

Vertical Envelopment and the Future Transport Rotorcraft

Operational Considerations for the Objective Force

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PREFACE

This report summarizes the research findings of an Arroyo Center analysis of the risks and uncertainties associated with developing a Future Transport Rotorcraft (FTR) to help fulfill a vertical envelopment mission for the Objective Force. In this concept, the FTR would move new medium-weight armored vehicles, known as the Future Combat Systems (FCS), about the battlefield and across enemy air defenses. The findings should be of interest to defense policymakers, military technologists, and concept developers.

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CONTENTS

Preface	iii
Figures	vii
Tables	ix
Summary	xi
Abbreviations	xvii
Chapter One	
INTRODUCTION	1
Chapter Two	
ASSESSMENT OF EXISTING ROTORCRAFT	
TECHNOLOGY/COST	5
Current Rotorcraft Capabilities	6
CH-53E Upgrade	8
Chapter Summary	11
Chapter Three	
ADVANCED TECHNOLOGY ROTORCRAFT	13
Cost/Weight	13
S&T Goals	15
FTR Concepts	17
Technology Versus Cost	18
Chapter Four	
SURVIVABILITY CONCERNS	29
FTR Survivability Against current Russian Air Defense	
systems	29
Countermeasures	35

Chapter Summary	39
Chapter Five	
POLICY IMPLICATIONS	41
Bibliography	49

FIGURES

1. Vertical Envelopment and the Objective Force	2
2. The V-12 Lifted 34 Tons in 1969	6
3. The FTR and Today's Large Rotorcraft	7
4. Mi-26 Cabin Size Already Adequate	8
5. CH-53E Upgrade Options	9
6. CH-53E Upgrades and Other Missions	10
7. Cost/Weight Estimates for the "Nominal" FTR	14
8. Phase II Rotorcraft S&T Goals	16
9. 2006 Technology Concepts Limited to Preliminary Sizing Calculations	18
10. Performance Improvements Have Kept Empty Weight Percentage from Declining	19
11. Historically, Product Maturation Has Not Lowered Price	20
12. Lower Weight Concepts Depend on Accelerating Technology	21
13. Transmissions	23
14. S&T Needs 2003–2007	25
15. Analysis Using NASA's TRLs Indicate Quad Tiltrotor Has the Highest Technical Risk of the Four Proposed FTR Design Concepts	26
16. Air Defense Laydown Based on Current Russian Army Capabilities	30
17. RJARS Results for Low-Altitude Routes from the Coast	32
18. "Typical" Enemy Infantry Company	33
19. FTR May Be Vulnerable to Very Thin Defenses	34
20. Hand-Held IR: Offense Leads Game	35

21. FTR and Air Defense Systems Costs	38
22. Two Vastly Different Versions of FTR	42
23. Is the FTR for Strategic Deployment?	43
24. C-130 Fleet Offers Significant Short-Range Payload . .	44

TABLES

S.1. Summary of Study Findings in the Areas of Cost, Risk, and Survivability	xiv
1. Unresolved Issues	45
2. Conclusions	46

BACKGROUND

The Future Combat Systems (FCS) as envisioned by the Chief of Staff of the Army, General Eric Shinseki, is a rapidly deployable, medium-weight family of combat vehicles that will have the lethality of today's heavy armor forces. Survivability will be achieved by a combination of new technology, enhanced vehicle mobility, and new concepts of operations. One concept uses rotorcraft to rapidly transport the FCS force around the battlefield. The use of heavy lift rotorcraft to "vertically envelop" the adversary with the FCS force package has shown significant promise in wargames and simulation models. This vertical envelopment concept has been of particular interest to planners considering options for the Objective Force, the mobile Army force structure that will emerge after 2010.

While theoretically attractive, the vertical envelopment concept places significant demands on any aircraft that could transport the FCS. Although the actual designs are yet to come, Objective Force planners have set initial nominal design specifications for FCS and the Future Transport Rotorcraft (FTR). Current design goals are for the FCS to weigh less than 20 tons, and for the FTR be able to execute 500-kilometer, round-trip FCS transport missions in an all-VTOL (vertical takeoff with payload, vertical landing with payload) mode. The FTR will be sufficiently robust to move freely about the battlefield with a minimum of limitations imposed by survivability concerns.

FTR CRITICAL ISSUES

The key FTR issues are the technical risk, cost, and survivability of the FTR both at the nominal parameters and at variations from those values. Senior policymakers have expressed interest in understanding the location of the “knee of the curve”—the point at which the technical challenges and uncertainties begin to grow and produce diminishing performance benefits—for each of these issues. Our primary goal was, therefore, to identify the knee in the technical risk versus performance, cost versus performance, and survivability versus threat curves. Our secondary goal was to put the study results in the context of implications for a potential Army Integrated Concept Team (ICT). The ICT is the first formal stage of the weapon acquisition process. When this study was completed in 2001, the Army’s Aviation School at Fort Rucker, Alabama, was poised to conduct the ICT but was unable to obtain the funding to initiate this effort.

ORGANIZATION OF THIS REPORT

Chapter One describes the overall FTR concept and the issues of development costs and technical feasibility with today’s technology. We show that the FTR would significantly exceed the payload-radius capabilities of today’s large rotorcraft. However, we also show that the modernization of existing rotorcraft with new, but flight-proven, subsystems might allow the transport of lighter weight FCS vehicles (about 12–15 tons) over distances within a 100-kilometer radius. Achieving 20-ton lift capability requires a new advanced transport aircraft start, with a \$10–20 billion development cost. Thus, the transport of 12- to 15-ton FCS vehicles over modest distances is one representation of the knee in the cost versus performance curve

Chapter Two reviews the impact of advanced rotorcraft technology on the feasibility (technology readiness levels) and cost of the FTR. New technology is needed to lower the weight of the FTR, which is assumed, at this preliminary point in the design process, to be a surrogate for cost. We discuss the use of weight in this manner and highlight some concerns about the validity of this metric. Assuming the relevance of the weight metric, we also show that bringing FTR costs down to historical patterns for rotorcraft (roughly 1.5 times the cost of comparable-load, fixed-wing aircraft) will require a significant

acceleration, beyond historical trends, of technical progress. We also show that there are significant uncertainties about translating that progress into cost reduction. While there is not an official cost number beyond which the FTR is unaffordable, program production costs in the tens of billions would appear to represent a knee in the affordability versus performance curve.

Survivability is discussed in Chapter Three. We used the RAND air defense simulation model to show that FTR attrition rates approach acceptable levels only under conditions of extensive suppression of enemy air defenses (SEAD), either by other aircraft, or by onboard IR and RF missile countermeasures (IRCM and RFCM). Additionally, high pilot situational awareness of the location of the air defense assets, along with stealthy FTR signatures, will be critical for FTR survivability against anti-aircraft artillery (AAA). We also describe how, historically, hand-held IR surface-to-air missiles (SAMs) have quickly developed countermeasures to each new generation of IRCM systems. These SAMs and other low-altitude air defense weapons are available to virtually any military force in the world, with cost being the only limitation. We conclude that major new defenses against IR and RF guided missiles, along with an AAA countermeasure development program, will be required for the FTR to have freedom of movement on the battlefield. The program has both significant cost and technical risks. Without an aggressive and successful survivability program the FTR will have significant operational limitations.

STUDY FINDINGS

Information used in this study was current as of July 2001. We have three principal findings from this study, which are summarized in Table A.1.

Cost. The first finding is that an FTR designed to carry a 12- to 15-ton payload on a 100-kilometer round trip, and flying around the battlefield rather than through it, offers vastly reduced cost and minimizes technical risks compared to an FTR meeting the nominal requirements.

Technical risk. Our second finding is that the FTR has significant technical risk. The Army science and technology (S&T) community is assuming that the pace of progress will exceed historical patterns. While progress at the component level has in certain cases exceeded

Table S.1**Summary of Study Findings in the Areas of Cost, Risk, and Survivability**

	Development	Production	Knee in the Curve
Cost	Current technology supports a 12- to 15-ton payload, 100-km combat range rotorcraft. New start required for rotorcraft. RDT&E: \$10–20 billion.	Even with optimistic technology projections, FTR per-unit flyaway costs over \$100 million vs. \$30–40 million for modified CH-53E.	New start: \$10–20 billion; CH-53E mod: \$200 million.
Technical risk	Basic research needed for quad tiltrotor. Ambitious goals for development of FTR engine, blade, and transmission.	TRLs sufficiently low resulting in uncertain manufacturing and maintenance costs.	TRL 3 for quad tiltrotor, 3–4 for dual tiltrotor, 5 for helicopter.
Survivability	Can counter 1st and 2nd generation IR SAMs, ballistic protection up to 25mm AAA.	Both new onboard and offboard IRCM and RFCM needed. Tiltrotor flight profile lower risk.	Current technology sufficient for low-end SAM threat. AAA threat problematic. Large developmental effort needed for current high-end threat.

historical patterns, it has not done so for some of the critical major subsystems (rotors/ blades, for example). The major technical risks, as opposed to feasibility (i.e., an FTR can be built, but at great expense), are that the time and development costs of the FTR will, in our estimation, be greater than is acceptable for the Objective Force planners. We therefore recommend that the Army S&T community work closely with the operational community and establish more modest goals that would still allow development of a militarily useful system.

Survivability. A significant component of the technical risk is survivability of the FTR. Our third finding is that the FTR will require a multibillion-dollar survivability enhancement program. Indepen-

dent of aircraft type, the requirement to land in enemy territory presents a major survivability design issue. Our analysis indicates that both conventional missile jammers and unconventional hard kill technologies must be developed to give the FTR the ability to survive on the battlefield. Current funding is insufficient to develop the technology in a timely fashion. Survivability equipment may increase aircraft weight by as much as 2 to 5 tons.

The vertical envelopment concept is sufficiently attractive that the Army should continue to consider its feasibility, but the Army must also realize that achievement of the nominal technical parameters is an ambitious and risky goal. The tradeoff space involving mission performance and FTR requirements, however, has not been fully explored. It is too early to focus on a point design for FTR or even exclusively on a VTOL solution. The development and acquisition community must continue and expand its interactions with force planners, modelers, and strategists if an affordable and militarily viable FTR is to be built.

ABBREVIATIONS

AAA	Anti-aircraft artillery
ADA	Air defense assets
AMRDEC	Aviation and Missile Research, Development, and Engineering Center (Army)
APC	Armored personnel carrier
ATD	Advanced technology demonstration
DEW	Directed Energy Weapon
DIRCM	Directed Infrared Counter Measure
FCS	Future Combat Systems
FLOT	Forward line of troops
FTR	Future Transport Rotorcraft
HMG	Hand-Held Machine Gun
HOGE	Hover out of ground effect
ICT	Integrated Concept Team
IRCM	Infrared countermeasures
JTAGG	Joint Turbine Advanced Gas Generator
LAV	Light Armored Vehicle
MANPADS	Man Portable Air Defense System
NASA	National Aeronautics and Space Administration

RDT&E	Research, development, test, and evaluation
RFCM	Radio frequency countermeasures
RJARS	RAND's Jamming Aircraft and Radar Simulation
RPG	Rocket-propelled grenade
S&T	Science and technology
SA	Situational awareness
SAMs	Surface-to-air missiles
SEAD	Suppression of enemy air defenses
TRADOC	Training and Doctrine Command
TRL	Technology Readiness Level
VTOL	Vertical takeoff and landing