EXECUTIVE SUMMARY

Introduction

The *Chesapeake* is a helicopter that has been designed in response to the Request for Proposal (RFP), issued for the 1998 *American Helicopter Society* Student Design Competition (sponsored by Boeing). The RFP identified the need for a civil short-haul VTOL aircraft. The primary market is expected to be the Northeast Corridor of the USA. It is envisaged that the VTOL infrastructure will be developed and integrated into the regional fixed wing flight operations. In particular a network of vertiports will be established, linking outlying areas with regional fixed wing hubs.

Specified Mission Requirements

The aircraft is to be optimized to maximize cost effectiveness. The standard mission consists of an un-refueled, two-leg roundtrip, with each leg a maximum of 200 nm. The standard version is a 19-seat aircraft, with launch in 2012. As a "lead-in" product, to be launched in 2007, a 12-seat derivative is required. This variant is to have commonality of all dynamic systems (including the rotor and transmission) and substantial commonality of subsystems. The fleet is sized to meet an initial requirement of 700,000 passenger miles per day, increasing to 1,100,000 passenger miles per day. The design is constrained by a stringent one-engine-inoperative (OEI) requirement that stipulates a OEI hover out of ground effect (HOGE), at mean-sea level, ISA+20, with a full passenger load and 60% fuel.

Aircraft Configuration Trade-Off Study

Both a conventional helicopter and a tiltrotor/tiltwing were considered as suitable candidates for this design, whereas compound helicopters, ABC and X-Wing were eliminated because of their poor cost effectiveness for the short-haul civil commuter mission. The trade study shows that a triple engine helicopter (with the option for switching-off one engine in cruise to improve the cruise efficiency) is more economical than a twin- or triple-engine helicopter (cruising on three engines) or a tiltrotor/tiltwing. In fact, the direct operating cost per air-seat-mile of the helicopter is 10% lower than that of a tiltrotor, for a typical 2x150 nm mission. The helicopter also offers several operational advantages, including: a lower disk loading (with associated lower downwash and reduced BVI noise during take-off and landing) and a lighter/more compact apron footprint.

The Chesapeake at a Glance

The Chesapeake is a 19 seat, triple engine helicopter with a fan-in-fin. The aircraft is designed to offer the passenger a "jet-smooth" ride, and the operator an affordable aircraft that is cost-competitive in the civil short-haul market. The spacious cabin is one of the largest in its class and with active vibration and noise-control offers a flight experience rivaling that of fixed wing turbojets.

- Advanced technologies are used to improve cost effectiveness. The Chesapeake has a low disk loading, five-bladed bearingless rotor. The composite rotor blades exhibit tip sweep and anhedral to improve performance and incorporate smart trailing edge flaps for automatic in-flight tracking and vibration control. It is anticipated that future versions will use multiple flaps to address both vibration control and and BVI noise reduction.

- A fully integrated health and usage monitoring system (HUMS) is used to oversee the status and direct on-condition maintenance of flight-critical dynamic components (including the transmission, rotor hub and rotor blades and the fan tail). The Chesapeake is powered by three IHPTET 930 kW (1250 hp) turboshaft engines, that have a 30 second, 125% emergency rating. The engines are controlled via a full authority digital engine control (FADEC) system, that offers advanced engine diagnostics and also reduces the pilot workload during one-engine-inoperative (OEI) operations. The aircraft exceeds the stipulated OEI requirements to the extent that hover out of ground effect, with one engine inoperative, in ISA+20, with full passenger load and 60% fuel can be sustained at 5500 ft. This performance increase is derived from the engines, which are sized to meet the requirement to cruise on two engines, rather than the baseline OEI requirement. The cost of the more powerful engines is offset by the improved cruise fuel consumption and the resultant lower take-off weight.

- A fan-in-fin anti-torque system is used to improve safety of ground operations. An asymmetric arrangement of the fan blades is used to reduce noise levels.

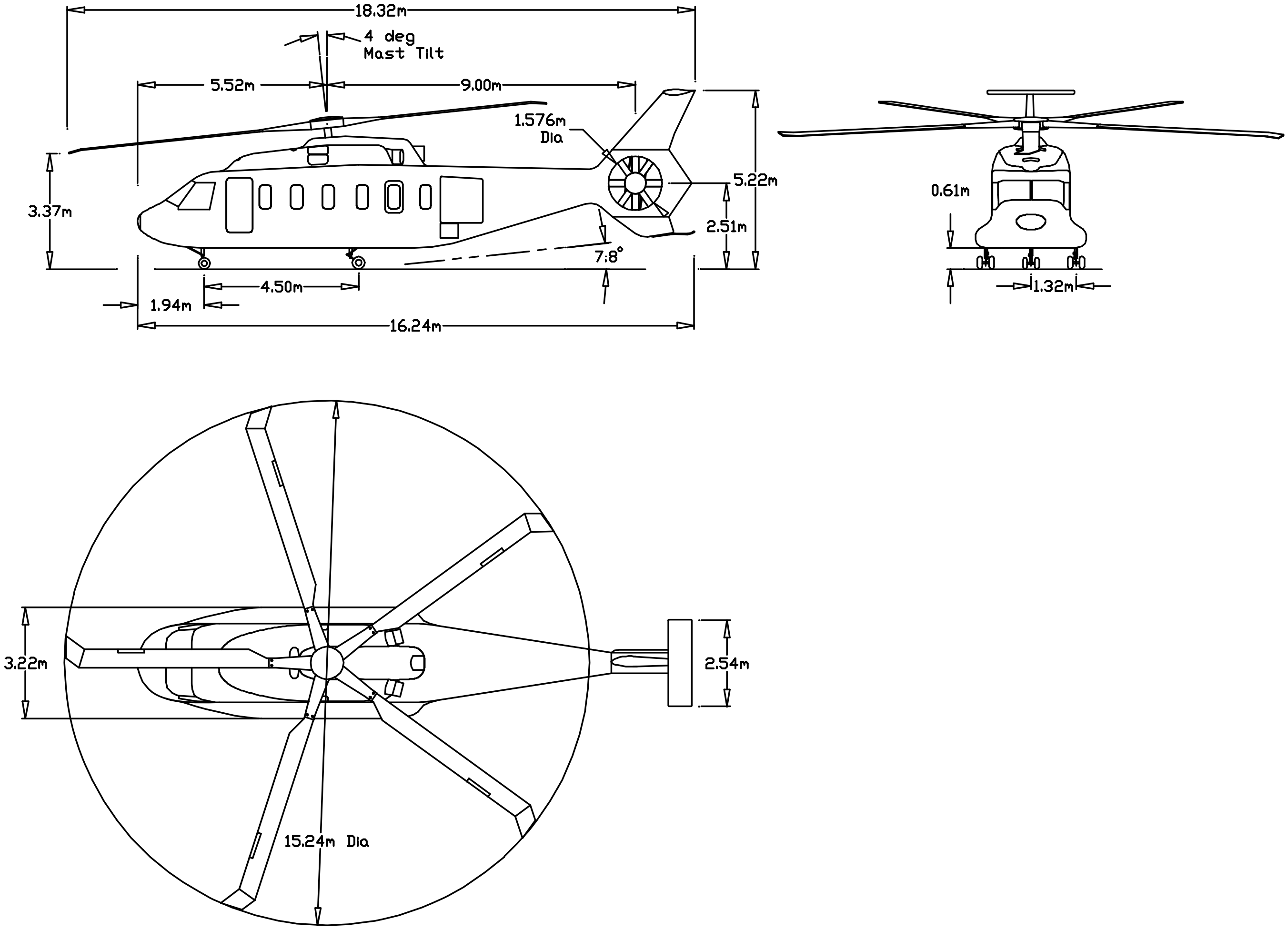
- Based on a preliminary cost analysis, it is expected that the Chesapeake will cost $9.03 million (1997) and will have a direct operating cost per air-seat-mile of $ 0.86 (this includes depreciation, financing, insurance, maintenance, fuel and crew).

The Chesapeake 12-Ne

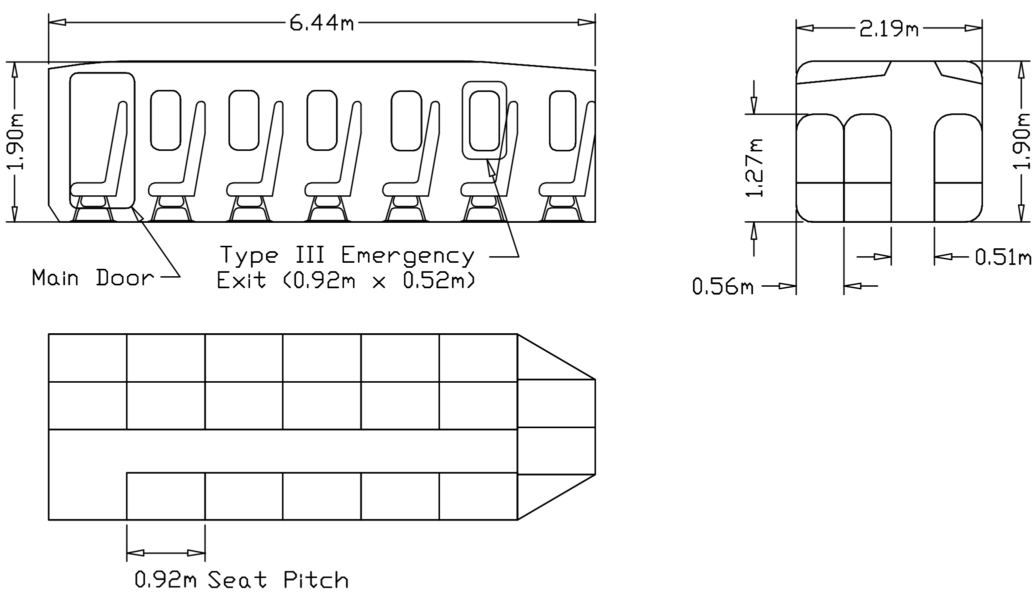
The 12 seat derivative version is the Chesapeake 12-Ne. This is a narrow-body version, with the seating reduced from three in-a-row to two in-a-row (in both configurations there is a an aisle). The 12-Ne has the same rotor, transmission system, empennage, fan-in-fin and undercarriage as the 19 seat aircraft. In addition, there is complete commonality of the electrical and hydraulic systems. In order to improve the cost-effectiveness of the 12-Ne, it is fitted with three smaller 745 kW (1000 hp) engines, and the aircraft range is limited to one 200 nm mission leg. Although the different engines will require separate certification, the lower installed power reduces the acquisition and direct operating costs. The 12-Ne is designed to meet the same mission requirements and performance criteria as the 19-seat version (except for the reduced mission range). The 12-Ne will have a purchase price of $7.61 million (1997) and a DOC/asm of $1.15. The DOC/asm is 34.5% more expensive than that of the 19-seat version.

Chesapeake Mission

Customized for the NE-corridor, the Chesapeake has a nominal cruise of 150 knots at 4000 ft, with a bad weather cruise altitude of 8000 ft. Maximum cruise speed is 160 knots. Based on flight operations below 8000 ft, the Chesapeake is offered with an unpressurised cabin. For marketing of aircraft in higher elevation regions, a pressurized cabin can be offered. The conversion from an unpressurised to a pressurized version is accommodated within the 2.5% take-off weight growth factor that has been incorporated into the baseline design.



The Chesapeake 19-seat civil short haul helicopter



19-Seat Cabin layout

The triple-engine Chesapeake derives a significant performance benefit from the twin-engine cruise configuration (with one engine switched-off). First, the engines operate closer to the most efficient maximum power setting, thereby reducing the fuel consumption and overall take-off weight. Second, the engines are sized for the twin engine cruise requirement and in this case exceed the OEI requirements. It is shown in the trade-study that the improved fuel-efficiency and lower aircraft weight offset the additional cost of the larger engines. The Chesapeake is thus capable of full payload performance under hot-and-high conditions, while meeting the OEI requirement to sustain hover out of ground effect. For example, in ISA+20 and with a full 19 passenger load, it is possible to complete the un-refueled two leg 2x200 nm mission, if take off is below 1500 ft. If the fuel is reduced to complete one 200 nm leg instead, take-off elevation can be as high as 5500 ft. In contrast the RFP only requires a single leg (1x200 nm) range for ISA+20 conditions, and take-off from sea-level. This design offers the operator an aircraft capable of sustaining on-time operations even under hot-and-high conditions, without having to curtail range or payload. This performance increase is derived primarily via the engines sized for twin-engine cruise.

Furthermore, although the aircraft is designed to fly two un-refueled, 200 nm mission legs, a survey of the existing airports in the North-East corridor indicates that the average flight leg will be approximately 150 nm.

Approach and Methodology

The University of Maryland design was conducted in conjunction with the Spring 1998 Helicopter Design Course (ENAE634), from February to May 1998. The design was aimed at exposing the team members to the different aspects of an engineering design endeavour. To this end, no commercial design codes or analysis tools were used. In order to develop an understanding and an overview of the fundamental aspects of the aircraft-configuration trade-off study, an in-house code was developed based on Dr. Tishchenko's lecture notes [Tish98]. This code employs first order models for simplicity and insight. The performance analysis is based on a rigid blade model (incorporating equivalent hinge offset and root-springs) with a linear inflow model. The University of Maryland Advanced Rotor Code (UMARC) was used for the detailed rotor design (including stability analysis, estimation of hub loads and active vibration control)

Down-load Document from WWW

This document can be down-loaded from the following internet address:
http://www.enae.umd.edu/AGRC/Design98/chesapeake.html

Notes for the Aircraft Table (on page 5)

1) DOC (direct operating cost) includes: depreciation, financing, insurance, maintenance, fuel and crew costs.

2) Fleet sizing and DOC are based on an average mission leg of 150 nm and an annual utilization of 2000 flight hours.

3) Climb, descent is on 3 engines, cruise in ISA+20 is on 3 engines.

4) 19-seat fleet size based on 1,100,000 passenger miles/day, 12-seat fleet size based on 700,000 passenger miles/day (both with a 70% load factor).

CHESAPEAKE DESIGN FEATURES AND PERFORMANCE SUMMARY

	19 PASSENGER		12 PASSENGER	
General Specifications	**Metric**	**English**	**Metric**	**English**
Gross Take-Off Weight (GTOW)	7000 kg	15432 lbs	5375 kg	11850 lbs
Empty weight	3856 kg	8502 lbs	3513 kg	7745 lbs
Payload + 2 Crew	2078 kg	4580 lbs	1379 kg	3040 lbs
Usable fuel capacity	1066 kg	2350 lbs	483 kg	1065 lbs
No. of engines	3		-same-	
Type of engines	RFP IHPTET		-same-	
Unit price (1997 $)	9.03 million		7.61 million	
Total DOC[1,2] per flight hour (1997 $)	2089		1777	
Total DOC per seat-mile (1997 $)	0.86		1.15	
Overall length (rotors turning)	18.32 m	60.10 ft	- same -	
Overall height	5.22 m	17.13 ft	- same -	
Max. fuselage width	3.22 m	10.56 ft	2.66 m	8.73 ft
Performance Specifications	All data is in ISA, at GTOW		(unless otherwise specified)	
Engines used in cruise[3]	2		-same-	
Nominal cruise altitude	1220 m	4000 ft	- same -	
Nominal cruise speed	278 km/h	150 knots	- same -	
Max cruise speed (4000 ft)	296 km/h	160 knots	287 km/h	155 knots
Max rate of climb (sea level, MCP)	17.8 m/s	3500 ft/min	20.3 m/s	4000 ft/min
HOGE	4877 m	16000 ft	6360 m	20860 ft
Range (with standard reserves)	980 km	529 nm	482 km	260 nm
OEI ceiling (ISA +20, 60% fuel)	1674 m	5491 ft	1910 m	6270ft
Engine Specifications	dry, un-installed, each			
Emergency power, 30 s	1165 kW	1563 hp	932 kW	1250 hp
Take-off (nominal) power, 2 min (TOP)	932 kW	1250 hp	746 kW	1000 hp
Intermediate rated power, 30 min (IRP)	861 kW	1155 hp	689 kW	924 hp
Max. continuous power (MCP)	737 kW	989 hp	590 kW	791 hp
Rotor Specifications	common for both the 19 and 12 seat version			
Number of blades	5		-same-	
Diameter	15.240 m	50.00 ft	-same-	
Chord	0.533 m	1.75 ft	-same-	
Tip speed	213.4 m/s	700 ft/s	-same-	
Twist	-10 deg (linear)		-same-	
Sweep	35 deg from 95% radius		-same-	
Anhedral	10 deg from 95% radius		-same-	
Shaft tilt	4 deg (forward)		-same-	
Root cut-out	30%R		-same-	
Airfoils	root to 65% :	RAE 9648	-same-	
	65% to 87.5% :	VR-7	-same-	
	87.5% to the tip:	VR-8	-same-	
Fan	common for both the 19 and 12 seat version			
Diameter	1.576 m	5.17 ft	-same-	
No. of blades	8		-same-	
Twist	-7 deg		-same-	
Tip Mach number	0.55		-same-	
Asymmetric blade spacing	35/55 deg		-same-	
Solidity	0.63		-same-	
Airfoil	NACA 63A312		-same-	
Cabin Specifications				
Interior length	6.44 m	21.13 ft	- same -	
Interior height	1.90 m	6.23 ft	- same -	
Interior width	2.19 m	7.19 ft	1.63 m	5.35 ft
Seat Pitch	0.92 m	3.02 ft	- same -	
Overhead baggage space per passenger	0.072 m^3	2.54 ft^3	0.069 m^3	2.44 ft^3
Baggage compartment	1.345 m^3	47.5 ft^3	0.869 m^3	30.7 ft^3
Fleet Sizing[2,4]	121		122	