Executive Summary

The ***Condor*** is a dedicated mountain search and rescue (SAR) helicopter designed in response to the 2004 American Helicopter Society's (AHS) Request for Proposals (RFP) for "Design for Certification: Mountain Rescue Helicopter". The RFP, sponsored by Agusta Westland, outlined the need for a helicopter conceived from the start as a platform specifically designed for mountain rescue operations. Helicopters currently performing these operations are adaptations of models characterized by good high-altitude performance, and lack several specific attributes desired in a search and rescue aircraft. The Condor features a high-powered twin engine system, with high altitude one engine inoperative (OEI) capabilities, an efficient rotor for hovering at extreme altitudes, and state-of-the-art search and rescue equipment. The Condor's superior performance capabilities and operational safety make it the ideal search and rescue helicopter for mountain extractions.

Mission Requirements

The primary mission outlined in the RFP is the rescue of 2 patients stranded in a mountainous environment. The rescue mission consists of a takeoff from 1,829 m (6,000 ft), a 1 hour outbound cruise flight at 140 knots, a 20 minute hoist operation with the recovery of 2 patients at 3,658 m (12,000 ft), and finally, a 1 hour return cruise flight. Furthermore, several performance capabilities are required including a cruise speed of at least 145 knots at 3,658 m (12,000 ft), a hover-out-of-ground-effect (HOGE) at maximum gross weight (MGW) at 4,572 m (15,000 ft), and the ability to maintain heading at that condition with a 40 knot crosswind from any azimuth. The most stringent of the performance requirements is the ability for HOGE at MGW with OEI at 3,658 m (12,000 ft). The RFP also specifies the equipment to be carried and the need for single pilot day/night Instrument Flight Rules (IFR) operations.

Configuration Selection

A thorough analysis of the RFP and the requirements stipulated therein preceded the selection of the most suitable aircraft characteristics. Initially, a set of design parameters were identified based on the specific needs of the outlined rescue mission. Several helicopter configurations were then comprehensively studied and evaluated on their ability to meet the given design requirements. The analysis showed that a conventional single rotor helicopter with a fan-in-fin anti-torque system was an optimal choice. The all-around performance capabilities of a conventional helicopter, in both cruise speed and hovering efficiency, low acquisition and operating cost, and the operational safety of a fan-in-fin tail rotor were among the primary features favoring this selection.

Design Methodology

The Condor design was performed in conjunction with the ENAE634 - Helicopter Design course taught at the University of Maryland in Spring 2004. This one semester course is aimed at introducing students to the various aspects of helicopter design and providing them with a fundamental understanding of the major design issues. During the course, the students developed analytical tools to perform the design study, and no commercial codes were used. The detailed rotor dynamics analysis was performed using the University of Maryland Advanced Rotor Code (UMARC), and all graphics were developed using I-DEAS CAD software.

Design Features

Designed from the start as an SAR helicopter for mountainous terrain, the Condor is a 3.25 ton, twin engine helicopter with a fan-in-fin anti-torque system. Along with the latest in search and rescue technologies, the Condor offers a high power-to-weight ratio with excellent high altitude performance. With particular attention paid to operational safety and reliability, the Condor is the ideal mountain helicopter for rescue mission success. Salient design features are listed below:

***Two Engine Configuration: OEI Capability* -** To meet the stringent OEI HOGE requirement at 3,658 m (12,000 ft), the Condor uses 2 high-powered CTS800-4N model gas turbine engines. Each engine has sufficient OEI continuous power to allow the helicopter to hover at 3,658 m (12,000 ft). Furthermore, the high level of power available from both engines enables the Condor to HOGE at extreme altitudes up to of 6,700 m (22,000 ft) and reach cruise speeds of 170 knots. In several situations, such as lower altitude rescues, it is possible to accommodate additional passengers or crew members.

Fan-in-Fin Anti-Torque System - A fan-in-fin anti-torque system enhances safety during flight and rescue operations, as well as on the ground, by housing the tail rotor in a duct. The system was designed to provide yaw authority under extreme mountainous conditions such as high altitude and high crosswinds. Furthermore, a vertical fin is utilized to offload the tail rotor during forward flight, reducing the shaft power required for the tail rotor.

Compact Configuration - The Condor features a compact configuration for operation in confined spaces. The fuselage shape is optimized for minimum footprint and maximum use of internal volume. Furthermore, the ducted fan-in-fin ensures safe flight near obstacles.

Autonomous Flight Control System - A full authority, triple redundant, Fly-By-Wire (FBW) Flight Control System (FCS) is implemented on the Condor. The autonomous system provides augmented stability control as well as mission specific auto navigation that substantially decreases pilot workload and increases safety.

Spacious Cabin Layout - To allow sufficient room for medical equipment, paramedics, and 2 patients in supine position, the cabin layout was designed to utilize the space efficiently and judiciously. To take advantage of vertical space, the patient litters are stacked on top of one another. This allows ample room for the paramedics to apply medical care to both patients.

Advanced Search and Rescue Equipment - The Condor is equipped with the latest in SAR technology, including forward looking infra-red (FLIR), global positioning system (GPS), and an integrated tracking device to locate beacons from stranded mountain climbers.

Retractable Wheel/Ski Landing Gear - The Condor uses a retractable wheeled landing gear with attachable skis for snow landings. The wheeled gear allows better ground maneuverability and mission readiness and does not interfere with the hoist during rescue operations. A retractable gear provides less parasitic drag than a fixed gear and therefore increases efficiency in high speed forward flight.

Onboard Medical Equipment - The Condor is equipped with onboard medical equipment so that paramedics can provide in-flight medical attention to passengers in need of care. Included are two Advanced Life Support (ALS) kits, two combination defibrillator/cardiac monitors rated for helicopter use, and a drop-off survival kit for victims who may have to be left behind.

Hoisting Operations - The Condor uses an externally mounted Goodrich 42325 hoist for recovery of passengers when landing is not possible. The cabin of the Condor is designed with a large sliding door for easy loading of hoisted litters. An internally mounted camera displays a view of the hoisting operation on the multi-function display in the cockpit. This assists the pilot in stabilizing the aircraft above the rescue site. Furthermore, the 12 m diameter rotor creates low downwash, minimizing interference with rescue operations.

Swashplateless Rotor Control - The Condor utilizes two trailing edge flaps on each blade for primary rotor control, thus eliminating the need for a conventional swashplate. The absence of mechanical linkages and bearings results in an aerodynamically clean and mechanically simple rotor. The control system consists of two trailing edge moment flaps embedded in a torsionally soft blade and actuated using compact piezo-hydraulic hybrid actuators. In addition to primary control, the flaps are capable of providing individual blade control (IBC) for vibration reduction throughout the flight envelope.

Composite Tailored Rotor Blades - Four composite rotor blades with a dual spanwise segmented flap-bending/torsion coupling (FBT-P/N) significantly reduce the 4/rev vibratory hub loads on the Condor. Along with the vibration reduction provided by the active flap IBC, the composite tailored rotor blades eliminate most of the vibrations from the helicopter fuselage, providing a *jet smooth* ride.

Bearingless Hub - The Condor uses a bearingless hub for higher control power which provides excellent handling qualities. Furthermore, the bearingless hub creates less parasitic drag in high speed forward flight.

De-icing System - Provision for de-icing the rotor blades and other vulnerable areas have been provided to enable the Condor to operate in the low temperature environment associated with high altitudes.

Crashworthiness - Special attention has been paid to the crashworthiness of the CONDOR, particularly in the design of the airframe, the selection of equipment, and the arrangement of the fuel system. In the airframe, the structural members are designed for maximum energy dissipation in the event of a crash. In addition, all furnishings such as seats and litters are rated for the inertial loads specified for certification (14CFR29.561), and medical equipment is securely packed and stowed.

Health Usage and Monitoring System (HUMS) - HUMS capability is designed into the Condor to help track the usage of flight critical components, and provide credits to standard maintenance schedules. The HUMS will lead to reduced maintenance cost as well as increased reliability, readiness, and safety.

Cost - Through use of high reliability subsystems and thoroughly proven technology, the Condor will have reduced maintenance and operational costs. This is especially attractive to prospective users such as volunteer rescue organizations who have limited budgets.

Certification - The Condor is designed for certification under CFR Title 14, Part 29, Airworthiness Standards: Transport Category Rotorcraft. Designed with currently available engines and subsystems, the Condor will be easy to certify and at the same time offers high reliability and safety in all modes of flight operation.

Conclusions

The Condor design offers an affordable and reliable platform designed to meet the unique requirements of a mountain search and rescue operation. The use of existing state-of-the-art equipment and subsystems satisfies certification requirements and results in a short development program. The Condor's use of innovative design technologies provides unsurpassed safety and reliability while reducing maintenance and operating costs. Specifically tailored for high altitude operation, the Condor meets, and in many cases exceeds the performance requirements in the RFP. Furthermore, its high power-to-weight ratio allows for multi-mission capability. The Condor design is the ideal solution for the task of high altitude rescue operations.

Performance Summary and Design Features

Performance Data

	Sea-Level	3,658 m (12,000 ft)
Design Cruise Speed (knots)	140	145
Speed for Best Range (knots)	140	145
Speed for Best Endurance (knots)	60	70
Max Cruise Speed (knots)	170	170
Max Range - Full w/ Reserve (km)	678	685
Max Endurance - Full w/ Reserve (h)	2.56	2.48
Max VROC (m/s)	13.3	13.1
Max Climb Rate (m/s)	34	33.3
HOGE Ceiling, Cont Power (m)	6,705	
OEI HOGE Ceiling, Cont Power (m)	3,660	
Service Ceiling (m)	7,620	

Vehicle Dimensions

Fuselage Length (m)	10.96
Overall Length (m)	13.91
Height - Hub (m)	3.44
Wheel Height (m)	0.5
Fuselage Width (m)	1.6
Horizontal Stabilizer Span (m)	0.4
Fuel Capacity (L)	970

Weights

Design Gross Weight (kg)	3024
Empty Weight (kg)	1533
Useful Load (kg)	1491
- Max Useable Fuel (kg)	650
- Crew (kg)	191
- SAR Equipment (kg)	113
- Max Payload (kg)	537

Engine Ratings

Engine TO Power (kW)	2028
Engine Max Cont (kW)	1910
Engine OEI Cont (kW)	1014
Engine OEI 2 min (kW)	1108
Transmission Max Cont (kW)	1360
Transmission OEI Cont(kW)	680
Transmission OEI 2 min (kW)	800

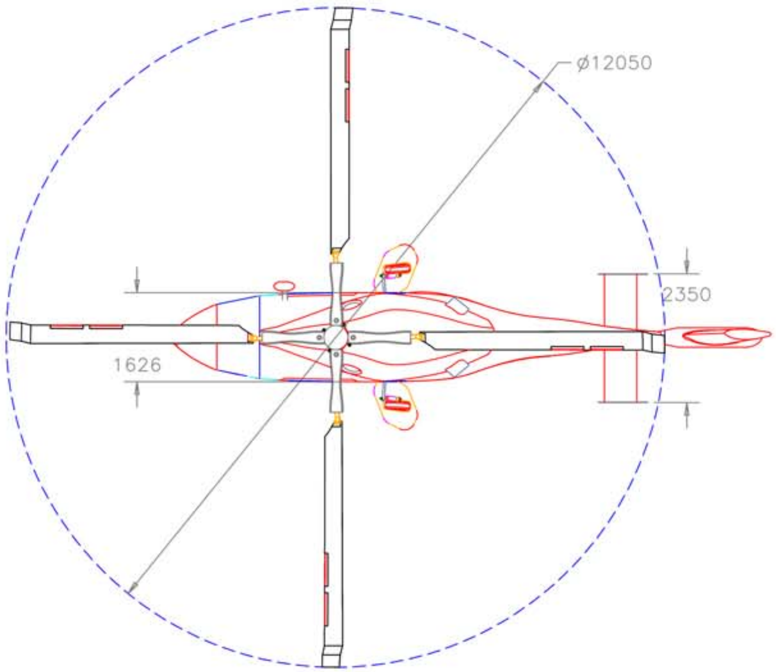
Main Rotor Specifications

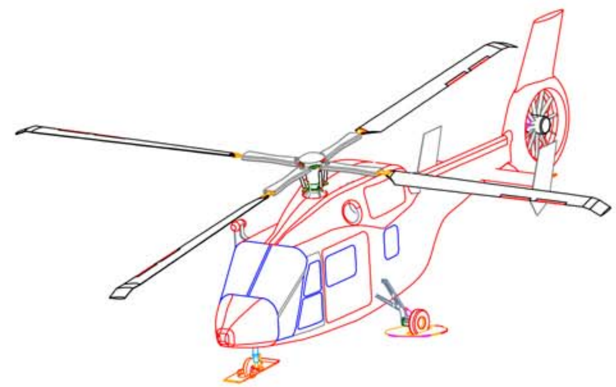
Diameter (m)	12.05
Number of Blades	4
Chord	
- Root (m)	0.344
- Tip (m)	0.31
Solidity	0.0727
Disk Loading (kg/m^2)	26.5
Blade Twist (deg)	-12
Tip Speed (m/s)	210
Shaft RPM	333
Shaft Tilt (deg)	6
Tip Sweep (deg)	20
Tip Anhedral (deg)	20
Root Cutout	25%
Airfoil Sections	RC(4)-10, RC(6)-8

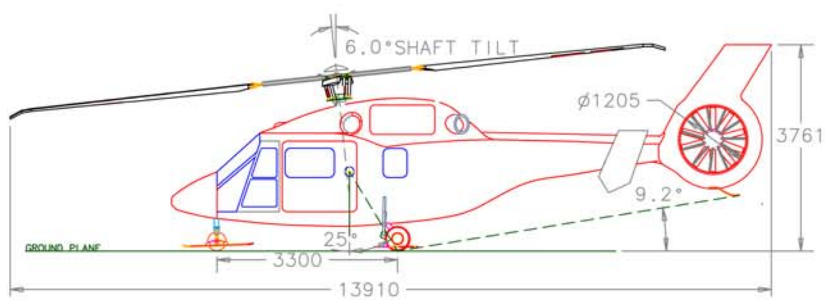
Fan-in-Fin Specifications

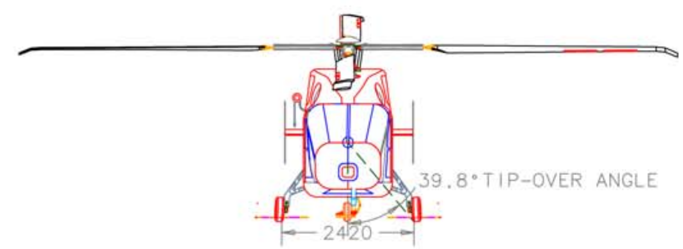
Diameter (m)	1.2
Number of Blades	10
Chord (m)	0.114
Solidity	0.606
Blade Twist (deg)	-10
Tip Speed (m/s)	180
Shaft RPM	2853
Root Cutout	30%
Airfoil Sections	NACA 63A312

Four View Drawing

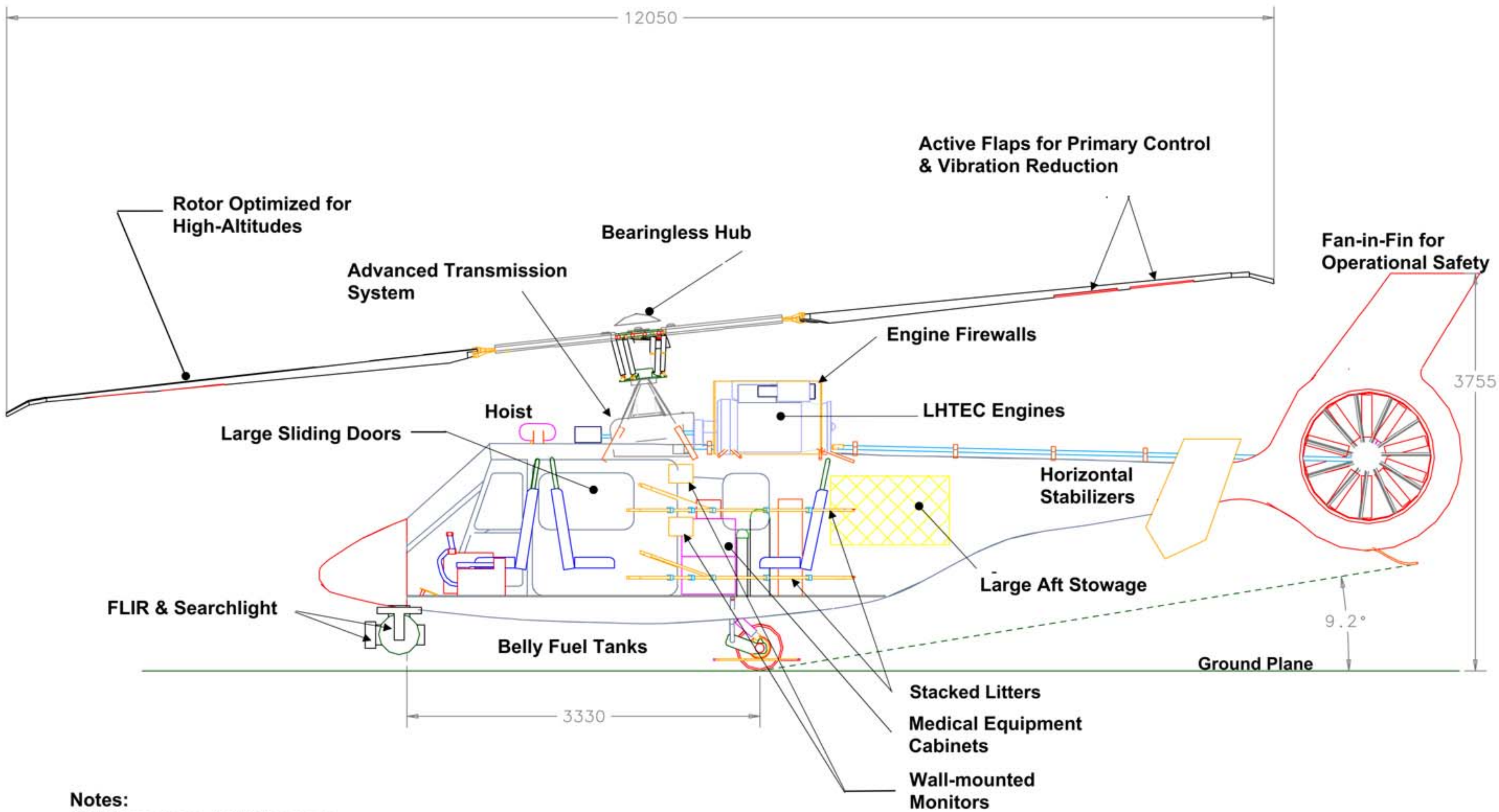








All dimensions in millimeters



Notes:
All Dimensions in Millimeters
For Clarity, Nose Gear & Cowling Not Shown

Inboard Profile