibility of the escalation of combat by use of nuclear and CBR weapons continue to make it dominant in postulating US equipment capabilities.

The Europe-NATO scenario focuses on the operations of the US V Corps in the Fulda Gap area as part of the NATO forces opposing an all-out conventional Warsaw Pact attack in the Central Region. The study examines the transportation requirements for the corps force from D-Day to D + 30 and through three phases of combat operations - delay, defense and counterattack.

The V Corps consists of an armored cavalry regiment and four divisions (1-armored division, 2-mechanized infantry division and 1-high technology motorized division) plus corps troops. The threat forces opposing the corps consist of two first echelon WP armies with a total of five divisions and one second echelon army with three more divisions. See Figure 2.4.

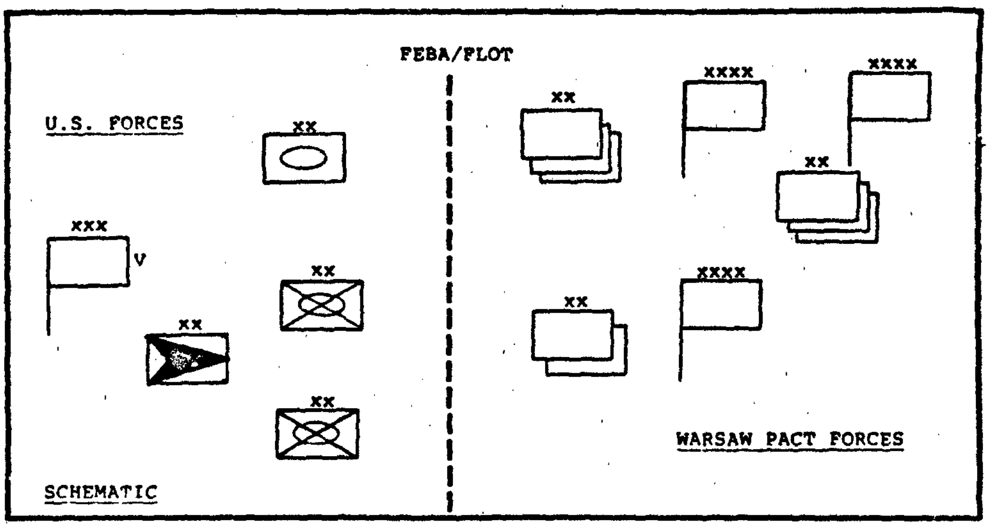

Figure 2.4 Opposing Forces in Europe

Southwest Asia Scenario

As the global supply of oil continues to dwindle, the importance of the reserves in this area will inevitable increase. Not only are the Soviets aware of Western dependence on this vital source, they are likely to compete for access as their own reserves are depleted. The threat is further magnified by seemingly intractable regional problems which create opportunities and temptations for Soviet adventurism, either directly, or by the use of surrogates. The temptation will become stronger as the Soviets' own power projection capability matures. It is expected that the Middle East/South West Asia will remain the most likely area of U.S. force commitment.

The scenario follows the operations of the US XVIII Airborne Corps as it opposes Soviet forces which have invaded Iran. The transportation rotorcraft requirements to support the Corps are examined over a 30-day period on the delay and defense phases of combat operations. The subsequent counterattack phase of operations is not included in the study since it involves heavy combat forces which were brought into the theater later and this becomes similar to the European scenario.

The XVIII Airborne Corps consists of three divisions - 1 airborne division, 1 - airborne (air assault) division and 1 - high technology motorized division. The threat forces opposing the US Corps are organised into three armies with a total of 17 divisions (See Figure 2.5). The scenario depicts forces engaged in combat operations on a wide front and deployed in great depth. The interesting characteristics of the theater include:

- Limited road net and infrastructure
- Larger operational area
- Demanding flight conditions (4000 ft, 95 degrees F)
- Dispersed forces

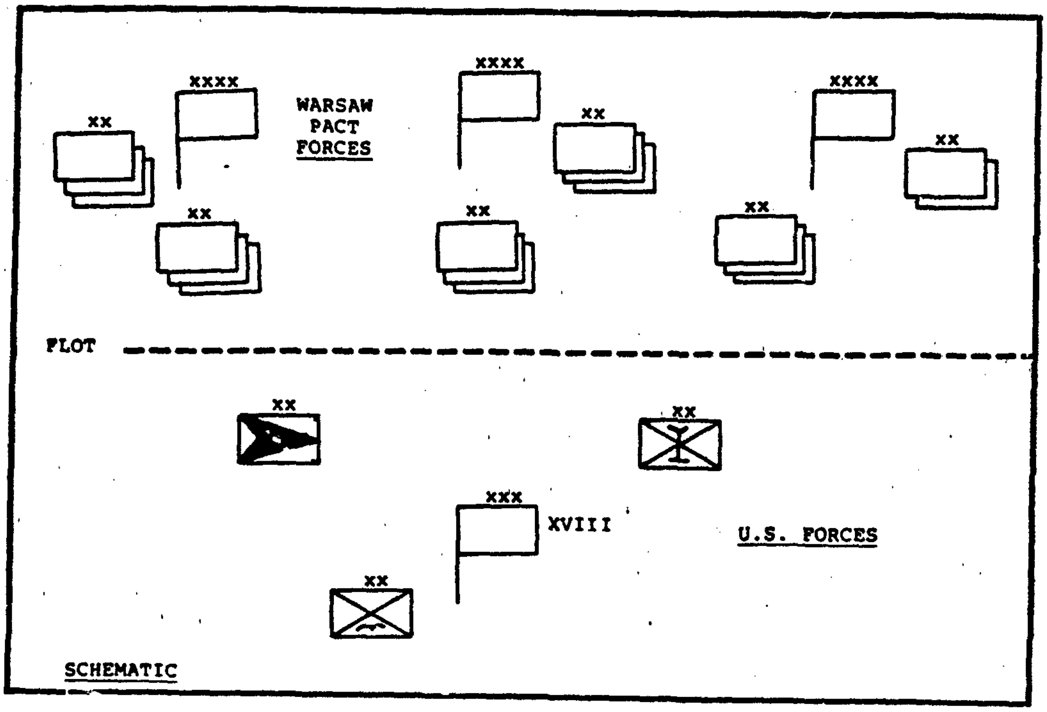

Figure 2.5. Opposing Forces in Southwest Asia

DEVELOPMENT OF TRANSPORTATION MISSIONS

Transportation missions are developed by combined quantitative and judgemental analysis of the combat service support requirements of a corps force in the context of the scenarios discribed above. The following discussion briefly describes the methodology and procedures since more detail is provided in Appendix A of Volume II.

Methodology

The methodology for determining the expected transportation missions in the 21st Century includes the following steps:

- Review of relevant studies and analyses.
- Identification of transportation missions which would be performed in each of the operational scenarios and which are representative of likely Army missions.
- Identification of the important qualitative and quantitative factors affecting each mission.
- Description of the tasks in terms of payload, distance, frequency, threat, and geographical and operational conditions.
- Judgemental prioritization of the missions.

Sources of information

The scenarios and missions are derived from a projection of future Army operations based on:

- Current contingency planning
- Programmed force planning (TAA-90)
- SCORES scenarios used for combat developments
- Army 21 Concept (formerly Air Land Battle 2000)

The scenarios are selected to set forth a variety of environmental and operational conditions and provide a reasonable basis for mission identification.

Two approaches are used for mission identification. Some are developed judgementally by the study team based on collective experience. Others are identified from the following sources:

- Army Aviation Mission Area Analysis
- Combat Service Support Mission Area Analysis
- HELILOG (1977)
- HELILOG Update (1983) - working papers
- TAA-90
- OMNIBUS-81
- Congressionally Mandated Mobility Study (1981)
- Discussions with appropriate experts within the Army

Assumptions and Constraints

The key assumptions used in the mission analysis are:

- Army missions in the 21st Century will be similar to those projected for 1990 in the Army 21 concept.
- Army 21, although evolutionary, adequately portrays future Army doctrine and force employment concepts.
- Current NATO and contingency corps scenarios, with minor adjustments, provide an adequate basis for mission identification.
- The U.S.Army force structure will change slowly and most divisional and non-divisional organizations projected for 1990 will exist in 2015.
- Supply consumption factors will not change dramatically.

- Trends which are identified but not yet fully accepted or programmed. are incorporated in this analysis.

- Light infantry divisions will be smaller and lighter than current infantry divisions.

- Ammunition usage will decrease with greater consumption of precision munitions.

- Precision munitions will be limited and the distribution will be centrally controlled.

- More high value equipment will be centrally controlled and distributed.

- There will be NBC decontamination and protection techniques which do not exist today.

TRANSPORTATION MISSION DESCRIPTIONS

After a careful review of relevant studies and analysis of the operational scenarios eleven generalized transportation missions have been identified. These are listed in Figure 2.6 and are described briefly below.

REPOSITIONING OF UNITS
MOVEMENT OF SPECIAL WEAPONS
MOVEMENT OF SUPPLIES AND EQUIPMENT
AERIAL PORT CLEARANCE
LOGISTICS OVER THE SHORE AND WATER PORT CLEARANCE
ENGINEER SUPPORT
BATTLEFIELD RECOVERY
MEDEVAC
PERSONNEL MOVEMENT
NBC SUPPORT
EVACUATION OF DECEASED PERSONNEL

Figure 2.6. Transportation Missions for Army Rotorcraft

Repositioning of Units

This mission includes the movement of both tactical and support units such as:

- Brigade task force deployments
- Combat assaults by infantry units
- Repositioning artillery and air defense
- Command post movements
- Positioning communication relay teams
- Establishment of FARRPs
- Movement of CSS units

Movement of Special Weapons

This mission is the transportation of nuclear cannon projectiles, nuclear missile warheads, and chemical and precision guided munitions. The air movement of nuclear projectiles and warheads is a high priority mission that often is necessiated by security requirements as much as by the need for speed. The movement of special weapons by Army aircraft is preferred for transport from the APOD or peacetime storage locations to the field storage locations (FSL), on to the SASP and in some cases, for transport to the artillery unit which will deliver the weapon on target.

Movement of Supplies and Equipment

Success in combat operations depends on continuous adequate logistical support. Army 21 intensifies this dependence and the need for rotorcraft which will be the preferred transportation mode for scarce, sensitive, or high priority items. Army rotorcraft support will frequently be required to assure timely delivery of critical POL, ammunition, and repair parts to combat units. Some airlift will be required at all echelons from brigade up to division, corps and echelons above corps. It is expected that there will always be a need for airlifting supplies and equipment on the battlefield even if the need does shift from one unit to another or from one area to another. The decision to use airlift in any given situation will be governed by the ongoing combat operations, the intensity of conflict, the availability/capability of land transportation, the distance to be traveled and the urgency of the need as well as the availability of rotorcraft.

Aerial Port of Debarkation (APOD) Clearance

Rapid movement of high priority cargo, both personnel and supplies/equipment, out of the aerial port or Forward Operating Base (FOB) is an important mission in any scenario and Army

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rotorcraft airlift is an extension of Air Force airlift. The use of Army rotorcraft for APOD Clearance sustains the forward movement of high priority cargo and at the same time relieves congestion and reduces vulnerability at the airfield.

The destination of cargo from the APOD would be theater storage areas, corps storage areas or supply points, division supply points or even to operational units depending upon need.

Sea Port of Debarkation (SPOD) Clearance and Logistics Over the Shore (LOTS)

Most cargo will be delivered to an operational theater by sea. It must be offloaded from ships and transported to storage areas, local transfer points or to reconstitution sites where combat forces and support units rendezvous.

When possible, established seaports are used. However, in some situations, particularly in contingency operations, port and harbor facilities may be inadequate, damaged or non-existent. In such cases, cargo may be delivered over an open beach (LOTS). In these cases, it is unlikely that sufficient indigenous lighterage and other cargo handling equipment would be available to move the cargo; it will be slow and lift-expensive to move sufficient offloading equipment from CONUS to the objective area. Hence, rotorcraft may be used to speed up unloading and port clearance.

The cargo to be moved by rotorcraft would include outsized equipment, 40 ft containers weighing up to 35 tons, 20 ft MILVANS weighing up to 23 tons and break-bulk cargo.

Engineer Support

Mobility and countermobility are key factors in the Army 21 concept. Friendly forces must move rapidly on the battlefield and overcome obstacles without delay. On the other hand, the enemy forces must be denied mobility by use of rapidly emplaced obstacles. Army Aviation will play an important role in both the mobility and countermobility missions.

Typical missions include emplacing scatterable mines and high technology barrier systems, moving and emplacing tactical bridging, moving bridging and obstacle crossing materials, and moving supplies and equipment to repair LOCs and airfields.

Battlefield Recovery

While battlefield recovery is normally carried out by ground transportation, recovery by rotorcraft may be required where time is critical, equipment has a high value, enemy capture would disclose sensitive information, or enemy materiel could provide valuable intelligence. Downed aircraft, high value support equipment, and new enemy equipment are examples of equipment which may be recovered by rotorcraft.

Medical Evacuation

Air is the preferred means of evacuation within the theater of operations and will be used to the extent possible for the evacuation of all patients in the combat zone. It includes battlefield pick-up for initial treatment and subsequent moves to medical facilities within the combat zone. Further evacuation from the combat to the Communications Zone (COMMZ) or EAC is accomplished by ground ambulance or by Air Force aircraft.

The Army has air ambulance companies and detachments which are dedicated to the air evacuation of patients within the division area, from division to corps and within the corps area. Transport rotorcraft will be used to augment this capability when needed.

Personnel Replacements

This mission includes forward movement of personnel replacements coming into the theater of operations, hospital returnees and personnel going on or returning from rest and recuperation leaves or passes. Although personnel can be moved by either ground or air transportation within the theater, many would be moved by Army rotorcraft. This would be particularly true in Southwest Asia where the distances are great and the road net is limited.

In general, the Air Force can be expected to move personnel into the aerial port of debarkation (APOD) or the Forward Operating Bases (FOB). At that point the Army would move the individuals to their final destinations.

NBC Support

Army aviation provides transport for individual protective gear (MOPP), collective shelters and decontamination equipment and supplies to areas where nuclear, chemical and/or biological weapons have been employed or where there is imminent threat of NBC employment. This is an important mission on the integrated nuclear-chemical-biological Army 21 battlefield.

Army aviation will provide airborne decontamination units for decontamination of high priority areas such as command posts.

Evacuation of Deceased Personnel

Within the battle area, any available ground or air transportation will be used to evacuate the dead to a brigade collecting point. Seldom will any special air lift be requested for this purpose. From the brigade area to the division collecting point or to a graves registration site in the corps or EAC area, scheduled ground or air transportation will be used. Rotorcraft will often backhaul remains after bringing supplies or other high priority cargo forward.

TRANSPORTATION MISSIONS IN EUROPE-NATO

Scenario Factors

The expected speed and intensity of combat operations in Europe and the high mobility implicit in the Army 21 concept create circumstances in which transportation rotorcraft will be needed. The following comments reflect the impact of scenario factors on rotorcraft missions:

- Unit moves by rotorcraft will occur primarily in emergency and opportune situations because of the well developed road and rail net in Europe and the area of operations is relatively limited in size.

- Tactical nuclear weapons may be needed to overcome the numerical strength of Warsaw Pact forces. In the event of hostilities special weapons already in the theater would be moved rapidly to dispersal locations. During combat operations, resupply and lateral relocation of special weapons would require airlift. The initial issue of chemical ammunition may also be airlifted to firing units for rapid retaliatory firing. The criticality of precision guided weapons may dictate their movement by air.

- Movement of supplies and equipment by rotorcraft will be limited to high priority demands such as barrier materials, POL, ammunition and repair parts. Some equipment replacement and emergency resupply of other types of supplies will also be accomplished by rotorcraft.

- APOD clearance by rotorcraft will move high priority cargo delivered by intertheater airlift and avoid

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hindrance of airlift turn around. Intertheather airlift of supplies and equipment will increase after initial reinforcement units using POMCUS have arrived in the theater.

- SPOD clearance and LOTS requirements in Europe are expected to be very limited because of the extensive modern port facilities. Even after substantial damage to ports sufficient capability would be available. However, representative SPOD and LOTS mission have been identified.

- Engineer operations will require frequent rotorcraft support for mobility and countermobility missions. Major factors in this mission are the numerous streams and rivers in Central Europe, the disruption of LOCs and the mobility inherent in the Army 21 concept.

- Battlefield recovery requirements will be affected by the intensity of combat, the large number of weapon systems involved and the increase lethality and range of weapons. It is expected that the heavy ground equipment will be evacuated with ground equipment.

- MEDEVAC by transport aircraft will supplement the air ambulance unit capabilities. Generally transport aircraft will be used for MEDEVAC only in areas behind the brigade rear boundaries because of the sophisticated threat encountered in the forward areas.

- Personnel replacements will flow into Europe at APODs. Rotorcraft will deliver personnel to both division and corps replacement units, but most will go to divisions.

- NBC movement demands will include transportation of shelters and decontamination supplies and the aerial decontamination of critical areas.

- The evacuation of deceased personnel will be a low priority mission even though personnel losses will be very high due to the intensity of combat in Europe. No daily work load figures were developed because evacuation would be handled on a back-haul basis.

Summary of Transportation Missions in Europe

The three tables listed below contain summaries of the typical daily mission workloads in each of the three phases of combat operation in the Europe-NATO scenarios. Additional descriptive details for these missions are provided in Appendix D, Volume II.

Table 2.1 - Mission Summary for Representative Day - Europe, Delay Phase.
Table 2.2 - Mission Summary for Representative Day - Europe, Defense.
Table 2.3 - Mission Summary for Representative Day - Europe, Counterattack.

The information displayed in these tabulations are:

- Mission type (identity)
- Mission frequency (number per day)
- Origin - destination of mission (echelon)
- Mission radius (km)
- Identity and weight (short tons) of largest non-divisible load
- Total number of short tons (ST) moved to accomplish each mission

TABLE 2.1. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DELAY PHASE

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
UNIT MOVES					
Artillery Battery	1	BDE	50	155mm Howitzer (8)	137
PAARP	6	BDE	50	Collapsible Fuel Drum (1.5)	31
Small Units	10	BDE	25	HMMWV (4) RADAR (5)	10 - 40
SUPPLIES AND EQUIPMENT					
Ammunition	1	EAC - CORPS	150	(BREAK BULK)	50
	1	CORPS - DIV	50	" "	100
	1	DIV - UNIT	50	" "	100
POL	1	EAC - CORPS	150	(BREAK BULK)	5
	1	CORPS - DIV	50	" "	5
	1	DIV - UNIT	50	" "	50
Repair Parts	1	EAC - CORPS	150	(BREAK BULK)	10
	1	EAC - DIV	200	" "	40
Other	1	EAC - CORPS	150	Commo Shelter (5)	50

TABLE 2.1. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DELAY PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
Others (Continued)					
	1	EAC - DIV	200	Commo Shelter (5)	50
	1	DIV - UNIT	50	" "	10
SPECIAL WEAPONS					
Nuclear Warheads	1	EAC - CORPS	150	2.5	10
	3	EAC - DIV	200	2.5	5
	6	WITHIN DIV	25	0.25	5
ENGINEER SUPPORT					
Emplace Bridge	1	BDE	50	Scissors Bridge (15) Trestle Section (10)	15
Barrier Material	1	BDE	50	(BREAK BULK)	30
Mine Laying	1	BDE	50	" "	30
Equipment	1	BDE	50	Bulldozer (12)	50

TABLE 2.1. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DELAY PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
APOD CLEARANCE					
APOD Clearance	1	APOD - CORPS	150	(BREAK BULK)	100
MED EVAC					
Casualties	1	DIV - CORPS	50	(PERSONNEL)	(50 PERS)
SPOD/LOTS					
Containers	1	PORT - EAC	25	Ammunition Container (35) MILVAN (23)	170
EQUIPMENT RECOVERY					
Aircraft	2	BDE - DIV	50	CH-47D (13)	13
Weapons	2	BDE - DIV	50	155mm Howitzer (8)	8
Support Equipment	1	DIV - EAC	150	C-E Shelter (5)	8
Enemy Equipment	1	BDE - CORPS	100	HIND Helicopter (13)	14

TABLE 2.1. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DELAY PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
<u>PERSONNEL</u>					
Replacements	1	EAC - DIV	200	(PERSONNEL)	(200 PERS)

TABLE 2.2. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DEFENSE PHASE

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
UNIT MOVES					
Artillery Battery	3	BDE	50	155mm Howitzer (8)	137
FAARP	6	BDE	25	Collapsible Fuel Drum (1.5)	31
Small Units	20	BDE	25	HMMWV (4)	10 - 40
Infantry Bn	1	DIV - BDE	50	HMMWV (4) LAV (14) MPGS (21)	230 1100
SUPPLIES AND EQUIPMENT					
Ammunition	1	EAC - CORPS	150	(BREAK BULK)	50
	1	CORPS - DIV	50	" "	100
	1	WITHIN CORPS	50	" "	50
	1	DIV - UNIT	25	" "	200

TABLE 2.2. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DEFENSE PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
(Continued)					
POL	1	EAC - CORPS	150	(BREAK BULK)	10
	1	EAC - DIV	200	" "	10
	1	DIV - UNITS	50	" "	150
Repair Parts	1	EAC - CORPS	150	(BREAK BULK)	60
Other	1	EAC - CORPS	150	" "	50
	1	EAC - DIV	200	" "	50
	1	DIV - UNIT	50	" "	10
SPECIAL WEAPONS					
Nuclear Weapons	1	EAC - CORPS	150	2.5	10
	3	EAC - DIV	200	2.5	5
	6	WITHIN DIV	25	0.25	5

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TABLE 2.2. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DEFENSE PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
ENGINEER SUPPORT					
Emplace Bridge	1	BDE	50	Scissors Bridge (15) Trestle Section (10)	15 OR 10
Barrier Material	1	BDE	50	(BREAK BULK)	30
Mine Laying	1	BDE	50	" "	30
Equipment	2	BDE	50	Bulldozer (121)	12
APOD CLEARANCE					
APOD Clearance	1	APOD - CORPS	150	(BREAK BULK)	100
	1	APOD - DIV	200	" "	100
MED EVAC					
Casualties	1	DIV - EAC	150	(PERSONNEL)	100
SPOD/LOTS					
Containers	1	PORT - EAC	25	Ammunition Container (35) MILVAN (23)	800

TABLE 2.2. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, DEFENSE PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
EQUIPMENT RECOVERY					
Aircraft	2	BDE - DIV	50	CH-47D (13)	13
Weapons	2	BDE - DIV	50	155mm Howitzer (8)	8
Support Equipment	1	DIV - EAC	150	C-E Shelter (14)	8
Enemy Equipment	1	BDE - CORPS	100	HIND Helicopter (14)	14
PERSONNEL					
Replacements	1	EAC - DIV	200	(PERSONNEL)	(200 PERS)

TABLE 2.3. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, COUNTERATTACK PHASE

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
UNIT MOVES					
Artillery Battery	6	BDE	50	155mm Howitzer (8)	137
Infantry Bn (Combat Assault)	2	BDE	50	HMMWV (4)	230
FAARP	9	BDE	50	Collapsible Fuel Drum (1.5)	31
Small Units	30	DIV - BDE	50	HMMWV (4) RADAR (5)	10 - 40
SUPPLIES AND EQUIPMENT					
Ammunition	1	EAC - CORPS	150	(BREAK BULK)	50
	1	CORPS - DIV	50	" "	200
	1	WITHIN CORPS	50	" "	50
	1	DIV - UNIT	25	" "	200
POL	1	EAC - CORPS	150	" "	10
	1	EAC - DIV	200	" "	10
	1	DIV - UNITS	50	" "	200

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TABLE 2.3. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, COUNTERATTACK PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
Repair Parts	1	EAC - CORPS	150	(BREAK BULK)	60
	1	EAC - DIV	200	" "	60
Other	1	EAC - CORPS	150	Commo Shelter (5)	25
	2	EAC - DIV	200	" "	25
	1	DIV - UNIT	50	" "	50
SPECIAL WEAPONS					
Nuclear Weapons	1	EAC - CORPS	150	5000	10
	3	EAC - DIV	200	5000	5
	6	WITHIN DIV	25	500	5
ENGINEER SUPPORT					
Emplace Bridge	3	BDE	75	Scissors Bridge (15)	15
Equipment	4	BDE	75	Bulldozer (12)	12

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TABLE 2.3. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, COUNTERATTACK PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
APOD CLEARANCE					
APOD Clearance	1	APOD - CORPS	150	(BREAK BULK)	100
	1	APOD - DIV	250	(BREAK BULK)	100
MED EVAC					
Casualties	1	DIV - EAC	150	(PERSONNEL)	100
SPOD/LOTS					
Containers	1	PORT - EAC	25	Ammunition Containers (35) MILVAN (23)	800
EQUIPMENT RECOVERY					
Aircraft	2	BDE - DIV	50	CH-47D (13)	13
Weapons	2	BDE - DIV	50	155mm Howitzer (8)	8
Support Equipment	1	DIV - EAC	150	C-E Shelter (8)	8
Enemy Equipment	1	BDE - CORPS	100	HIND Helicopter (14)	14

TABLE 2.3. MISSION SUMMARY FOR REPRESENTATIVE DAY - EUROPE, COUNTERATTACK PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
<u>PERSONNEL</u>					
Replacements	DAILY	EAC - DIV	200	(PERSONNEL)	(200 PERS)

TRANSPORTATION MISSIONS IN SOUTHWEST ASIA

Scenario Factors

The Southwest Asia scenario provides a significantly different environment from NATO:

- Limited rail and road network
- Difficult mountainous terrain
- Severe temperature and altitude flying conditions
- Less concentrated threat force

The specific scenario factors and assumptions which impact on the rotorcraft missions are listed below:

- Most of the initial deployment of units from the APODs will be by rotorcraft. Also much of the later repositioning of units during combat operations will be by rotorcraft.

- Although the US forces must be prepared for NBC conditions, it is assumed that nuclear and chemical weapons are not employed in Southwest Asia.

- Movement of supplies and equipment is more dependent upon rotorcraft than in Europe because of the larger area of operations and the lack of roads and railroads and the dispersion of forces.

- APOD clearance will be important because of the greater reliance upon intertheater airlift due in turn to the long sea routes from the CONUS. Use of forward APODs, which will be collocated with or near the division base (support command) will reduce some of the distances involved in rotorcraft clearance of the APOD.

- SPOD clearance and LOTS demands on rotorcraft are increased because of the lack of container ship berths.

- Engineer support is aggravated by the wide dispersion of forces and the nature of the terrain. Both the mobility mission and the countermobility mission require rotorcraft support both in the mountains and in the desert areas. Typical problems include transport of bridging and barrier materials plus the transport of road and airfield repair equipment. The emplacement of scatterable mines by rotorcraft is also required.

- Battlefield recovery will place special demands on rotorcraft because of the isolation of battle areas and the difficulty of replacing equipment.

- MEDEVAC workload for transport rotorcraft will be heavy because of the great distances and the poor road net. Further, air ambulance units may be transported to the theater by ship; this slow arrival would shift the MEDEVAC problem to transport rotorcraft.

- Personnel replacements must be moved from APODs to units over great distances.

- Evacuation of deceased personnel by rotorcraft would be primary on a back haul basis. Further, the personnel loss rates are expected to be low in this theater. No workload for rotorcraft is included.

Summary of Transportation Missions in Southwest Asia

The two tables listed below contain summaries of the typical daily mission workloads in delay and defense phases of combat operations in Southwest Asia. Additional descriptive details on these missions are provided in Appendix D, Volume II.

Table 2.4 - Mission Summary for Representative Day - Southwest Asia, Delay

Table 2.5 - Mission Summary for Representative Day - Southwest Asia, Defense

The subsequent counterattack phase is not included in the analysis since it involves heavy forces brought into the theater later and is thus similar to the European scenario.

TABLE 2.4. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DELAY PHASE

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
UNIT MOVES					
Brigade TF	2 PER 10 DAYS	APOD - BDE	150	ABN - BDE: HMMWV (4)	1100
				HTLD BDE (8) 155mm Howitzer (8) LAV (14) MPGS (21)	5000
Infantry Bn	1	DIV - BDE	100	HMMWV (4)	230
Artillery Battery	3	BDE	100	155mm Howitzer (8)	137
FAARP	6	BDE	100	Collapsible Fuel Drum (1.5)	31
Small Units	30	DIV	100	HMMWV (4) Commo Shelter (5)	5 - 10
SUPPLIES AND EQUIPMENT					
Ammunition	1	CORPS - BDE	150	(BREAK BULK)	200
POL	1	CORPS - BDE	150	(BREAK BULK)	200
Repair Parts	1	DIV - BDE	100	(BREAK BULK)	20

TABLE 2.4. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DELAY PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
(Continued)					
Water	1	DIV - BDE	100	(BREAK BULK)	30
Other	1	CORPS - BDE	150	Commo Shelter (5)	25
<u>ENGINEER SUPPORT</u>					
Emplace Bridge	1	DIV - BDE	150	Bridge Section (10)	10
Barrier Material	1	DIV - BDE	150	(BREAK BULK)	5
Equipment	2	DIV - BDE	150	Bulldozer (12)	(12)
<u>APOD CLEARANCE</u>					
APOD Clearance	1	APOD - DIV	50	(BREAK BULK)	600
<u>MED EVAC</u>					
Casualties	1	DIV - CORPS	150	(PERSONNEL)	(500 PERS)

TABLE 2.4. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DELAY PHASE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
SPOD/LOTS					
Containers	1	PORT - CORPS	25	Ammunition Containers (35)	500
EQUIPMENT RECOVERY					
Aircraft	2	BDE - DIV	100	CH-47D (13)	13
Weapons	5	BDE - DIV	100	155mm Howitzer (8)	8
Support Equipment	4	DIV - CORPS	100	C-E Shelter (8)	8
Enemy Equipment	1	BDE - CORPS	150	HIND (14)	14
PERSONNEL					
Replacements	DAILY	APOD - DIV	150	(PERSONNEL)	(100 PERS)

TABLE 2.5. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DEFENSE

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
UNIT MOVES					
Infantry Bn	2	DIV - BDE	100	HMMWV (4) OR LAV (14)	230 OR 1100
Artillery Battery	6	BDE	50	155mm Howitzer (8)	137
FAARP	10	BDE	100	Collapsible Fuel Drum (1.5)	31
Small Units	20	DIV	75	HMMWV (4)	5 - 10
SUPPLIES AND EQUIPMENT					
Ammunition	1	CORPS - BDE	100	(BREAK BULK)	900
POL	1	CORPS - BDE	100	(BREAK BULK)	200
Repair Parts	1	DIV - BDE	130	(BREAK BULK)	40
Water	1	DIV - BDE	100	(BREAK BULK)	80
Other	1	DIV - BDE	100	Commo Shelter (5)	25

TABLE 2.5. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DEFENSE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
ENGINEER SUPPORT					
Emplace Bridge	2	DIV - BDE	100	Bridge Section (10)	10
Barrier Material	1	DIV - BDE	100	(BREAK BULK)	10
Minelaying	1	DIV - BDE	100	" "	10
Equipment	2	DIV - BDE	100	Bulldozer (12)	12
APOD CLEARANCE					
APOD Clearance	1	APOD - DIV	150	(BREAK BULK)	450
MED EVAC					
Casualties	1	DIV - CORPS	150	(PERSONNEL)	(700 PERS)
SPOD/LOTS					
Containers	1	PORT - CORPS	25	Ammunition Container (35)	500

TABLE 2.5. MISSION SUMMARY FOR REPRESENTATIVE DAY - SOUTHWEST ASIA, DEFENSE (CON'T)

Unclassified

Mission	Number Per Day	Location	Mission Radius (KM)	Largest Non-Divisible Load (ST)	Mission Load (ST)
EQUIPMENT RECOVERY					
Aircraft	2	BDE - DIV	100	CH-47D (13)	13
Weapons	5	BDE - DIV	100	155mm Howitzer (8)	8
Support Equipment	4	DIV - CORPS	100	C-E Shelter (8)	8
Enemy Equipment	1	BDE - CORPS	150	HIND Helicopter (14)	14
PERSONNEL					
Replacements	1	APOD - DIV	150	(PERSONNEL)	(200 PERS)

PRIORITIES

Since mission priorities are situation dependent, 20 individuals with broad military experience in all aspects of Army combat and support operations were asked to prioritize the eleven missions for transportation rotorcraft. Their judgements are summarized in Figure 2.7.

PRIORITY	MISSION
1	UNIT MOVES
	SUPPLIES AND EQUIPMENT
2	SPECIAL WEAPONS
3	ENGINEER SUPPORT
4	APOD CLEARANCE
5	MEDEVAC
	PORT CLEARANCE AND LOTS*
6	RECOVERY OF EQUIPMENT
	CBR SUPPORT *
	PERSONNEL
7	DECEASED PERSONNEL

*These missions depend on the situation

Figure 2.7. Transportation Mission Priorities.

Relative priorities depend on the scenario and force mission. The priorities listed in Figure 2.7 are for a non-specific situation. Priorities in Europe could be different from those in Southwest Asia.

There is a pattern to combat operations which will determine the priorities for transportation missions as well as all other elements of the command. First, maneuver the force (unit moves) against the enemy. Second, support the force (engineer support, resupply, special weapons). Finally, sustain the force (APOD clearance, personnel moves, etc.).

SELF DEPLOYMENT

A requirement exists to transport rotorcraft from CONUS to the geographical areas prescribed by the two scenarios. An inherent shortage of sealift and airlifts makes self deployability a most attractive transportation alternative. The most demanding part of the self deployment routes to Europe and beyond is the trans-Atlantic crossing. Figure 2.8 shows self-deployment routes to Europe and Southwest Asia involving island hopping. Rotorcraft capabilities to accomplish these journeys are compared in Chapter 5 of this report.

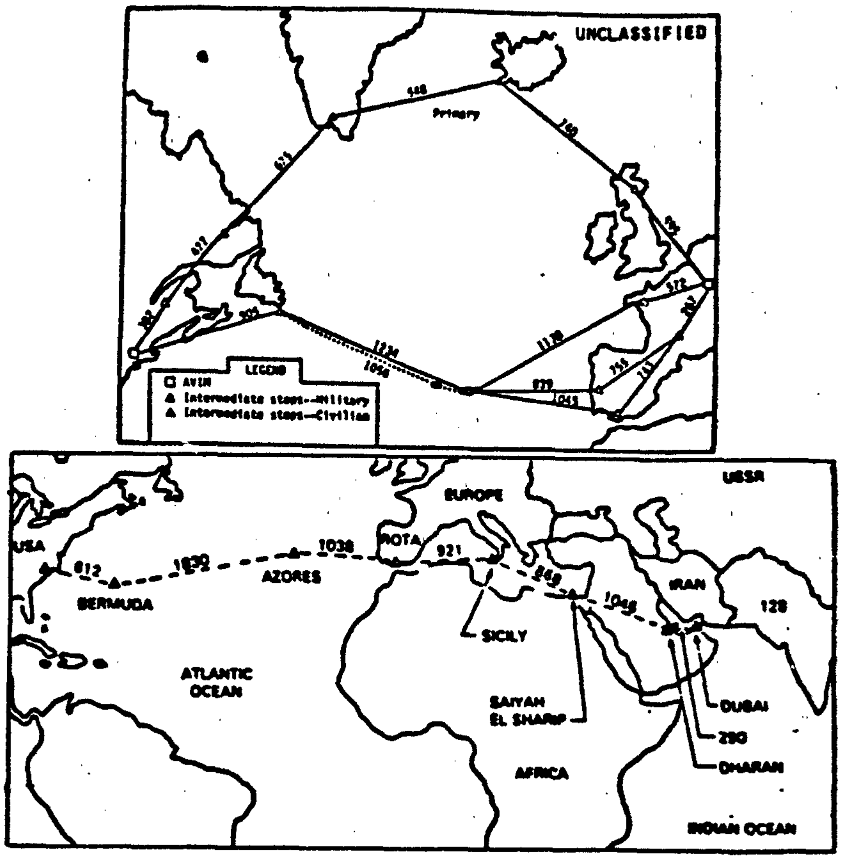

Figure 2.8. Self Deployment Routes to Europe and Southwest Asia

SUMMARY

The foregoing assessment determines the performance requirements for a future transport rotorcraft fleet.

Although mission requirements are situational, the two scenarios used in this study provide a good basis for the determination of reasonable requirements for rotorcraft workloads. Requirements for other areas of employment can be subsumed in the two situations generated and presented.

U.S. interests are global; the future transport rotorcraft fleet must be designed to support U.S. forces anywhere they are committed in defense of those interests. Since the specific areas of commitment cannot be predicted and the range of potential environments is great, rotorcraft must be designed to operate under the most stringent conditions.

Most transport rotorcraft missions will be in a low threat environment. Even under the concept of "islands of conflict" there would be large unoccupied areas which could be crossed without risk. Hence, the self-protection capability is not required on a daily basis. Protection in a high threat situation can be provided by other means (escorts, air defense suppression, etc.).

Army 21, the Army's evolutionary concept for warfare in the 21st Century, will emphasize speed, mobility, deep attack, and continuous operations on an integrated battlefield. This can only increase airlift requirements, placing greater demands on Army transport rotorcraft.

Rotorcraft performance is affected by weather and terrain, threat, and operational factors which must be considered in designing the future rotorcraft fleet; coping with these demands will involve weight, performance degradation in other areas (e.g., lift, speed), cost, or all three. They must be the subject of careful tradeoff analyses in the design of the fleet.

The urgency of rapid deployment, the shortage of, and competition for, strategic airlift, and the comparatively large requirements for rotorcraft necessitate self-deployment to theaters of operation. Kits similar to the External Stores Support System (ESSS) to provide the capability to carry additional fuel and could result in the ability to self-deploy over the Atlantic ocean routes. A self deployment range of 1500 nautical miles for ocean crossing would be desireable.

Rotorcraft will be required to perform a wide range of missions. These have been indentified in this study and the resultant list correlated with all other recent aviation requirement studies.

In general, the priority of missions will be:

- Maneuvering the force
- Support and sustain the force
- Other necessary tasks

With situational exceptions, the highest priority missions will be to move combat and combat support units and to resupply these units. The fleet must be robust enough to handle the exceptions while still accomplishing this basic highest-priority workloads.

There is a heavy requirement for rotorcraft support of a Corps slice, whether in NATO or SW Asia.

The daily rotorcraft lift workload in NATO is likely to range from approximately 110,000 to 280,000 STON-KM depending on the combat intensity or tactical situation.

The daily rotorcraft demands for a SW Asia scenario are even higher due to the lack of transportation infrastructure and the large distances involved; the corps daily workload likely ranging from 360,000 STONs to peaks as high as 1,000,000 STONs if a Brigade Task Force of a HTMD is required to be moved. The workloads would be even larger if Air Force aircraft cannot deliver to FOBs in the division areas.

In the two scenarios used in this evaluation a maximum radius of operation of 250 km is required. A key factor in this radius is the assumption that the Air Force will deliver personnel and cargo to FOBs in or near division areas.

The Army's utility and medium lift helicopters can carry most combat and resupply loads but heavy weapons/vehicles are beyond their lift limits, even for short hauls. Deciding what <u>MUST</u> be carried by rotorcraft is a key decision for the Army.

Section 3
TECHNOLOGY BASE

GENERAL

This section describes the evolution of the rotorcraft candidates used in this evaluation. The origin and development of candidate procurement and operating cost estimates are also presented. Since the Army Aviation Mission Area Analysis, the Army Aviaticn Modernization Plan, and the Statement of Work for this study discuss the continued use of the UH-60A and the CH-47D in the 1995-2015 time frame, these rotorcraft are also considered in this analysis.

The pivotal considerations in the selection of rotorcraft technologies for evaluation are the availability of credible flight performance (i.e. payload, radius) and cost (i.e. procurement and operating) data. These considerations limited the technologies considered to those which have already been examined by the rotorcraft community and made available to MRC for this study. The application of these considerations results in the selection of the rotorcraft identified in Table 3.1 for the least cost mix analysis. These data are also used to identify and describe rotorcraft concepts over a wider range of useful loads for conventional shaft driven rotor, tilt rotor, warm cycle rotor propulsion, and lighter-than-air technologies. Based upon this information quantitative parametric techniques are used to describe the least cost rotorcraft concepts and technologies for selected missions in Section 4 of this report.

TECHNOLOGY OVERVIEW

The rotorcraft technologies evaluated in this analysis evolved from Army planning documents, papers contained in

TABLE 3-1. SELECTED ROTORCRAFT CANDIDATES

Rotorcraft Useful Load (Klbs)	Rotorcraft Representing Design Technology					
	Conventional Shaft Driven Rotor	Tilt Rotor	Composite	Uprated Engine	Lighter Than Air	Warm Cycle
4.4	UH-1H					
9.7	UH-60A[1]					
23.0		JVX				
27.5	CH-47D					
34.4			COMP47			
40.4	CH-53E[1]					
51.2				MOD53		
83.1	HLH					
100.0					HLA	
174.0						HWC

1/ Single Ship and Twinned

technical journals, and reports provided by the aircraft industry. The technologies considered are:

- Conventional Shaft Driven Rotor
  - Twinned Conventional Shaft Driven Rotorcraft
  - Conventional Shaft Driven Rotorcraft using Composite Materials
  - Conventional Shaft Driven Rotorcraft with Uprated Engines
- Tilt rotor
- Warm Cycle Rotor Propulsion
- Lighter-than-air

The paragraphs which follow describe the rotorcraft candidate selected to represent each technology in the least t mix analysis. The information presented is designed to provide input data for the mix analysis and for the development of the parametric data base used to evolve the least cost technology concepts. More extensive descriptions of these candidates can be found in Field Manuals, Tech Manuals and Aerospace Contractor Reports.

CONVENTIONAL SHAFT DRIVEN ROTORCRAFT

The UH-1H, UH-60A, CH-47D, CH-53E and the Heavy Lift Helicopter (HLH) are included in this technology category. The principal physical, cost, and performance characteristics of these five platforms are presented in Tables 3.2 and 3.3. Table 3.2 shows the platform weights, speeds, and payloads as a function of environment, configuration, and mission radii used in this analysis. Estimates of payload and outbound speed for each candidate operating in the twin mode are also indicated.

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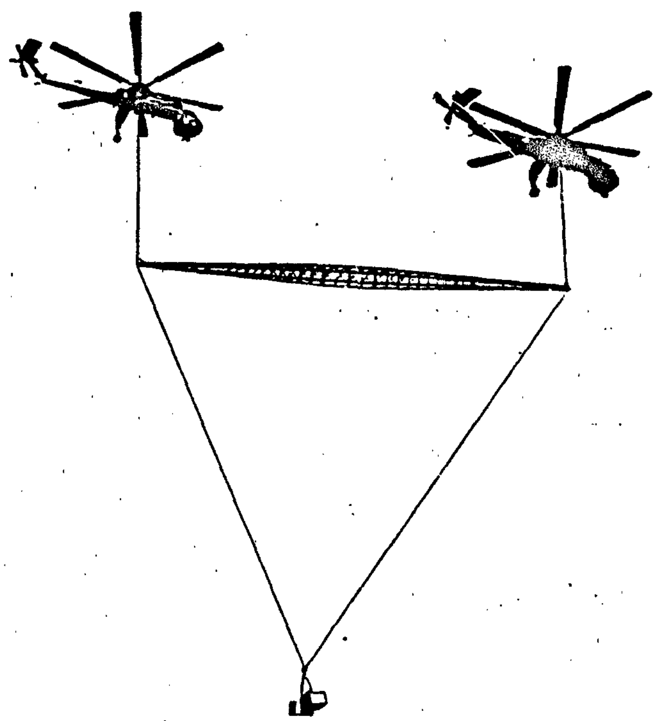
TABLE 3.2. CHARACTERISTICS OF CONVENTIONAL SHAFT DRIVEN ROTORCRAFT

Platform	Environment	Take Off Gross Weight (Lbs)	Basic Weight (Lbs)	Payload (Lbs)* Radius (Km)			Speed (Knots)* Load		
				50	100	150	Empty	Internal	External
UH-1H	2000'/70°	9500	5132	3820	3522	3224	112	110	95
	4000'/95°	8550	5132	2940	2680	2420	110	95	92
UH-60A	2000'/70°	20250	10500	8890	8481	8071	148	136	110
	4000'/95°	18217	10500	6891	6489	6088	146	125	105
CH-47D	2000'/70°	48250	22500	23500	22399	21297	137	130	125
	4000'/95°	42900	22500	18272	17256	16241	140	118	115
CH-53E	2000'/70°	65160	31100	31084	29586	28088	133	131	125
	4000'/95°	55276	31100	21490	20163	18836	125	125	120
HLH	2000'/70°	133200	64900	61954	58915	55876	145	—	130
	4000'/95°	118000	64900	47339	44623	41907	142	—	125

*Twinned Conventional Shaft Driven Rotorcraft
- -Payload = 1.8 x single ship value
- -Outbound Speed = 80 knots
- -Illustrated below:



The procurement and operating cost data used in this analysis for conventional shaft driven platforms are summarized in Table 3-3. The sources of this information are also provided. Where necessary OSD Indices are used to escalate other year dollars to the 1984 dollars displayed.

TABLE 3-3. COST DATA FOR CONVENTIONAL SHAFT DRIVEN ROTORCRAFT

Platform	Procurement Cost (M$84)	Operations Cost(K$84/hr)	Cost Data Source
UH-1H	1.4	1.34	DACA-CAC,K31795 57057H 31000/32000
UH-60A	3.6	2.07	DACA-CAC,K32293 57057H 34000
CH-47D	16.3	2.21	DACA-CAC,H30517 55167 J10000
CH-53E	19.7	2.93	Cmdr,Naval Air System Command,
HLH	34.4	3.50	AVSCOM, 55259 H00000 W/HI

The annual flying hour programs from FM 101-20 are used in the development of the operations costs shown. These are 300 hours for the UH-1H and UH-60A, and 240 hours for the CH-47D. Other Army sources specify 240 hours for the HLH and the data available on the CH-53E specify costs based upon 360 hours per year.

TILT ROTOR, ADVANCED COMPOSITE, AND ENGINE UPRATING

The rotorcraft concepts that reflect tilt rotor, composite construction, and engine uprating technologies are the JVX, an advanced-composite CH-47 (Comp-47) and the CH-53E (MOD-53) with Modern Technology Demonstration Engines (MTDE), respectively. It should be noted that both the JVX and the MOD-53 use the MTDE. The COMP-47 uses with the T55-L-712 engines of the CH-47D.

The characteristcs of the JVX,COMP-47 and the MOD-53 rotorcraft are summarized in Table 3.4. These include speed and payload as a function of environment, load configuration, and mission radius respectively.

The relative advantages of tilt rotor technology are illustrated in Figure 3.1. The tilt rotor concept results in higher payload than conventional helicopters for protracted mission radii. Further, the concept is capable of substantially higher airspeeds than rotory wing platforms.

The payload radius benefits of advanced composite technology in the CH-47D airframe and rotor are illustrated in Figure 3.2. Specific data regarding the operational characteristics resulting from this technology are contained in the next section of this report.

The payload radius effects of installing various engines in the CH-53E are shown in Figure 3.3. The left side of the figure indicates uprating benefits under Sea Level/Standard Conditions and the right section illustrates the more pronounced benefits resulting from operations at 4000'/95 F.

Procurement and operating cost estimates for the JVX, COMP-47, and MOD-53 are summarized in Table 3.5.

TABLE 3-4. CHARACTERISTICS OF TILT ROTOR, ADVANCED COMPOSITE AND UPRATED ENGINE ROTORCRAFT

Platform	Environment	Take Off Gross Weight (Lbs)	Basic Weight (Lbs)	Payload (Lbs) Radius (Km)			Speed (Knots) Load		
				50	100	150	Empty	Internal	External
JVX	2000'/70°	49000	30000	17228	16506	15784	260	260	150
	4000'/95°	44000	30000	12425	11750	11076	235	235	150
COMP-47	2000'/70°	52600	20100	30294	29262	28231	162	155	125
	4000'/95°	46761	20100	24572	23622	22671	165	143	115
MOD-53	2000'/70°	75500	31800	40998	39638	38277	133	131	125
	4000'/95°	67000	31800	32788	31610	30432	125	125	125

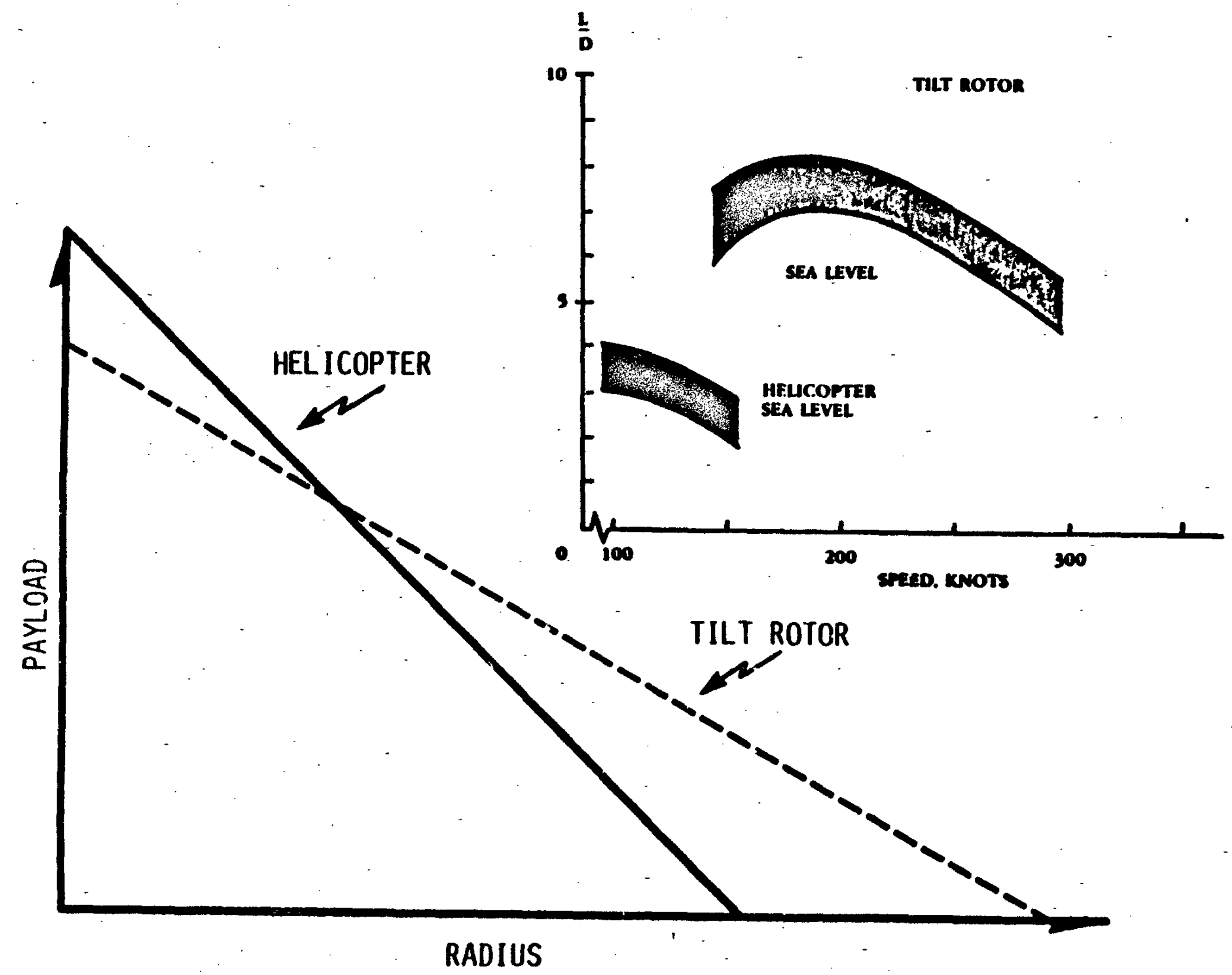


Figure 3.1. Relative Advantages of Tilt Rotor Technology

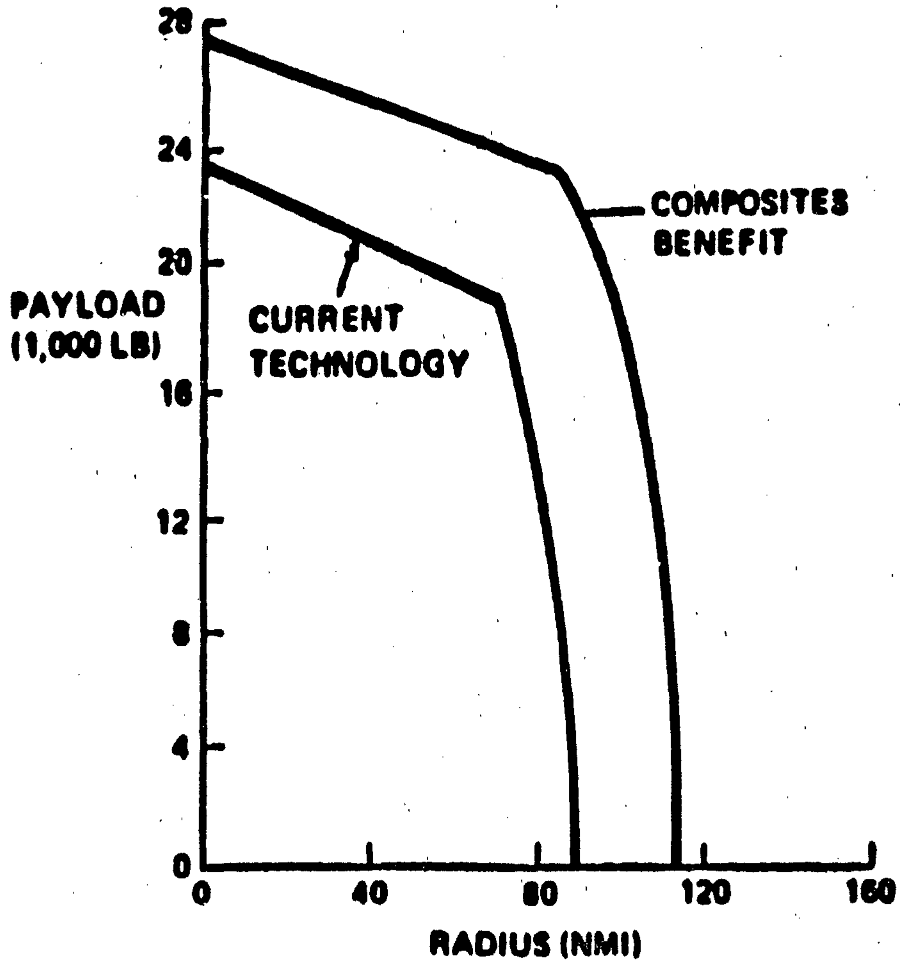


Figure 3.2. Advantages of Advanced Composite Technology

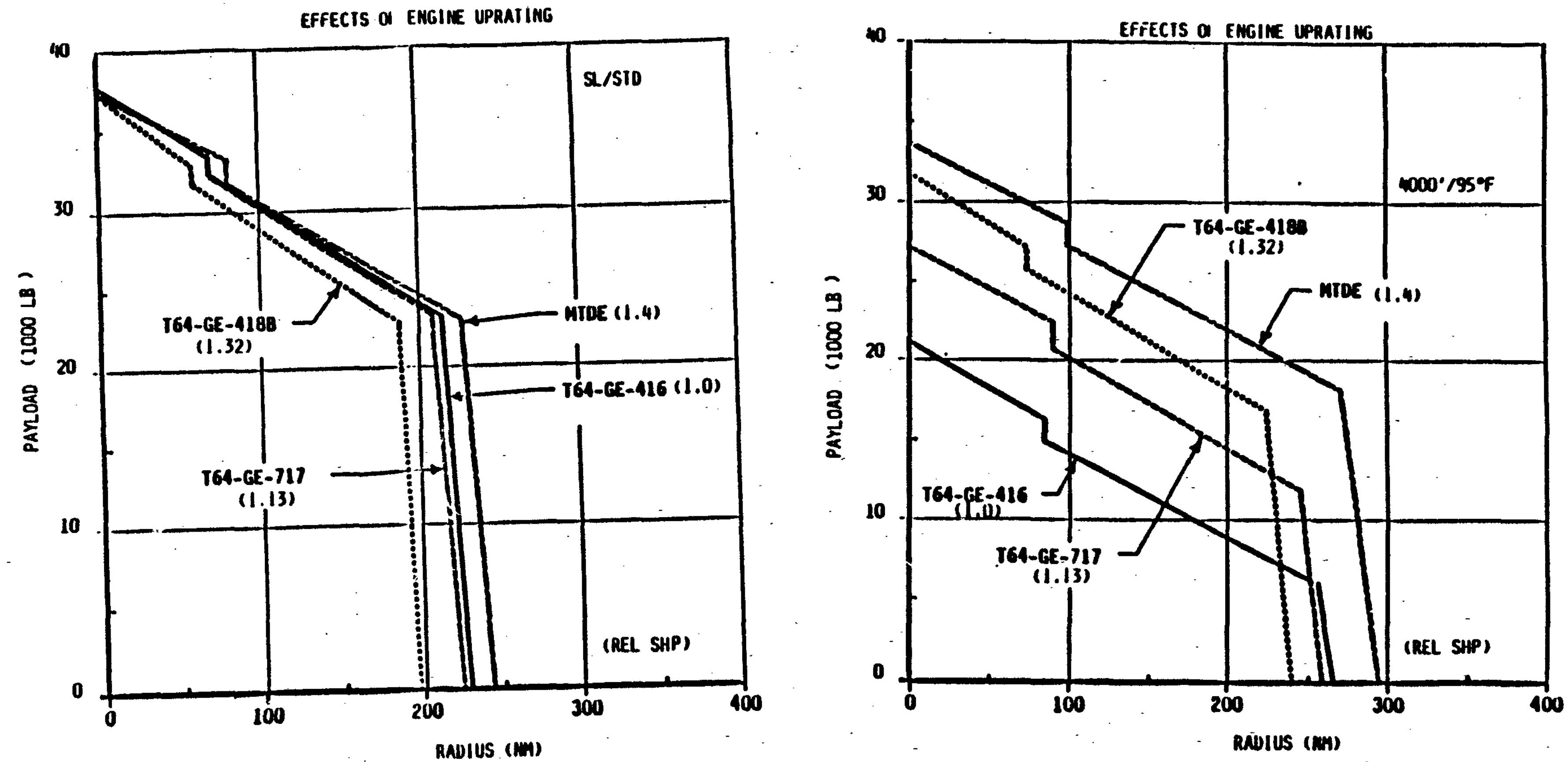


Figure 3.3. Effects of Uprated Engines on the CH-53E

TABLE 3.5. COST DATA FOR TILT ROTOR, ADVANCE COMPOSITE, AND ENGINE UPRATING

Platform	Procurement Cost (M$84)	Operations Cost (K$84/hr)	Cost Data Source
JVX	18.4	1.59	Proc:Army Avn Mod Plan Opns:Sikorsky Cost Functions
COMP-47	19.6	2.15	Proc and Opns Costs from Boeing Vertol Data
MOD-53	28.7	3.10	Proc:Re-engine CH-53E for 9M$84 Opns:Assumed to be 50% greater than UH-60A

LIGHTER-THAN-AIR AND WARM CYCLE

The last two rotorcraft technologies examined in this study are Lighter-than-Air and Warm Cycle Propulsion. These technologies are reflected in the physical and operational characteristics of the concepts described in Table 3.6 and illustrated in Figure 3.4.

Procurement and operating costs for the Lighter-than-Air concept are developed from data provided by Goodyear Aerospace. Cost data for the Warm Cycle concept are derived from SAE technical papers. These cost estimates are presented in Table 3.7.

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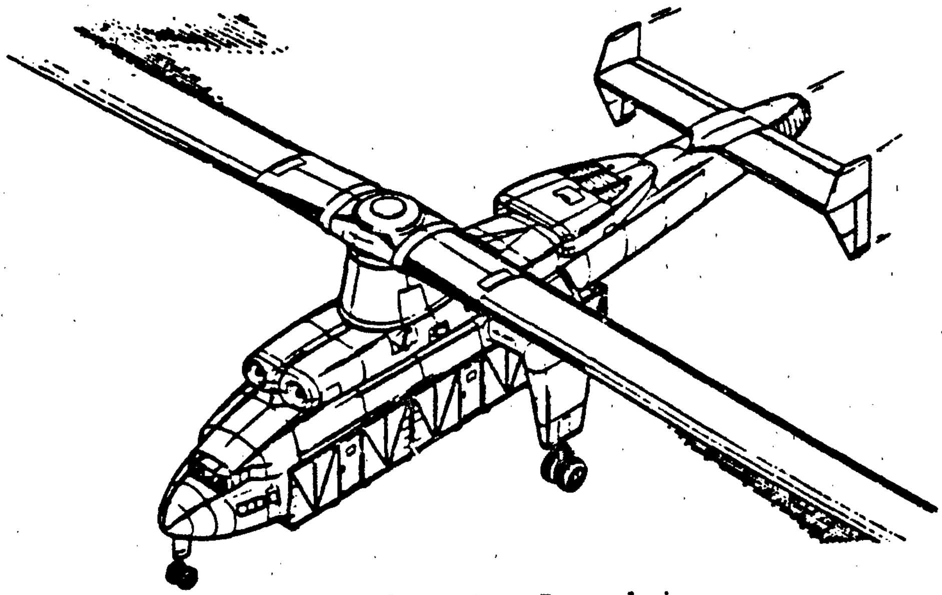
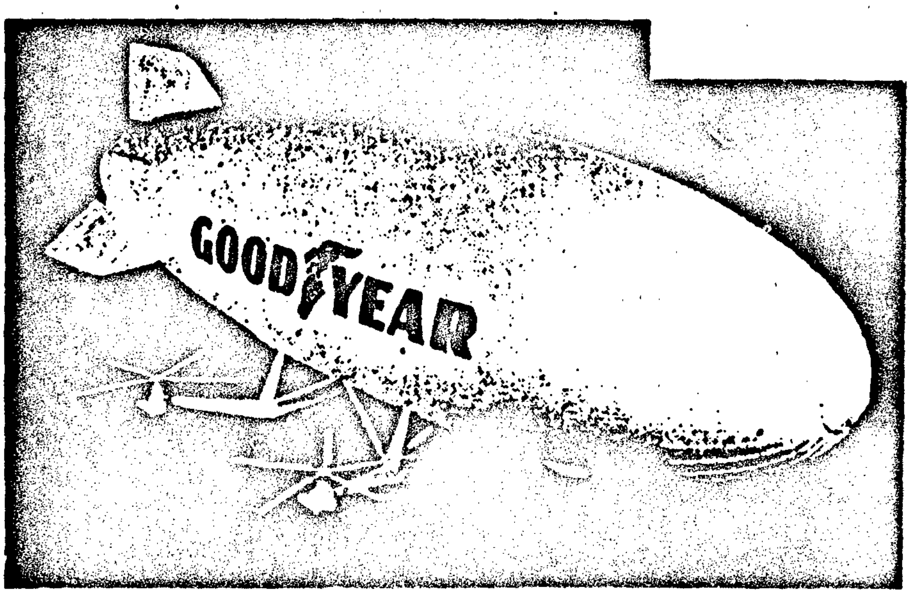
TABLE 3-6. CHARACTERISTICS OF LIGHTER-THAN-AIR AND WARM CYCLE ROTORCRAFT

Platform	Environment	Take Off Gross Weight (Lbs)	Basic Weight (Lbs)	Payload (Lbs) Radius (Km)			Speed (Knots)
				50	100	150	
Lighter-than-Air	2000'/70°	168790 1/	85300	73714	67544	61373	80
	4000'/95°	150000 1/	85300	55936	50383	44829	80
Warm Cycle	2000'/70°	244150	94300	136554	128759	120965	100
	4000'/95°	217000	94300	111416	104801	98187	100

1/ Total Lift (Buoyant + Rotors)



Warm Cycle Rotor Propulsion



Lighter-than-Air

Figure 3.4. Warm Cycle and Lighter-than-Air Rotorcraft Candidates

TABLE 3-7. COST DATA FOR LIGHTER-THAN-AIR AND WARM CYCLE ROTORCRAFT

Platform	Procurement Cost (M$84)	Operations Cost (K$84/hr)
Lighter-than-Air	25.4	5.64
Warm Cycle	56.7	12.96

PARAMETRIC ROTORCRAFT DESIGNS

The data base developed to describe the rotorcraft concepts in the preceeding paragraphs .. used to estimate the characteristics of larger and smaller conceptual designs tailored to specific mission requirements. The characteristics which can be approximated through the application of parameteric interpolation and extrapolation for a given payload, radius, and operating environment are:

- Maximum Take Off Gross Weight
- Basic Weight
- Useful Load
- Required Fuel
- Procurement Cost
- Operating Cost per Hour
- Mission Accomplishment Cost

These characteristics are developed for the following principal rotorcraft technologies evaluated in this study:

- Conventional Shaft Driven Rotor
- Tilt Rotor
- Warm Cycle Rotor Propulsion
- Lighter-Than-Air

Selected results of the application of the estimating process are shown as a function of payload for a 150 KM radius mission in Europe (2000'/70° F) and Southwest Asia (4000'/95° F) in Table 3.8. Comparisons of rotorcraft technological concepts, tailored for specific missions developed for this study, are presented in Section 4 of this report.

TABLE 3-8. ESTIMATED ROTORCRAFT CHARACTERISTICS
(150 KM MISSION RADIUS)

Technology	Environment	Payload (Klbs)	Weight (Klbs)		Cost	
			Gross	Basic	Procurement (M$84)	Oper (K$84)
Conventional Shaft Driver Rotor	Europe	7.0	19.2	9.5	3.13	1.93
		35.0	85.2	38.9	23.6	3.41
		70.0	174.6	81.2	41.6	5.99
	Southwest Asia	7.0	25.8	12.7	4.96	2.09
		35.0	113.8	52.2	29.7	4.24
		70.0	235.1	110.0	53.0	7.74
Tilt Rotor	Europe	7.0	24.3	14.1	5.06	1.50
		35.0	121.6	70.7	35.2	3.21
		70.0	243.1	141.4	61.4	5.74
	Southwest Asia	7.0	37.4	21.8	10.6	1.55
		35.0	187.1	108.8	49.7	4.58
		70.0	374.1	217.5	82.7	8.47
Warm Cycle	Europe	7.0	27.0	15.5	5.35	2.10
		35.0	104.2	52.7	27.8	3.96
		70.0	174.0	77.7	41.4	6.65
	Southwest Asia	7.0	41.9	23.8	11.5	2.16
		35.0	143.6	71.6	35.1	5.16
		70.0	227.9	100.9	51.7	9.28
Lighter-Than-Air	Europe	7.0	20.2	9.7	3.35	2.00
		35.0	101.0	48.5	27.1	3.87
		70.0	202.0	97.1	46.9	6.79
	Southwest Asia	7.0	28.3	13.6	5.79	2.10
		35.0	141.4	68.0	34.6	5.03
		70.0	282.7	135.9	60.8	9.12

Section 4
SYSTEM DEFINITION

TECHNICAL APPROACH

The methodology chosen to accomplish the objectives of this study is divided into two phases. The first phase consist of evaluating the least cost mix of specific rotorcraft concepts to accomplish all of the mission defined for Europe and Southwest Asia in Task 1 and discussed in Section 2. The second phase consists of evolving rotorcraft design points from the menu of missions for both theaters and identifying and describing the least cost technological concept associated with each design point. The results of both of these phases, combined with other measures of effectiveness, are used to develop the conclusions and recommendations presented in Section 5 of this report.

LEAST COST MIX OF ROTORCRAFT CANDIDATES

The ability of the individual rotorcraft candidates described in Section 3 to accomplish transportation missions is assessed using a computational model. This model, an "OR" Matrix generator, determines the number of rotorcraft of each type required to complete each mission in each combat phase. Mission characteristics such as tonnage, size, radius and time constraints are model inputs along with candidate characteristi s such as payload, fuel consumption, speed and internal cargo capacity. Model output is the number of candidate rotorcraft required to complete each mission in each phase of combat considered in this analysis.

An "AND" Matrix generator is also developed and employed to identify the rotorcraft candidates which complete each transportation mission for the least cost. The inputs to this model include the "OR" Matrix and cost estimates per flying hour for each rotorcraft candidate. Cost estimates per flying hour combined with flying time to perform each mission produces a cost per mission for each candidate rotorcraft. A linear program subset of this model is then used to select the least cost rotorcraft candidate to complete each of the daily transportation missions. Output from this model is an "AND" Matrix for each phase of combat.

The least cost mix of rotorcraft to accomplish transportation missions for each combat phase is determined by comparing the daily mission schedule with the "AND" Matrix results. First, all missions for which the same rotorcraft candidate is chosen are scrutinized for opportunities to reuse a rotorcraft for more than one mission. Second, all least cost rotorcraft candidates for individual tasks are reviewed for opportunities to replace candidates that would increase the cost of accomplishing some individual missions but would reduce the total life cycle costs of the resulting mix.

Assumptions

Although it is desirable to accurately quantify all variables involved in this analysis, it is impossible to do so. Thus carefully chosen assumptions are made to reduce the problem to a manageable size and to maintain a reasonable degree of relative accuracy. These assumptions are summarised in the following paragraphs.

Each rotorcraft carries enough fuel to complete one mission sortie with a 30 minute fuel reserve. If fuel requirements for a mission is greater than the internal fuel capacity, bladders are used and a weight penalty of four percent is added to the candidate's empty weight.

Each rotorcraft carries as much payload as possible. If the rotorcraft cubes out, the remainder of the payload is carried externally. A three percent weight penalty is added for externally carried break bulk cargo. A five percent weight penalty is added for externally carried nondivisible loads of three items or more.

Loading and unloading times are as follows:

- 6 minutes for an external load
- 6 minutes for each internally loaded driven or towed nondivisible load
- .004 minute per cubic foot for internally loaded break bulk cargo

A refueling time of .0015 minutes per pound of fuel is also used.

The war time flying hour program for each rotorcraft candidate is tabulated below. The sources for the values selected are also indicated. The maximum combat daily flying hour program for the CH-47D available from Army sources is 3.5 hours as shown.

Candidate Rotorcraft	Combat Flying Hours Per Day	Flying Hour Source
UH1H	6.0	AAMAA
UH60	6.0	AAMAA
CH47D	3.5	AAMAA
CH 53E	6.0	Assumed Equivalent to UH-1, UH-60
JVX	6.0	1/
HLH	6.0	Assumed Equivalent to UH-1, UH-60

HLA	6.0	Assumed Equivalent to UH-1, UH-60
HWC	6.0	"
MOD 53E	6.0	"
COMP 47D	6.0	"

1/ Equivalent to U8, U21, C12 which are equivalent to UH-1, UH-60 on a Wartime Annual Flying Hour Basis (FM-101-20)

The costs per flying hour for each rotorcraft candidate based on procurement cost and 20 year life cycle peacetime annual operating cost are summarized in Table 4.1.

TABLE 4.1. CANDIDATE FLYING HOUR COSTS

Candidate Rotorcraft	Procurement Cost (M$84)	Operating Cost Per Hr (K$84)	Peacetime Annual Flying Prog (Hr/Yr)	Total Cost Per Flying Hour (K$84)
UH1H	1.4	1.34	300	1.6
UH60	3.6	2.07	300	2.[illegible]
CH47D	16.3	2.21	240	5.6
TWIN UH60	7.2	4.14	300	5.4
CH 53E	19.7	2.93	360	5.7
TWIN CH 53E	39.4	5.86	360	11.4
JVX	18.4	1.59	300	4.7
HLH	34.4	3.50	300	9.2
HLA	25.4	5.64	300	9.9
HWC	56.7	12.96	300	22.4
MOD 53E	28.7	3.10	300	7.9
COMP 47	19.6	2.15	300	5.4

Capabilities of Candidate Rotorcraft

The candidates evaluated represent a variety of rotorcraft technologies and reflect both advantages and disadvantages.

Furthermore, there is an even distribution of advantages and disadvantages across the ranges of payloads, radii, and mission time constraints identified in the daily transportation missions.

Capabilities of the candidate rotorcraft are measured by four criterion; payload capability, fuel consumption, air speed and radius of action. The payload, range, fuel consumption interdependancy for each rotorcraft candidate operating with internal payloads is represented in Figure 4.1. The external payload capacity of the same rotorcraft are shown in Figure 4.2. Since the Warm Cycle, Lighter-than-Air, and the HLH candidates are only configured for external payloads, in this evaluation, the payload radius capability of these rotorcraft are shown separately in Figure 4.3. The capability of the CH-53E is also shown on this figure for reference.

Mission Performance Analysis

The first step in the performance analysis is to match the capabilities of the candidate rotorcraft with the daily transportation missions. Matching is done by the "OR" Matrix generator and the resulting "OR" Matrices are shown in Tables 4.2 through 4.6. It should be noted that the results shown in the tabulations are non-integer solutions to identify unused payload for breakbulk cargo and to avoid accumulating rounding errors at this early stage in the calculation process.

The second step in this analysis is to integrate the costs for each candidate rotorcraft to complete each mission and to determine the least cost candidate for each mission. This is accomplished by the "AND" matrix generator.

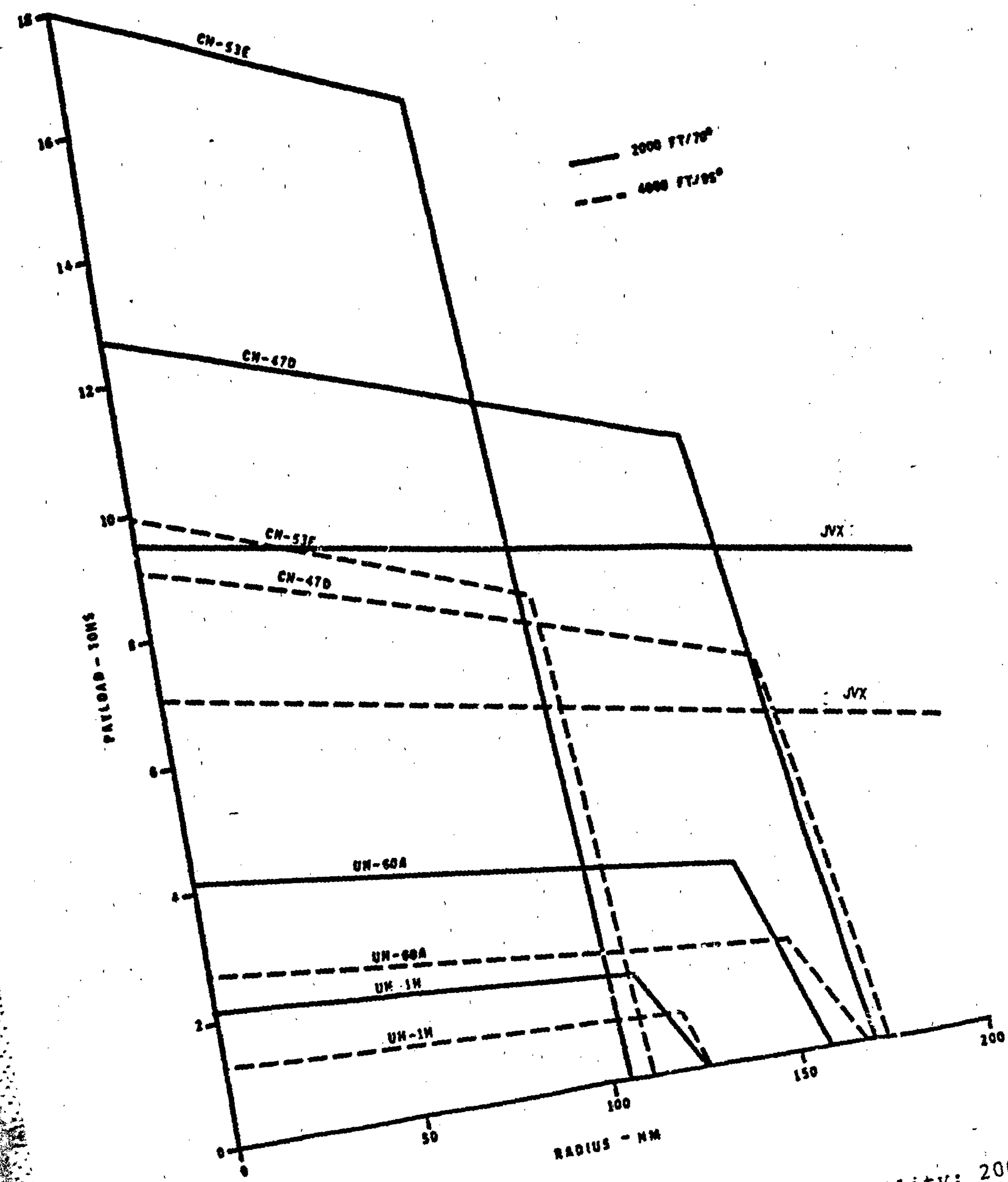


Figure 4.1. Internal Payload - Radius Capability; 200 FPM ROC

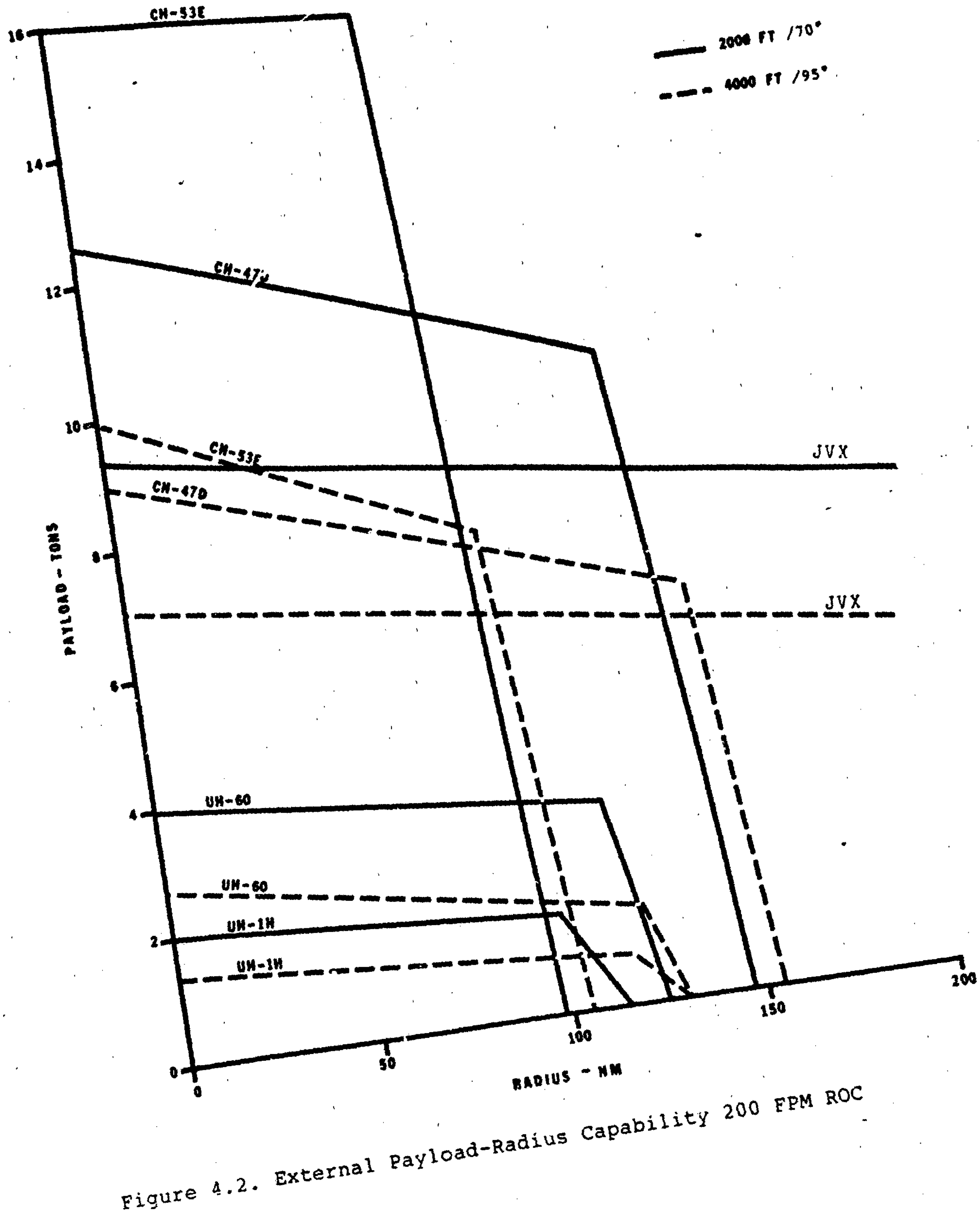


Figure 4.2. External Payload-Radius Capability 200 FPM ROC

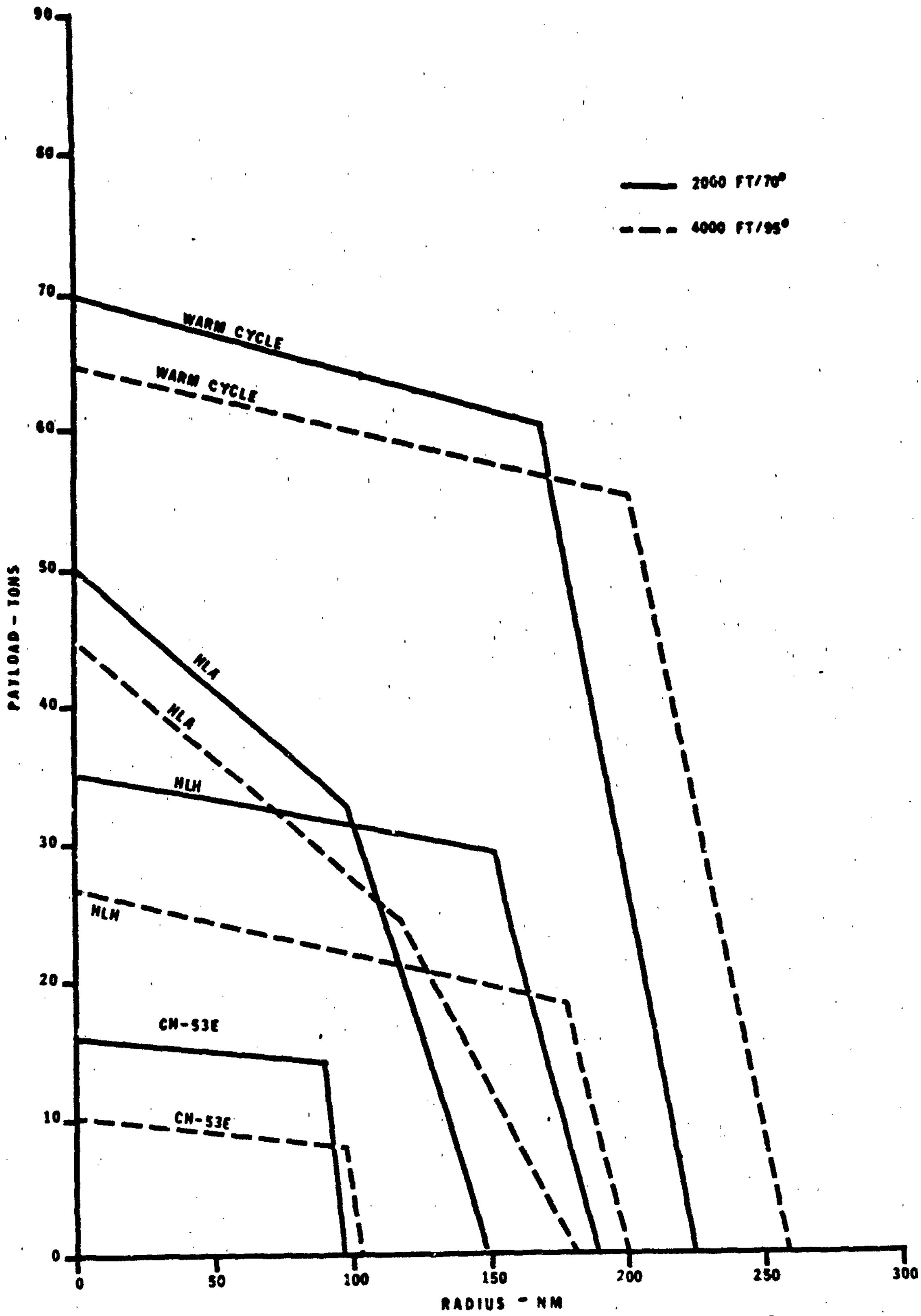


Figure 4.3. External Payload - Radius Capability - 200 FPM ROC

TABLE 4-2. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT
(DELAY PHASE - EUROPE)

Mission		Number of Platforms by Type											
		UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
1212	FAARP	16.24	7.01	2.52	3.86	1.76	.97	3.11	.87	.71	.40	1.35	1.96
4322	Mine Laying	15.61	6.71	2.55	3.66	1.93	1.07	3.44	.97	.81	.44	1.46	1.97
1321	Small Unit												
	HMMWV	N/C	2.64	1.00	1.44	.75	.42	1.36	.38	.31	.17	.58	.78
	Radar	N/C	N/C	.42	.60	.31	.17	.57	.16	.13	.07	.24	.32
	Supplies	.50	.22	.08	.12	.06	.03	.11	.03	.03	.01	.05	.06
	Personnel	1.14	.50	.19	.27	.14	.08	.25	.08	N/C	.03	.11	.15
1112	Arty Btry												
	HMMWV	N/C	.90	.34	.50	.26	.15	.46	.13	.11	.06	.20	.26
	155 Howitzer	N/C	N/C	4.09	5.95	3.09	1.74	5.57	1.55	1.30	.70	2.34	3.17
	2½T Truck	N/C	N/C	3.57	5.21	2.70	1.52	4.88	1.36	1.14	.62	2.05	2.77
	Ammo	35.38	15.22	5.78	8.29	4.37	3.67	7.80	2.20	1.85	1.00	2.98	4.47
	Personnel	5.20	2.25	.86	1.22	.64	.26	[illegible]	[illegible]	N/C	.15	.49	.66
2XXX	Supplies/Equip	62.81	22.10	14.80	15.56	6.54	5.52	7.20	3.81	7.36	2.60	4.82	6.29
2445	Commo Shelter	N/C	N/C	.47	.71	.36	.20	.63	.18	.16	.08	.26	.35
3111	Lt Spec Weapons	2.52	1.10	.42	.60	.31	.17	.57	.16	.13	.07	.24	.32
3125/3126	Hvy Spec Weapons	N/C	2.55	.97	1.47	.74	.44	1.29	.38	.34	.17	.53	.72
4112	Scissor Bridge	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
4122	TRestle Bridge	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
4232	Bar Material	15.61	6.71	2.55	3.66	1.93	1.07	3.44	.97	.81	.44	1.46	1.97
4412	Lt Bulldozer	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
5115	APOD Clearance	23.68	7.10	4.68	5.20	2.06	2.10	2.31	1.39	1.90	.97	1.52	2.04
6112	MEDEVAC	5.00	4.00	2.00	2.00	1.00	1.00	3.00	1.00	N/C	1.00	1.00	2.00
7111	MILVAN Supply	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
7211	MILVAN Ammo	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7121	40' Cont. Sup.	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7221	40' Cont. Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	N/C	N/C
8112	CH-47D	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8212	155 Howitzer	N/C	N/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8315	C-E Shelter	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8414	HIND Helicopter	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
9126	Personnel	19.00	15.00	7.00	8.00	4.00	2.00	9.00	2.00	N/C	1.00	4.00	7.00

TABLE 4-3. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT (DEFENSE PHASE - EUROPE)

	Mission	Number of Platforms by Type											
		UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
1211	FAARP	16.41	7.17	2.71	3.90	2.05	1.13	3.69	1.03	.83	.46	1.57	2.12
4322	Mine Laying	15.61	6.71	2.55	3.66	1.93	1.07	3.44	.97	.81	.44	1.46	1.97
1311	Small Unit												
	HMMWV	N/C	71.99	27.23	39.70	20.59	11.60	37.15	10.33	8.68	4.69	15.61	21.13
	Supplies	5.20	2.24	.85	1.22	.64	.36	1.15	.32	.27	.15	.49	.66
	Personnel	26.01	11.19	4.25	6.10	3.21	1.78	5.73	1.61	N/C	.73	2.44	3.29
1112	Arty Btry												
	HMMWV	N/C	.90	.34	.50	.26	.15	.46	.13	.11	.06	.20	.26
	155 Howitzer	N/C	N/C	4.09	5.95	3.09	1.74	5.57	1.55	1.30	.70	2.34	3.17
	2½T Truck	N/C	N/C	3.57	5.21	2.70	1.52	4.88	1.36	1.14	.62	2.05	2.77
	Ammo	35.38	15.22	5.78	8.29	4.37	3.67	7.80	2.20	1.85	1.00	2.98	4.47
	Personnel*	5.20	2.25	.86	1.22	.64	.36	1.16	.35	N/C	.15	.49	.66
1412	Inf Bn (HTLD)												
	HMMWV	N/C	71.99	27.23	39.70	20.59	11.60	37.15	10.33	8.68	4.69	15.61	21.13
	Supplies/Equip	5.20	2.24	.85	1.22	.64	.36	1.15	.32	.27	.15	.49	.66
	Personnel	26.01	11.19	4.25	6.10	3.21	1.78	5.73	1.61	N/C	.73	2.44	3.29
1422	Inf Bn												
	HMMWV	N/C	24.30	9.19	13.40	6.95	3.92	12.54	3.49	2.93	1.58	5.27	7.13
	LAV	N/C	N/C	N/C	N/C	18.02	10.15	N/C	9.07	7.60	4.10	13.66	18.49
	MPGS	N/C	N/C	N/C	N/C	N/C	22.84	N/C	20.34	17.09	9.23	N/C	N/C
	Supplies/Equip	9.89	4.25	1.62	2.32	1.22	.68	2.18	.61	.52	.28	.93	[illegible]
	Personnel	32.52	13.99	5.31	7.62	4.02	2.22	7.17	2.02	N/C	[illegible]	3.05	[illegible]
2XXX	Supplies/Equip	89.37	31.56	21.10	21.62	9.32	7.99	10.41	5.54	9.41	3.73	6.88	8.91
3111	Lt Spec. Weapons	2.52	1.10	.42	.60	.31	.17	.57	.16	.13	.07	.24	.32
3125/26	Hvy Spec. Weapons	N/C	2.55	.97	1.47	.74	.44	1.29	.38	.34	.17	.53	.72
4112	Scissor Bridge	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
4122	Trestle Bridge	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
4232	Barrier Material	15.61	6.71	2.55	3.66	1.93	1.07	3.44	.97	.81	.44	1.46	1.97
4412	Bulldozer	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
5115/16	APOD Clearance	49.34	17.01	11.24	13.40	4.97	4.76	5.30	2.86	6.12	1.99	2.73	4.85
6125	MEDEVAC	17.00	17.00	4.00	9.00	5.00	3.00	9.00	1.00	N/C	1.00	5.00	4.00
7111	MILVAN Supply	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
7211	MILVAN Ammo	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7121	40' Cont. Supply	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7221	40' Cont. Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	N/C	N/C
8112	CH-47D	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8212	155 Howitzer	N/C	N/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8315	C-E Shelter	N/C	N/C	1.00	1.00	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8414	HIND Helicopter	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
9126	Personnel	19.00	15.00	7.00	8.00	4.00	2.00	9.00	2.00	N/C	1.00	4.00	7.00

*300 Assault Troops moved by UH-60A

TABLE 4-4. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT
(COUNTER ATTACK PHASE - EUROPE)

Mission	Number of Platforms by Type											
	UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
1212 FAARP	16.24	7.01	2.52	3.86	1.76	.97	3.11	.87	.71	.40	1.35	1.96
1322 Small Unit												
HMMWV	N/C	3.60	1.36	1.98	1.03	.58	1.86	.52	.43	.23	.78	1.06
Radar	N/C	N/C	.43	.62	.32	.18	.58	.16	.14	.07	.24	.33
Supplies	1.04	.45	.17	.24	.13	.07	.23	.06	.05	.03	.10	.13
Personnel	1.17	.50	.19	.27	.14	.08	.26	.07	N/C	.03	.11	.15
1112 Arty Btry												
HMMWV	N/C	.90	.34	.50	.26	.15	.46	.13	.11	.06	.20	.26
155 Howitzer	N/C	N/C	4.09	5.95	3.09	1.74	5.57	1.55	1.30	.70	2.34	3.17
2½T Truck	N/C	N/C	3.57	5.21	2.70	1.52	4.88	1.36	1.14	.62	2.05	2.77
Ammo	35.38	15.22	5.78	8.29	4.37	3.67	7.80	2.20	1.85	1.00	2.98	4.47
Personnel	5.20	2.25	.86	1.22	.64	.36	1.16	.35	N/C	.15	.49	.66
1412 Inf Bn (Assault)												
HMMWV	N/C	71.99	27.23	39.70	20.59	11.60	37.15	10.33	8.68	4.69	15.61	21.13
Supplies/Equip	5.20	2.24	.85	1.22	.64	.36	1.15	.32	.27	.15	.49	.66
Personnel *	26.01	11.19	4.25	6.10	3.21	1.78	5.73	1.61	N/C	.73	2.44	[illegible]
2XXX Supplies/Equip	107.26	39.39	26.42	25.63	11.78	9.32	13.67	6.85	10.69	4.50	8.77	11.14
2445 Commo Shelter	N/C	N/C	.47	.71	.31	.20	.63	.18	.16	.08	.26	.35
3111 Lt Spec Weapons	2.52	1.10	.42	.60	.31	.17	.57	.16	.13	.07	.24	.32
3125/26 Hvy Spec Weapons	N/C	2.55	.97	1.47	.74	.44	1.29	.38	.34	.17	.53	.72
4113 Scissor Bridge	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
4413 Bulldozer	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
5115/17 APOD Clearance	60.21	22.69	13.85	13.85	6.67	7.54	6.16	3.73	6.66	3.18	4.78	4.95
6125 MEDEVAC	17.00	17.00	4.00	9.00	5.00	3.00	9.00	1.00	N/C	1.00	5.00	4.00
7111 MILVAN Supplies	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
7211 MILVAN Ammo	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7121 40' Cont. Supply	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	N/C	N/C
7221 40' Cont. Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	N/C	N/C
8112 CH-47D	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8212 155 Howitzer	N/C	N/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8315 C-E Shelter	N/C	N/C	1.00	1.00	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8414 HIND Helicopter	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
[illegible]6 Personnel	19.00	15.00	7.00	8.00	4.00	2.00	9.00	2.00	N/C	1.00	4.00	7.00

*All Troops moved by UH-60A

TABLE 4.5. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT
(DELAY PHASE - SWA)

	Mission	Number of Platforms by Type											
		UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
1214	FAARP	17.53	7.28	2.77	4.06	2.10	1.20	3.72	1.05	.89	.49	1.56	2.12
1334	Small Unit												
	C-E Shelter	N/C	N/C	.45	.66	.34	.20	.61	.17	.15	.07	.25	.34
	HMMWV	N/C	2.83	1.07	1.59	.81	.47	1.45	.41	.36	.16	.61	.82
	Supplies	.56	.23	.09	.13	.07	.04	.12	.03	.03	.02	.05	.07
	Personnel	1.67	.69	.26	.39	.22	.13	.37	.10	N/C	.04	.14	.19
1112	Arty Btry												
	HMMWV	N/C	N/C	.36	.53	.27	.16	.48	.14	.12	.06	.20	.27
	155 Howitzer	N/C	N/C	3.75	5.56	2.84	1.64	5.09	1.43	1.24	.65	2.12	2.87
	2½ T Truck	N/C	N/C	4.29	N/C	3.24	1.88	5.82	1.63	1.42	.75	2.42	3.28
	Ammo	38.65	16.09	6.15	8.80	4.65	2.59	8.15	2.34	2.04	1.07	3.47	4.68
	Personnel	5.60	2.33	.89	1.28	.67	.37	1.18	.34	N/C	.16	.50	.68
1424	Inf Bn												
	HMMWV	N/C	N/C	1.85	2.86	1.59	.97	2.73	.72	.64	.31	1.01	1.35
	Supplies/Equip	1.49	.61	.23	.34	.20	.12	.33	.09	.08	.04	.13	.17
	Personnel*	37.18	15.23	5.78	8.58	4.94	2.90	8.27	2.24	N/C	.95	3.16	4.19
1515	Bde Task Force												
	HMMWV	N/C	N/C	74.87	118.72	64.56	41.29	109.79	29.02	27.13	12.38	39.96	53.64
	105 Howitzer	N/C	11.83	4.43	7.03	3.82	2.44	6.50	1.72	1.61	.73	2.37	3.18
	Small Empl Exca	N/C	1.97	.74	1.17	.64	.41	1.08	.29	.27	.12	.39	.53
	Ammo/Supplies	90.37	35.46	13.51	20.12	11.62	6.91	18.99	5.23	4.91	2.24	7.23	9.56
	Personnel**	277.28	108.78	41.45	61.73	35.67	21.19	58.20	16.04	N/C	6.97	22.18	29.22
1525	Bde Task Force												
	HMMWV	N/C	N/C	67.49	107.01	58.19	37.21	98.96	26.15	24.45	11.16	36.01	48.34
	155 Howitzer	N/C	N/C	17.73	N/C	15.29	9.78	N/C	6.87	6.42	2.93	9.46	12.70
	LAV	N/C	N/C	N/C	N/C	N/C	57.04	N/C	40.09	37.48	17.11	55.20	N/C
	MPGS	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	84.32	38.50	N/C	N/C
	5 T Truck	N/C	N/C	N/C	N/C	N/C	13.45	N/C	9.45	8.83	4.03	13.01	17.47
	Bulldozer	N/C	1.97	.74	1.17	.64	.41	1.08	.29	.27	.12	.39	.53
	Ammo/Supplies	286.72	112.49	42.86	63.83	36.88	21.92	60.26	16.59	15.57	7.11	22.94	30.33
	Personnel	218.74	85.8[illegible]	32.70	48.70	28.14	16.72	45.9[illegible]	12.65	N/C	5.4[illegible]	17.[illegible]0	23.14
2XXX	Supplies/Equip	146.64	43.15	28.42	24.87	18.62	11.23	15.47	8.28	11.83	5.39	11.60	11.59
2445	Commo Shelter	N/C	N/C	.62	.98	.53	.34	.90	.24	.22	.10	.33	.44
4133	Bdge Section	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	1.00
4215	Barrier Matl.	4.11	1.61	.61	.91	.53	.34	.90	.24	.22	.10	.33	.44
4415	Bulldozer	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	N/C
	Personnel	.21	.08	.03	.05	.03	.02	.04	.01	N/C	.01	.02	.02

*All Troops moved by UH-60A
**900 Assault Troops moved by UH-60A

TABLE 4.5. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT (DELAY PHASE - SWA) (CONT.)

	Mission	Number of Platforms by Type											
		UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
5135	APOD Clearance	191.69	56.41	21.49	32.01	24.66	14.65	20.15	11.08	15.61	7.13	15.33	15.20
6135	MEDEVAL	84	84	20	42	20	18	42	4	N/C	4	20	20
7111	MILVAN Supplies	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	N/C
7211	MILVAN Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	1.00	N/C	N/C
7121	40' Cont Supplies	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	1.00	N/C	N/C
7221	40' Cont Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	N/C	N/C
8114	CH47D	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	N/C
8214	155 Howitzer	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8314	C-E Shelter	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8415	HIND Helo.	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
9115	Personnel	11	8	4	4	1	1	4	1	N/C	1	1	4

TABLE 4.6. PLATFORMS REQUIRED FOR MISSION ACCOMPLISHMENT (DEFENSE PHASE - SWA)

Mission		Number of Platforms by Type											
		UH-1H	UH-60A	CH-47D	Twin UH-60A	CH-53E	Twin CH-53E	JVX	HLH	HLA	HWC	MOD-53	COMP-47
1214	FAARP	17.53	7.28	2.77	4.06	2.10	1.20	3.72	1.05	.89	.49	1.56	2.12
4312	Mine Laying	7.44	3.05	1.16	1.72	.99	.58	1.65	.45	.40	.19	.63	.85
1313	Small Unit												
	HMMWV	N/C	N/C	1.80	2.74	1.54	.93	2.15	.70	.60	.30	.99	1.33
	Supplies	.71	.30	.11	.17	.10	.06	.16	.04	.04	.02	.06	.08
	Personnel	1.60	.67	.25	.37	.22	.13	.36	.10	N/C	.04	.14	.19
1112	Arty Btry												
	HMMWV	N/C	N/C	.44	.66	.37	.22	.64	.17	.14	.07	.24	.33
	155 Howitzer	N/C	N/C	5.25	N/C	4.47	2.65	N/C	2.03	1.72	.86	2.93	3.91
	2½ T Truck	N/C	N/C	4.60	N/C	3.91	2.35	N/C	1.73	1.50	.75	2.56	3.42
	Ammo	46.87	19.91	7.55	11.15	6.42	3.73	10.96	2.91	2.46	1.24	4.21	5.59
	Personnel	6.80	2.88	1.08	1.62	.92	.54	1.60	.36	N/C	.18	.60	.81
1414	Inr Bn (HTLD)												
	HMMWV	N/C	N/C	37.04	57.15	31.74	19.48	54.47	14.34	12.70	6.11	20.25	27.09
	Supplies/Equip	7.44	3.05	1.16	1.72	.99	.58	1.65	.45	.40	.19	.63	.84
	Personnel*	37.18	15.23	5.78	8.58	4.94	2.90	8.27	2.24	N/C	.95	3.16	4.19
1424	Inf Bn												
	HMMWV	N/C	N/C	12.52	19.29	10.71	6.58	18.38	4.84	4.29	2.06	6.83	9.14
	LAV	N/C	N/C	N/C	N/C	N/C	17.05	N/C	12.55	11.11	5.34	17.72	N/C
	MPGS	N/C	N/C	N/C	N/C	N/C	N/C	N/C	28.24	25.01	12.02	N/C	N/C
	Supplies/Equip	14.13	5.79	2.20	3.26	1.88	1.10	3.14	.85	.75	.36	1.20	1.59
	Personnel	46.48	[illegible]	[illegible]	10.72	6.18	3.63	10.34	2.79	N/C	1.19	3.95	5.24
2XXX	Supplies/Equip	348.12	99.78	74.28	68.24	37.04	26.87	38.72	16.74	24.78	11.91	23.69	26.17
4134	Bdge Section	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
4224	Barrier Matl.	7.44	3.05	1.16	1.72	.99	.58	1.65	.45	.40	.19	.63	.85
4414	Bulldozer	N/C	N/C	N/C	N/C	N/C	.73		.54	.48	.23	.76	N/C
5125	APOD Clearance	143.77	42.30	27.64	24.01	18.49	10.97	15.11	8.32	11.71	5.34	11.50	11.41
6145	MEDEVAC	117	117	30	59	30	25	59	5	N/C	5	30	30
7111	MILVAN Supplies	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	N/C
7211	MILVAN Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	1.00	N/C	N/C
7121	40' Cont Supplies	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	1.00	1.00	N/C	N/C
7221	40' Cont Ammo	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	1.00	N/C	N/C
8114	CH47D	N/C	N/C	N/C	N/C	N/C	1.00	N/C	1.00	1.00	1.00	1.00	N/C
8214	155 Howitzer	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8314	C-E Shelter	N/C	N/C	1.00	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	1.00
8415	Hind Helo	N/C	N/C	N/C	N/C	1.00	1.00	N/C	1.00	1.00	1.00	1.00	N/C
9125	Personnel	5.00	4.00	2.00	4.00	1.00	1.00	4.00	1.00	N/C	1.00	1.00	2.00

*All Troops Moved by UH-60A

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To demonstrate the advantages of the newer technology candidates and the limitations of the planned rotorcraft candidates and fleet size, four iterations of the least cost mix analysis are performed. These are:

- Limiting the type and quantity of candidate rotorcraft to those in the current force structure.

- Limiting the type of rotorcraft to that in the force structure but with no limit on the quantity available.

- Employing the type and quantity of rotorcraft in the force structure supplemented with advanced technology candidates.

- Employing the type and quantity of rotorcraft candidates as required as if there is no current force structure.

These four iterations are applied to each of the three phases of combat in Europe and the two phases in Southwest Asia. The results of these calculations are shown in Tables 4.7 through 4.11.

Table 4.7 shows the number of rotorcraft assigned to, and used by, the US V Corps in Europe and the XVIII Airborne Corps deployed to Southwest Asia (SWA). The structure of the force in Europe consists of corps assets, three heavy divisions, and one High Technology Motorized Division (HTMD). The structure of the airborne force in Southwest Asia includes Corps assets, one airborne division, one air assault division, and one HTMD. As indicated in the tabulation all of the available CH-47D rotorcraft are used in both theaters. Thirty seven percent (44/120) of the available UH-60As are used in Europe and 73% (153/210) and needed in SWA. None of the available UH-1H

TABLE 4.7. PREFERRED MIX OF CURRENT ROTORCRAFT
(QUANTITY LIMITED TO PLANNED FORCE STRUCTURE)

CANDIDATE ROTORCRAFT	EUROPE				SOUTHWEST ASIA		
	QUANTITY AVAILABLE	USED			QUANTITY AVAILABLE	USED	
		DELAY	DEFENSE	C'ATK		DELAY	DEFENSE
UH-1H	56	-	-	-	72	-	-
UH-60	120	-	44	12	210	153	83
CH-47D	80	53	80	70	112	112	112

NOTE: MISSION SHORT FALLS IDENTIFIED IN TABLE 4-9 platforms are employed in either theater for accomplishing transportation missions. Due to the payload limitations of the rotorcraft considered a significant number of missions cannot be performed in either theater.

Table 4.8 displays the perferred mixes of the types of rotorcraft is the force structure but is developed without limitations on the quantity available in Corps organizations. Examination of these data reveals a heavy demand for CH-47D assets in both theaters. Corps operations in Europe requires 93 Chinooks (16% more than the 80 in the organization). In SWA these results indicate a need for 192 CH-47Ds which is 71% greater than the 112 availabale at Corps and division level. It should be noted that the selection of 9 UH-60A in Europe and 51 UH-60A in Southwest Asia is the result of the requirement to move assault troops specified for selected missions in Tables 4.2 through 4.6.

TABLE 4.8. PREFERRED MIX OF CURRENT ROTORCRAFT
(QUANTITY UNLIMITED)

CANDIDATE ROTORCRAFT	EUROPE			SW ASIA	
	DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UH-1H	-	-	-	-	-
UH-60	-	9	12	51	16
CH-47D	53	93	70	192	164

Note: Mission shortfalls identified in Table 4-9.

Table 4.9 identifies the mission requirements which cannot be met by the current rotorcraft. The cause of these shortfalls is the non-divisible loads which are too heavy for the CH-47D.

TABLE 4.9. TRANSPORTATION MISSIONS NOT ACCOMPLISHABLE BY CURRENT ROTORCRAFT

MISSION (No. & Description)	EQUIPMENT ITEM (Weight-Tons)	NUMBER OF EQUIPMENT ITEMS NOT TRANSPORTED				
		EUROPE			SW ASIA	
		DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UNIT MOVES						
1422/1424 Inf Bn	LAV(14)	-	20	-	-	20
	MPGS(21)	-	30	-	-	30
1525 Bde Tsk Force	5Ton Truck(11)	-	-	-	18	-
	LAV(14)	-	-	-	60	-
	MPGS(21)	-	-	-	90	-
ENGINEER SUPPORT						
4112/4113 Scissor Bridge	Scissor Bdge(15)	1	1	3	-	-
4134/4135 Bridge Section	Bdge Section(10)	-	-	-	1	2
4413/4414/4415 Bull-dozer	Bulldozer(12)	2	2	4	2	2
SPOD/LOTS						
7111 MILVAN-Supplies	MILVAN(15)	2	10	10	5	5
7211 MILVAN-Ammo	MILVAN(23)	2	8	8	6	6
7121 40ft Container Supplies	Container(23)	1	8	8	5	5
7221 40ft Container Ammo	Container(35)	2	8	8	5	5

Tables 4.10 and 4.11 present the results of least cost mix evaluations where all of the daily mission requirements specified for both theaters are accomplished. In both cases, the UH-60A continues to be required to insert the assault troops for selected missions.

In the first case (Table 4.10) the results are based upon the use of current UH-60 and CH-47D rotorcraft augmented with advanced technology candidates to accomplish all missions. Since the current rotorcraft are assumed to be available, their procurement costs are sunk and only operating costs per hour are reflected in their cost and selection. The total mix costs of 1843 (M$) for Europe and 19364 (M$) for Southwest Asia are based upon operating the UH-60As and the CH-47Ds and procurring and operating the advanced technology candidates shown.

TABLE 4.10. PREFERRED MIX OF PLANNED AND NEW TECHNOLOGY ROTORCRAFT

CANDIDATE ROTORCRAFT	EUROPE			SW ASIA	
	DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UH-60	-	9	12	51	16
CH-47D	41	19	70	73	76
HLH	2*	30*	2*	40	41*
HWC	-	-	-	39	-
COMP 47	-	-	-	18	3
TOTAL MIX COST ($M84)	546	1976	1003	9452	3374

*Twin HLH required for 40 ft ammo container SPOD/LOTS mission.

The second case (Table 4.11) is developed based upon procuring and operating all of the selected candidates. Examination of these results show mix cost increases to 2364 M$ for Europe and 20196 M$ for SWA. Further, these results indicate the replacement of the CH-47D by JVX, HLH, and Composite CH-47 (COMP 47) platforms.

TABLE 4.11. PREFERRED MIX OF ROTORCRAFT ASSUMING NO PLANNED FORCE STRUCTURE

CANDIDATE ROTORCRAFT	EUROPE			SW ASIA	
	DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UH-60		9	12	51	16
JVX	15	12	6		
HLH	7*	36*	11*	40	39*
HWC				39	-
COMP 47	2	5	16	61	41
TOTAL MIX COST ($M84)	872	2635	1488	10260	3750

*Twin HLH required for 40 ft container SPOD/LOTS missions.

Once the candidate fleet mixes for all five phases and the two cases are developed, the most demanding phase is chosen for each theater to identify the least cost mix for that theater These least cost mixes are shown in Table 4.12 along with the associated life cycle cost.

TABLE 4.12. SELECTED ROTORCRAFT MIXES

CANDIDATES	EUROPE	SW ASIA
UH-60	9	51
CH-47D	19	73
HLH	30	40
HWC		39
COMP 47		18
LIFE CYCLE COST (M$84)	1976	9452

LEAST COST ROTORCRAFT CONCEPTS

The second phase of the methodology consists of the identification and description of least cost rotorcraft concepts designed to specific mission requirements. These requirements are based upon payloads and radii which occur at high daily frequencies in Europe and Southwest Asia. The high frequency missions selected to represent rotorcraft concept design points are identified in Table 4.13. It should be noted that all of the payloads are specific non-divisible load materiel items. Further, the payload variations range from 3000 to 70000 lbs and the maximum radius for both theaters is 15C km.

Parametric design and cost data, evolved from the rotorcraft candidates evaluated in the mix analysis, are used to describe conceptual rotorcraft for each of the selected design points. These parametric data are developed for conventional shaft driven rotor, tilt rotor, warm cycle rotor propulsion, and lighter-than-air technologies. The results of the preliminary design calculations for each technology in each theater and at

TABLE 4.13. HIGH FREQUENCY MISSIONS SELECTED AS ROTORCRAFT DESIGN POINTS

EUROPE				SW ASIA			
Payload (Klbs)	Materiel Item	Radius (KM)	No. Per Day	Payload (Klbs)	Materiel Item	Radius (KM)	No. Per Day
3	Collapsible Fuel Drum	50	258	3	Collapsible Fuel Drum	100	224
8	HMMWV	50	454	8	HMMWV	150	319
16	155MM Howitzer	150	69	16	155MM Howitzer	150	74
30	Mil Van (Supplies)	75	26	23	2-1/2 & 5 Ton Trucks	100	42
46	Mil Van (Ammo) 40' Container	25	35	28	LAV	150	28
70	40' Container (Ammo)	25	18	42	MPGS	150	39
				72	40' Container (Ammo)	25	10

each design point are summarized in Table 4.14. The data shown are the design gross weights and the relative costs to accomplish each high frequency mission.

Examination of these results indicates a preference for the tilt rotor concept in both theaters for payloads of 3000 lbs. In Europe the tilt rotor is also preferred for the 8000 lb. payload mission. For payloads of 16 through 70 thousand pounds in the European environment (i.e., 2000'/70 F) the conventional shaft driven rotor concept is considered equal to tilt rotor designs since the costs of mission accomplishment for both technologies are within 20% of each other. In Southwest Asia, using the 20% window is mission cost, the conventional shaft driven rotor concepts are equal to the tilt rotor concepts for the 8 through 70 thousa pound payload missions. It should be noted that the preference for, or competitive position of, tilt rotor technology is sensitive to hover and downwash considerations. The mission profiles evaluated do not require protracted hover operations and the effects of downwash and disc loading are not included in any of these comparisons.

The warm cycle rotor propulsion and the lighter-than-air technologies are not preferred over conventional and tilt rotor for any of the payload/radii considered. Using the 20% cost window for mission accomplishments these two technologies are equivalent for all missions in both theaters except for the 46 and 70K lb payloads in Europe and the 42 and 70 Klb payloads in SW Asia. Warm cycle rotor propulsion is preferred over lighter-than-air at these four design points.

TABLE 4.14. COMPARISON OF ROTORCRAFT DESIGNS FOR ACCOMPLISHING SELECTED HIGH FREQUENCY MISSIONS

Theater	Mission		Rotorcraft Technology							
	Payload (Klbs)	Radius (Km)	Conv. Shaft Driven		Tilt Rotor		Warm Cycle Prop.		Lighter-than-Air	
			Gross Wt (Klbs)	Mis. Cost (K$)	Gross Wt (Klbs)	Mis. Cost (K$)	Gross Wt (Klbs)	Mis. Cost (K$)	Gross Wt (Klbs)	Mis. Cost (K$)
Europe (2000'/ 70° F)	3	50	7.8	0.59	9.3	0.37	9.9	0.84	7.3	0.89
	8	50	19.6	1.08	24.9	0.74	25.3	1.56	19.4	1.67
	16	150	39.6	5.04	55.6	4.66	55.8	8.60	46.2	9.06
	30	75	70.2	3.98	95.6	3.53	84.4	5.91	75.8	6.80
	46	25	100.3	1.80	139.0	1.56	112.7	2.46	107.3	2.96
	70	25	154.6	2.52	211.5	2.22	156.8	3.27	163.2	4.12
SW Asia (4000'/ 95° F)	3	100	11.1	1.32	14.1	0.65	17.0	2.42	10.8	2.22
	8	150	28.9	4.03	42.8	3.56	46.3	7.35	32.3	6.76
	16	150	51.0	6.40	85.5	6.47	81.3	11.50	64.6	12.00
	23	100	68.8	5.38	113.3	5.36	97.5	8.81	82.5	9.68
	28	150	90.0	9.93	149.7	9.95	122.7	15.80	113.1	18.50
	42	150	145.3	13.70	224.5	14.00	162.7	20.40	169.6	25.50
	70	25	201.7	3.15	307.8	3.00	200.4	4.24	215.2	5.20

Section 5
PRINCIPAL FINDINGS

GENERAL

This section summarizes the principal findings developed from this analysis. It contains items of significance derived from the definition of future aviation missions, the description of candidate rotorcraft, and the identification of rotorcraft mixes to accomplish future mission requirements. Further, this section addresses rotorcraft measures of effectiveness and other concept evaluation criteria. The section ends with some recommendations regarding rotorcraft technology programs and a brief discussion of the limitations/cautions associated with this analysis and its findings.

TRANSPORTATION REQUIREMENTS

The future transportation requirements developed for this study identify and define the demands of future battlefield support. The ability to perform these tasks provides the basis upon which alternative advanced rotorcraft designs are examined and compared.

Transportation Missions

The demand for support by transportation rotorcraft is expected to be significant on the battlefields of the 21st century. The Army concepts for future combat operations and tactics emphasize mobility, flexibility, and agility. The Army 21 concepts call for rapid maneuver and deep attacks on enemy combat formations. Rotorcraft will perform vital roles in both

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combat support and combat service support mission areas. In this context the following transportation rotorcraft missions have been identified:

- Repositioning of Units
- Movement of Supplies and Equipment
- Movement of Special Weapons
- Engineer Support
- Aerial Port Clearance
- Medical Evacuation
- Sea Port Clearance and Logistics over the Shore
- Recovery of Equipment
- CBR Support
- Personnel Movement (Replacements and Returnees)
- Evacuation of Deceased Personnel

The quantification of the above missions is scenario dependent and is discussed below.

Representative Workloads

Within the context of two scenarios, Europe III-Sequence 2A and Mid East III, representative daily workloads have been developed. An overview of the representative daily missions is provided in three figures. Figure 5.1 shows the total number of daily transportation rotorcraft missions in each phase of combat operations in the Europe and Southwest Asia scenarios. Figure 5.2 compares the total tonnage of the daily missions for rotorcraft. Figure 5.3 depicts the minimum, mean and maximum radii of these missions.

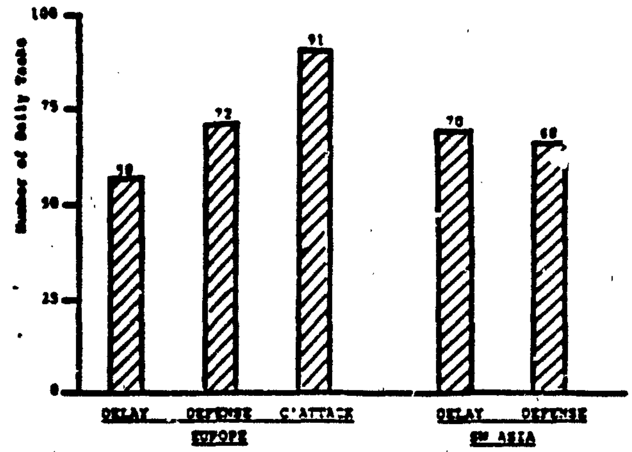

Figure 5-1. Number of Transportation Tasks Per Day

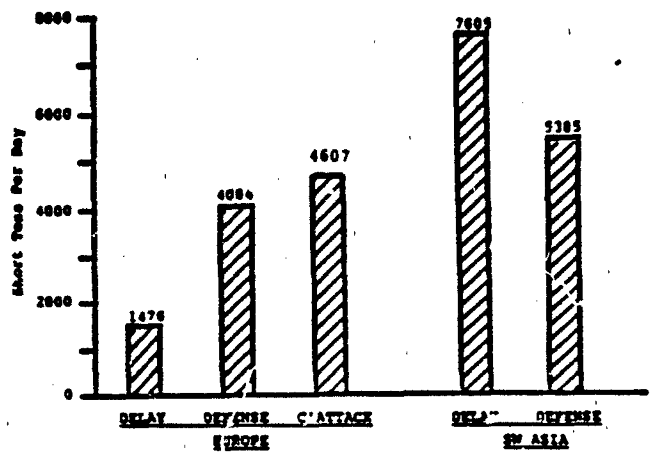

Figure 5-2. Total Number of Short Tons Transported Per Day

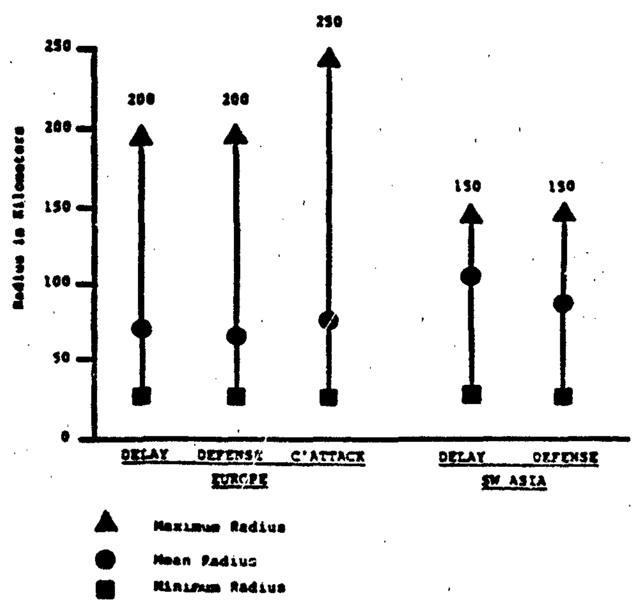

Figure 5-3. Radii of Transportation Rotorcraft Tasks

Mission Characteristics

Although missions may differ as to the tonnage, distance and frequency there are some common characteristics. The types of loads to be carried are the same for many different missions. The loads may be break-bulk cargo, heavy non-divisible loads, or personnel. One category, unit moves, combines cargo, heavy equipment and personnel lift requirements in a special way and requires a carefully coordinated movment.

The nature of the payloads and the distances over which they must be transported have a direct and significant impact in defining the characteristics and capabilities of the future rotorcraft fleet. The size and weight of non-divisible loads and, to a lesser extent, of break-bulk cargo loads determine the lift capabilities required in the future fleet. The travel distance for the missions together with payloads establish range and endurance parameters for the future rotorcraft.

FUTURE ROTORCRAFT FLEETS

Examination of the results presented in Section 4 of this report reveals that the fleet mixes shown in Table 5.1 are preferred for accomplishing future aviation mission requirements. These fleets will accomplish all of the tasks in the phases of conflict examined. It should be noted that the values shown are based upon daily requirements and do not include attrition from accidents or enemy action. Further, the development of these values is based upon equal effectiveness - variable cost analyses. This insures that each of the four mixes perform each mission and all missions equally. For each mission the same payload is moved the same radius within the same time. All missions are performed in the same order (i.e., some simultaneously, others sequentially) and are completed within one

24 hour period. Within the limits of input data accuracy and the effects of simplifying assumptions, the resulting four mixes provide identical mission performance but vary in life cycle cost as shown.

TABLE 5.1. PREFERRED FLEET MIXES

Platform Wt. Class (klbs)		Platform Technology 1/	Candidate Selected	Number of Platforms			
Gross	Useful			Europe		Southwest Asia	
20	10	CSDR	UH-60A	9	19	51	51
50	25	TR	JVX	0	12	0	0
	30	CSDR	CH-47D	19	0	73	0
	35	CSDR	COMP-47	0	5	18	61
150	80	CSDR	HLH	30	36	40	40
275	175	CSDR/WC	HWC	0	0	39	39
Mix Life Cycle Cost (M$84)				1976	2635	9452	10260

1/ CSDR = Conventional Shaft Driven Rotor
TR = Tilt Rotor
WC = Warm Cycle Rotor Propulsion

EVALUATION OF ROTORCRAFT CANDIDATES

The technologies examined in this study are represented by twelve rotorcraft candidates. The relative advantages derived from each technology can be estimated by comparing the capabilities of each candidate according to a set of common measures of effectiveness (MCEs). The measures are:

1. The fraction of rotorcraft missions a candidate is capable of accomplishing

2. The fraction of total combat power a candidate is capable of moving1/

1/ Fraction of Combat Power Moved is addressed in Volume II of this report.

3. The fraction of logistics resupply requirements each candidate is capable of satisfying.

4. Candidate self deployment range

5. Candidate self deployment time

6. Candidate daily flying hours

7. Presence of the candidate in the Least Cost Mix

Other criteria used to evaluate each candidate are:

1. Ton-km/Day
2. Troop-km/Day
3. Operating cost per Ton-km
4. Operating cost per Troop-km

Table 5.2 shows the percent of the missions by phase and theater that each rotorcraft candidate is able to accomplish. These data are based upon the payload/radius capabilities of the candidate, the payload/radius requirements of each mission, and the number of missions in each combat phase.

Table 5.3 shows similar data for the logistics resupply missions included in each phase of combat. These missions represent from 40 to 60% of the total number in Europe and from 20 to 30% of the total missions identified for SWAsia.

Figure 5.4 compares the relative ferry range of each candidate and also shows estimates of flight times for these ranges. Range information for the UH-1H, UH-60A, CH-47D, CH-53E, JVX and HLH reflect published data for these platforms. Range data for the other candidates are estimates based upon fuel

TABLE 5.2. CANDIDATE TASK ACCOMPLISHMENT CAPABILITY

(% of Tasks Accomplishable)

CANDIDATE ROTORCRAFT	EUROPE			SW ASIA	
	DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UH-1H	48	40	34	20	29
UH-60	55	75	41	20	29
CH-47D	83	85	85	84	82
TWIN 60	79	85	85	67	60
CH-53E	95	94	97	86	87
TWIN 53	98	99	99	94	94
JVX	83	82	84	71	63
HLH	98	99	99	97	99
HLA	93	94	56	43	56
HWC	100	100	100	100	100
MOD-53	95	94	97	94	94
COMP 47	91	93	92	86	85

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TABLE 5.3. CANDIDATE LOGISTICS RESUPPLY CAPABILITY
(% of Tasks Accomplishable)

CANDIDATE ROTORCRAFT	EUROPE			SW ASIA	
	DELAY	DEFENSE	C'ATK	DELAY	DEFENSE
UH-1H	73	76	76	68	80
UH-60	85	86	87	68	80
CH-47D	88	86	89	75	80
TWIN 60	88	86	89	75	80
CH-53E	91	91	92	75	80
TWIN 53	97	97	97	81	85
JVX	88	86	89	75	80
HLH	97	97	97	94	95
HLA	100	100	100	94	95
HWC	100	100	100	100	100
MOD-53	91	91	95	81	85
COMP 47	88	86	89	75	75

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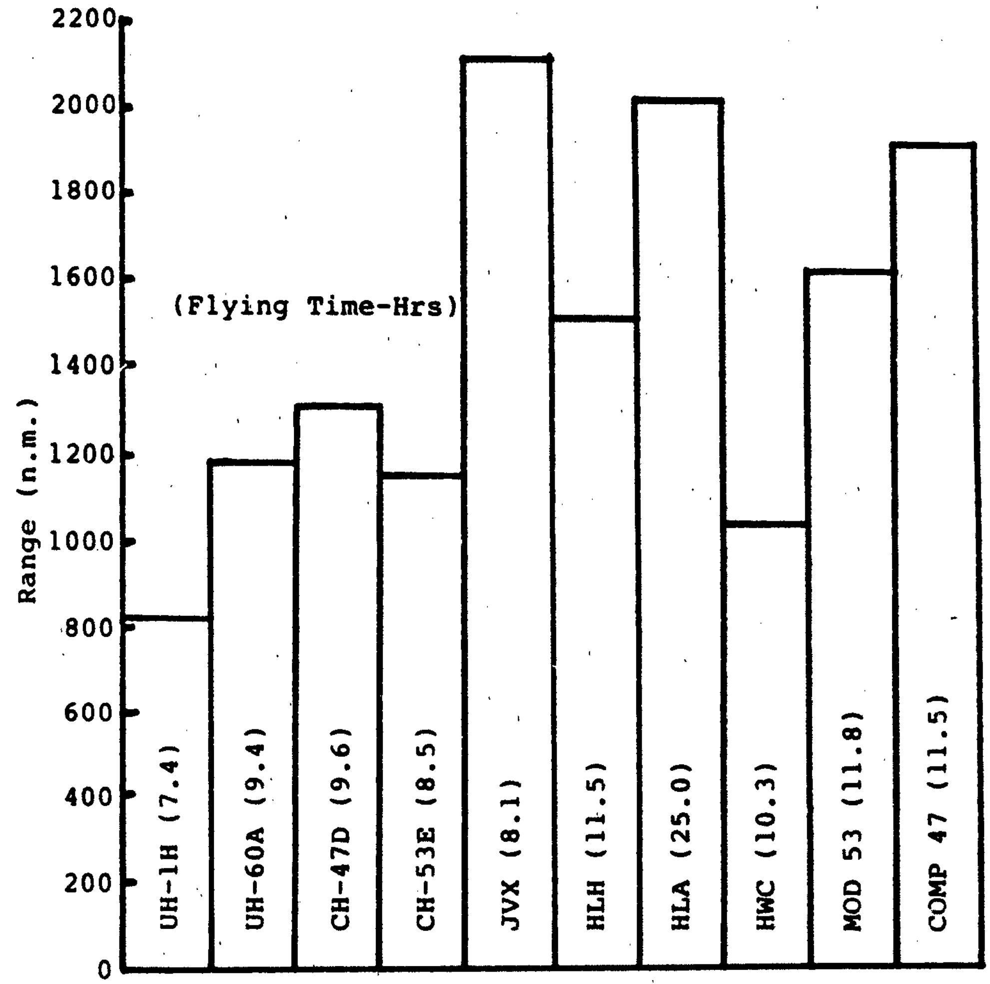

Figure 5.4 Relative Ferry Range of Rotorcraft Candidates

capacities and flow rates. Flight times for all candidates are estimates derived from ferry range and speed calculations.

Tables 5.4 and 5.5 provides information useful in assessing the relative deployability of each rotorcraft candidate. Both tabulations are based upon deployment distances from CONUS to various destinations taken from AFR 173-13. Table 5.4 is derived from these distances and the ferry ranges of each platform. Table 5.5 evolves from the same distances and the estimated speeds of each rotorcraft.

Estimates for daily flying hour programs of each rotorcraft candidate have already been presented on Section Four of this report. For comparative purposes, all platforms can be assumed to provide 6 flying hours per combat day.

The rotorcraft candidates selected for the least cost mixes developed in Section Four have been identified in Table 5.1. As indicated in this display the slightly higher cost mixes result from the procurement of all selected candidates.

Table 5.6 displays the other criteria used to further evaluate each rotorcraft candidate. The criteria shown, calculated for Sea Level/Standard conditions, are:

1. Ton-km/Day
2. Troop-km/Day
3. Operating cost per Ton-km
4. Operating cost per Troop-km

The relative ranking of each rotorcraft candidate in each of the ten areas of evaluation is shown in Table 5.7. The most capable candidate (No. 1) through the least capable (Nos 12, 10, or 9) are indicated in each area. Employment of these rankings must be based upon rating the relative importance of these

TABLE 5.4. RELATIVE DEPLOYABILITY OF ROTORCRAFT CANDIDATES

Rotorcraft Candidate	Approximate Number of Refueling Stops						
	Deployment Destination						
	Europe 1/ (4000 nm)	Mid East 1/ (6400 nm)	North 1/ Africa (5500 nm)	Southwest 1/ Asia (6600 nm)	Southeast 2/ Asia (7500 nm)	Australia 2/ (8500 nm)	Japan 2/ (4500 nm)
UH-1H	5	8	7	8	9	10	6
UH-60A	3	5	5	6	6	7	4
CH-47D	3	5	4	5	6	7	3
JVX	2	3	3	3	4	4	2
CH-53E	3	6	5	6	7	7	4
HLH	3	4	4	4	5	6	3
HLA	2	3	3	3	4	4	2
HWC	4	6	5	6	7	8	4
MOD-53	2	4	3	4	5	5	3
COMP-47	2	3	3	3	4	4	2

1/ East Coast Origin
2/ West Coast Origin

TABLE 5.5. RELATIVE DEPLOYMENT DURATIONS OF ROTORCRAFT CANDIDATES

Rotorcraft Candidate	Approximate Deployment Flight Time (Hrs)						
	Deployment Destination						
	Europe[1] (4000 nm)	Mid East[1] (6400 nm)	North[1] Africa (5500 nm)	Southwest[1] Asia (6600 nm)	Southeast[2] Asia (7500 nm)	Australia[2] (8500 nm)	Japan[2] (4500 nm)
UH-1H	36	58	50	60	68	77	41
UH-60A	32	51	44	52	59	67	36
CH-47D	29	47	40	49	55	62	33
JVX	15	25	21	25	29	33	17
CH-53E	30	47	41	49	56	63	33
HLH	31	49	42	51	58	65	35
HLA	50	80	69	82	94	106	56
HWC	40	64	55	66	75	85	45
MOD-53	30	47	41	49	56	63	33
COMP-47	24	39	33	40	45	52	27

1/ East Coast Origin
2/ West Coast Origin

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TABLE 5.6. OTHER CANDIDATE ROTORCRAFT EVALUATION CRITERIA*

CANDIDATE ROTORCRAFT	TON-KM/DAY 1/	TROOP-KM/DAY 2/	OPNS $ / TON-KM	OPNS $ / TROOP-KM
UH1H	2614	13068	3.08	.61
UH60	4990	16632	2.49	.74
CH47D	12128	29106	.64	.27
TWIN60	7776	N/A	3.19	N/A
CH53E	29472	80190	.59	.22
TWIN53	32335	N/A	1.09	N/A
JVX	33292	67392	.29	.14
HLH	58353	336960 3/	.36	.07
HLA	43260	N/A	.78	N/A
HWC	93789	259200 3/	.83	.30
MOD53	37325	80190	.48	.22
COMP47	30650	58806	.43	.22

*Calculated for Sea Level/Standard Conditions
1/ Useful Load x Speed x Daily Flying Hours
2/ Troop Capacity x Speed x Daily Flying Hours
3/ Troop Carrier Pod, 240 Personnel

TABLE 5.7. CANDIDATE RANKING IN ALL EVALUATION CRITERIA

Candidate Rotorcraft	Task Accomp	Combat Power Moved	Resupply Satisfied	Deployment Range	Deployment Time	Fleet Mix	Ton-Km/Day	Troop-Km/Day	Cost/Ton-Km	Cost/Troop-Km
UH-1H	12	12	12	10	7	12	12	9	11	8
UH-60	11	11	11	7	5	1	11	8	10	9
CH-47D	7	8	8	6	3	1	9	7	6	6
TWIN-60	9	10	9	N/A	N/A	12	10	N/A	12	N/A
CH-53E	5	6	6	8	5	12	8	4	5	5
TWIN-53	3	4	4	N/A	N/A	12	6	N/A	9	N/A
JVX	8	9	7	1	1	2	5	5	1	2
HLH	2	3	3	5	6	1	2	1	2	1
HLA	10	2	2	2	9	12	3	N/A	7	N/A
HWC	1	1	1	9	8	1	1	2	8	7
MOD-53	4	5	5	4	4	12	4	3	4	3
COMP-47	6	7	10	3	2	1	7	6	3	4

evaluation criteria. The rating of these criteria is not performed in this analysis.

SELECTION OF ROTORCRAFT TECHNOLOGIES

The rotorcraft mix analysis summarized in the preceeding paragraphs, indicates the type and quantity of specific rotorcraft needed to accomplish the daily transportation missions identified in Section 2 of this report. The rotorcraft candidate analysis expands on the mix evaluation to compare candidates over a larger set of measures of effectiveness and evaluation criteria. The selection of rotorcraft technology is based upon design points developed from mission definitions and parametric analyses of rotorcraft technologies. The technologies and concepts identified in Table 5.8 are those which should receive special emphasis in future rotorcraft development programs.

Table 5.8 indicates that Tilt Rotor technology results in the least cost rotorcraft concept for 3000 lb payload missions in both theaters and for 8000 lb missions in Europe. For mission payloads greater than 8000 lbs, in both theaters, Tilt Rotor and Conventional Shaft Driven Rotor technologies result in rotorcraft concepts which are essentially equal is mission accomplishment cost. The data displayed also provides estimates of rotorcraft and basic weights and the life cycle cost for one platform. The latter is based upon procurement cost estimates, a 300 hr annual flying program, and a 20 year life cycle.

PRINCIPAL FINDINGS

The information presented in Tables 5.1 and 5.8 is summarized as follows:

TABLE 5.8. PREFERRED TECHNOLOGIES AND ROTORCRAFT CONCEPTS FOR FUTURE ARMY AVIATION TRANSPORTATION MISSIONS

Theater	Rotorcraft Mission		Preferred Rotorcraft Technology	Rotorcraft Concept		
	Payload (Klbs)	Radius (Km)		Gross Weight (Klbs)	Basic Weight (Klbs)	Life Cycle Cost (M$84)
Europe	3	50	Tilt Rotor	9.3	5.4	7.0
	8	50	Tilt Rotor	24.9	14.4	14.2
	16	150	Tilt Rotor	55.6	32.3	30.0
			Cnvtnl SDR*	39.6	18.3	23.4
	30	75	Tilt Rotor	95.6	55.6	45.3
			Cnvtnl SDR*	70.2	30.5	36.6
	46	25	Tilt Rotor	139.0	80.8	60.0
			Cnvtnl SDR*	100.3	46.0	50.0
	70	25	Tilt Rotor	211.5	113.0	85.5
			Cnvtnl SDR*	154.6	71.7	70.0
SW Asia	3	100	Tilt Rotor	14.1	8.2	9.3
	8	150	Tilt Rotor	42.8	24.9	22.9
			Cnvtnl SDR*	28.9	14.1	18.7
	16	150	Tilt Rotor	85.5	49.7	41.6
			Cnvtnl SDR*	51.0	23.1	30.0
	23	100	Tilt Rotor	113.3	65.8	51.6
			Cnvtnl SDR*	68.8	31.1	37.4
	28	150	Tilt Rotor	149.7	87.0	63.9
			Cnvtnl SDR*	90.0	41.0	46.0
	42	150	Tilt Rotor	224.5	130.5	89.8
			Cnvtnl SDR*	145.3	63.5	63.6
	70	25	Tilt Rotor	307.8	179.3	115.6
			Cnvtnl SDR*	201.7	94.0	87.6

* Conventional Shaft Driven Rotor

1. Corps Operations in Europe require approximately 60 rotorcraft for daily transportation missions.

2. Corps Operations in SW Asia require approximately 200 rotorcraft for daily transportation missions.

3. Approximately 50% of the required rotorcraft have a payload/radius capability greater than the CH-47D.

4. Tilt Rotor Technology and conventional shaft driven rotor tachnology result in the most cost-effectaive rotorcraft concepts.

5. Engine uprating and composite construction significantly improves the overall preference of current rotorcraft.

6. The technique of twinning medium lift rotorcraft warrants emphasis. Twinning light rotorcraft does not appear to be warranted.

7. Warm Cycle Rotor Propulsion technology and Lighter-than-air technology do not result in cost-effective rotorcraft concepts.

ISSUES AND CAUTIONS

The findings resulting from this evaluation of rotorcraft missions, candidates, and technologies are limited by the scope of this analysis, the assumptions made, and the estimates employed. Within these limitations the study results provide valuable insights into the nature of future aviation missions and the quantity and design of platforms for their accomplishment.