Executive Summary

Introduction

The 406-UM TerpRanger is an upgrade program for the Bell Model 206 JetRanger, designed in response to the 2002 AHS International Request For Proposals (RFP) for a Light Helicopter Upgrade Program. The RFP recognized the existence of an abundant resource of aging light helicopters, retired or soon to be retired, that presents an opportunity for upgrade and re-manufacture for the purpose of increased performance, safety, and reliability, while at a fraction of the cost of acquisition of a newly manufactured commercial helicopter. The purpose of this student design competition, co-sponsored by Bell Helicopter Textron, was to identify a candidate helicopter and develop a commercially viable upgrade program for it. The design has been developed for an existing helicopter; consequently, it is envisaged that this upgrade program is to be implemented within the next five years. The TerpRanger upgrade therefore incorporates cutting-edge technology solutions that are expected to mature within this time period.

Mission Requirements

The target performance goals specified by the RFP are a cruise speed of 140 knots, an absolute dry-tank range of 400 nautical miles and an increase in payload capability. In addition, the upgraded helicopter must incorporate improvements in safety and reliability, retain its wide-ranging multi-role missions capability, and have a low acquisition and operating cost. As most light helicopters are typically capable of 110-130 knots, the 140 knot cruise speed is the most stringent of the requirements. The TerpRanger design has, therefore, been optimized for high-speed flight while maintaining low cost of operation and extensive multi-mission capability.

Selection of Candidate Helicopter

To select a helicopter for the upgrade program, a pool of potentially suitable candidates was examined. Each helicopter was ranked on the basis of an *index of upgradability*, which is a measure of the upgrade potential of a particular helicopter. The index is based on factors such as the age of a particular helicopter model, the materials used in its manufacture, the design of its main rotor, and the number of aircraft of that model in service. From this analysis, the JetRanger emerged as the helicopter with the most potential for a successful upgrade program.

Design Methodology

The TerpRanger upgrade design was conducted in conjunction with the Spring 2002 Helicopter Design course at the University of Maryland. The course is aimed at introducing students to the different aspects of a real-world helicopter design and manufacturing process, and providing them with a thorough understanding of the issues involved. To this end, no commercial helicopter design or analysis tools were used. The University of Maryland Advanced Rotor Code (UMARC) was modified to carry out the detailed rotor design, including aeroelastic stability analysis and estimation of hub loads. The helicopter graphics were developed using I-DEAS CAD software.

Design Approach

With a high cruising speed being the principal performance goal for the design, the TerpRanger design focuses on minimizing the power required in cruise while simultaneously increasing the power margins of the propulsion system. The increases in speed and range must be accompanied by reductions in vibration levels; hence, special consideration has been given to this issue. Because the primary purpose of this upgrade program is to provide a high-performance helicopter at a price lower than that of a newly manufactured aircraft, low acquisition and operating costs are a fundamental consideration in the design process.

The TerpRanger: Improved Performance

The TerpRanger can cruise at 144 knots (SL/ISA), carrying a 1125 lb payload for a distance of 424 nautical miles. This represents with a 24% increase in cruise speed, a 20% increase in payload capability and a 15% improvement in range over the baseline JetRanger, for only a 2% increase in direct operating costs. Such a performance enhancement will allow, for example, non-stop travel from Washington, D.C., to Boston in less than 3 hours.

The key component of the upgrade program is a new *four-bladed, composite, hingeless main rotor system with modern airfoil sections and an advanced-geometry blade tip*. The new rotor postpones retreating-blade stall and advancing-blade drag-divergence to higher advance ratios by tailoring the airfoil distribution along the span, which in turn reduces the vibration levels and power requirements at the desired cruise speed. Fuselage drag is reduced by 15% through: tilting the main rotor shaft forward by 6° to reduce the fuselage angle of attack in cruise, shortening the main rotor shaft, and providing fairings for the high-drag components of the airframe – the main rotor hub and the skid landing gear.

The TerpRanger incorporates a *state-of-the-art engine*, the scaleable specifications for which are given in the RFP. The engine is based on the DoD/NASA/Industry Integrated High Performance Turbine Engine Technology (IHPTET) initiative and has a higher power-to-weight ratio and lower specific fuel consumption than other existing engines. The TerpRanger also features a *redesigned drivetrain*, in which modern design methods are used to increase the stress levels on the gearbox components, and hence reduce weight. New materials and manufacturing methods are used to improve their strength and reliability.

The TerpRanger: Improved Passenger Comfort

The TerpRanger upgrade guarantees a smooth, high-speed ride for its occupants. The four-bladed main rotor produces lower hub loads and associated vibration levels at high speeds. Complementing this is a choice of three different *vibration-reduction devices*: passive Liquid Inertia Vibration Eliminators or Anti-resonance Force Isolators that attenuate the primary 4/rev vibrations by 60-70%, or an Active Vibration Reduction System (AVRS) that adaptively reduces vibrations of all frequencies by over 50%. With the incorporation of AVRS, it may be possible to achieve a "jet smooth ride" in the TerpRanger. Cabin noise levels are also reduced by a piezoelectric actuated, active strut system bonded to the surface of the transmission support pylons.

The TerpRanger: Improved Public Acceptance

High noise levels are a major concern for broadening public acceptance of helicopters. The TerpRanger design addresses this issue by lowering the tip speed of its rotors and using an advanced-geometry blade tip on its main rotor, resulting in *lower noise levels*.

The TerpRanger: Improved Reliability

The TerpRanger's dynamic components have been designed to lengthen service lives and minimize *maintenance requirements*. Both the main and tail rotors have components made of composite materials that only need to be replaced on-condition. The main rotor incorporates *active tracking tabs* that allow the pilot to track the blades while in flight, thereby doing away with the need to spend valuable time tracking the blades manually by conventional methods on the ground. The new engine is of modern design and requires far less servicing than the Rolls-Royce / Allison 250-series turboshaft that it replaces. A fully integrated HUMS and diagnostics system for both the rotors and drivetrain will be available as an optional system. Improved reliability translates into less maintenance downtime and lower operating expenses.

The TerpRanger: Improved Safety

Safety is an important feature of the design of the TerpRanger. A new layout for the pilot's instrument panel with *Multi-Function Displays*, a *Global Positioning System* and other modern navigational aids help reduce pilot workload and improve situational awareness. The improved reliability of the dynamic components of the helicopter reduces the possibility of their failure during flight. In the unlikely event of an accident, the occupants are protected by the *excellent autorotational characteristics* of the helicopter, a *crashworthy fuel tank*, a new *cockpit airbag system* and *energy-absorbing stroking seats* for the pilot and front-seat passenger. Lightning protection for the composite main rotor is provided by the titanium leading-edge erosion strip that runs down the entire length of the blade, providing a conductive path to the hub and the airframe.

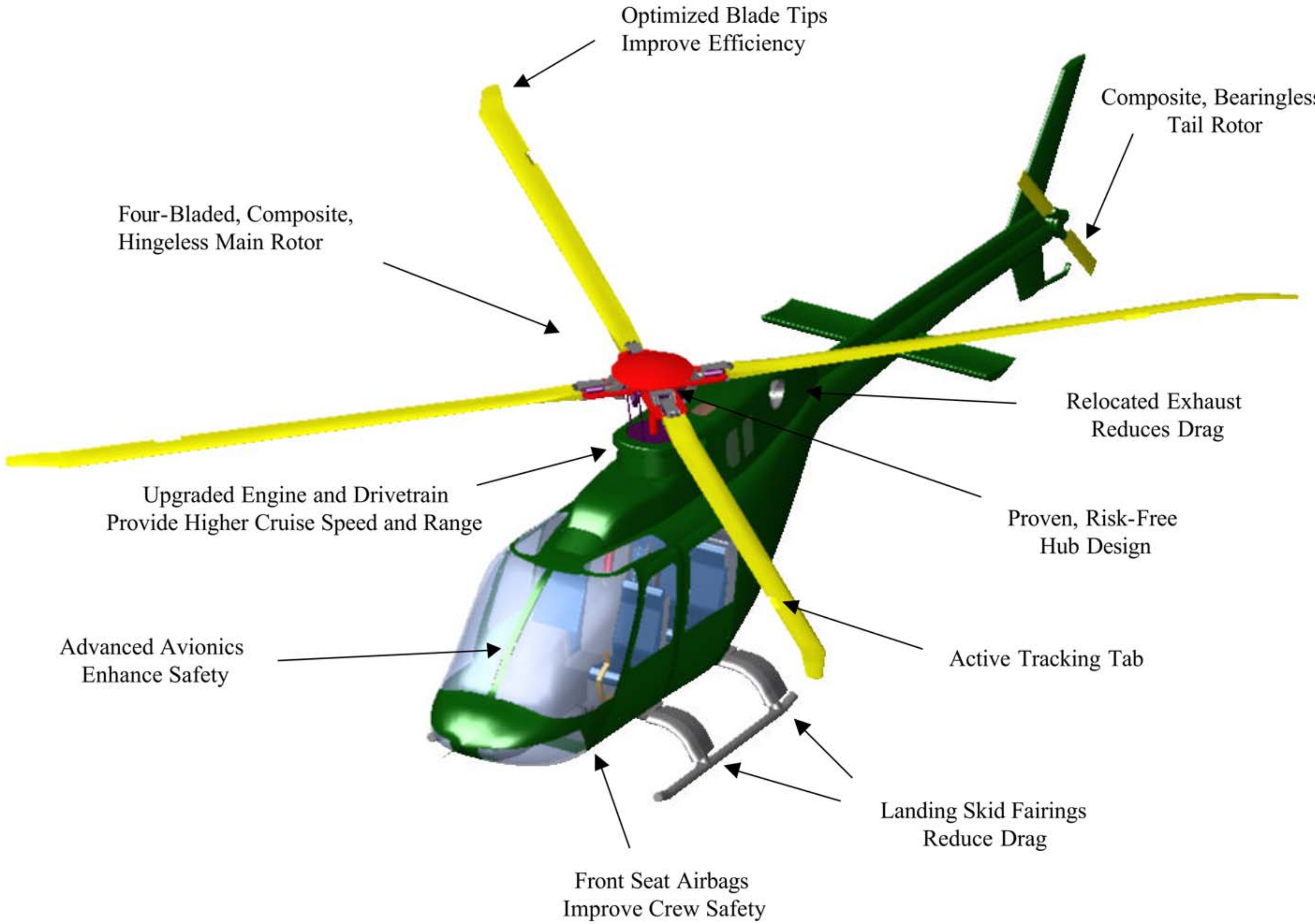
The TerpRanger: Improved Affordability

Operators of Bell helicopters greatly appreciate the simplicity of design that is their hallmark, and the TerpRanger design embodies this philosophy. *Design simplicity* translates into *ease and low cost of manufacture,* and consequently minimizes the purchase price of the aircraft. At $1.16 million, the TerpRanger upgrade offers high performance, reliability, and safety at a price that compares favorably with that of other helicopters in its class: the MD 500E, the Schweizer 333, and the Eurocopter EC-120 Colibri. Furthermore, because of the lower maintenance requirements and improved fuel efficiency of its new engine, the TerpRanger also has *low operating costs* ($410/FH), which is comparable to those of its competitors.

The TerpRanger: Improved Versatility

The Bell JetRanger is a *multi-role helicopter*, adaptable to a wide variety of missions. The TerpRanger design improves this versatility still further: its higher cruise speed and increased range and payload make it suitable for missions that are commonly performed by larger, more expensive aircraft, such as the Bell 430, and its low cost of ownership make it attractive to potential helicopter operators.

The JetRanger has been one of the world's most popular light helicopters for the past 25 years. The TerpRanger Upgrade Program will ensure that it retains this exalted status for many more years to come.



TerpRanger Highlights

Performance Summary and Physical Data

Sea-level Performance

	JetRanger		*TerpRanger*	
	ISA	***ISA + 20***	***ISA***	***ISA + 20***
Cruise speed (kts)	116	N/A	144	146
V_{NE} (kts)	122	N/A	158	161
Speed for best range (kts)	113	117	148	152
Speed for best endurance (kts)	48	N/A	62	64
Range (full fuel & payload), maximum (n. mi.)	368	368	424	450
Endurance (full payload), maximum (hrs)	4.6	N/A	4.05	4.21
HOGE ceiling (ft)	5,300	3,000	10,000	8,250
HIGE ceiling (ft)	13,000	10,200	13,900	11,850
Service ceiling (ft)	13,500	12,800	19,860	18,020
VROC, maximum (ft/min)	N/A	N/A	740	705
Climb Rate, maximum (ft/min)	1,280	N/A	1,715	1,590

Vehicle Dimensions

	JetRanger	*TerpRanger*
Fuselage length (ft)	31.2	31.2
Length overall, rotors turning (ft)	38.8	38.3
Height (hub) (ft)	9.5	8.6
Skid height (ft)	1	1
Fuselage width (ft)	4.33	4.33
Horizontal stabilizer span (ft)	6.4	6.4
Width of skids (ft)	6.4	6.4

Weights

	JetRanger	*TerpRanger*
Design gross weight (lb)	3200	3524
Empty weight (lb)	1647	1705
Useful load (lb) (Payload + Fuel)*	1382	1585
Maximum usable fuel (lb / US gal)	619 / 91	686 / 101
Payload with full fuel (lb)	763	899

* Excluding the weight of the pilot

Main Rotor Specifications

	JetRanger	*TerpRanger*
Diameter (ft)	33.3	32.43
Number of blades	2	4
Chord (ft)		
Root	1.1	0.67
Tip	1.1	0.42
Twist (°)	-10	-13
Tip speed (ft/s)	687.59	672.4
Rotational speed (rpm)	394	396
Shaft tilt (°)	5	6
Tip sweep (°)	0	20
Tip anhedral	0	5
Root cut-out (%)	20	20
Airfoil sections	NACA 0012 mod.	OA-212, VR-12, VR-15

Tail Rotor Specifications

	JetRanger	*TerpRanger*
Diameter (ft)	5.42	5.4
Number of blades	2	2
Chord (ft)		
Root	0.5	0.46
Tip	0.5	0.46
Twist (°)	0	0
Tip speed (ft/s)	723.6	672.4
Rotational speed (rpm)	2550	2378
Airfoil sections	NACA 0012	NACA 0012

Power Ratings

	JetRanger	*TerpRanger*
Engine TO rating (shp)	420	500
Engine MCP rating (shp)	370	400
Transmission TO rating (shp)	317	420
Transmission MCP rating (shp)	270	390