MASTER OF SCIENCE
IN
AERONAUTICAL ENGINEERING

AVIONICS SYSTEM DEVELOPMENT FOR A ROTARY WING
UNMANNED AERIAL VEHICLE
Daniel S. Greer-Commander, United States Navy
B.S., University of Texas, 1981
Master of Science in Aeronautical Engineering-June 1998
Advisor: Russ W. Duren, Department of Aeronautics and Astronautics
Second Reader: Isaac I. Kaminer, Department of Aeronautics and Astronautics

The Naval Postgraduate School has developed a successful Rapid Flight Test Prototyping System (RLFTPS) for the development of software for remote computer control of fixed wing Unmanned Aerial Vehicles (UAV). This thesis reviews the work accomplished to mount sensors on a small remote controlled helicopter with instrumentation compatible with the RFTPS: an inertial measurement unit, a Global Positioning System (GPS) receiver, an altitude sensor and associated power supply and telemetry equipment. A helicopter with sufficient lift capability was selected and a lightweight aluminum structure was built to serve as both an avionics platform for the necessary equipment and also as a landing skid. Since the altitude sensors used for fixed wing UAVs, such as barometric sensors and GPS, do not provide sufficient accuracy for low altitude hover control, a lightweight, precision altimeter was developed using ultrasound technology. Circuitry was developed to drive a Polaroid 6500 Series Ranging Module and process the output data in a form compatible with the RFTPS avionics architecture. Flight testing revealed severe vibrations throughout the helicopter. An alternative avionics package of reduced size was constructed to house the sonic altimeter and a three-axis accelerometer. Subsequent test flight results and recommendations for further research are provided.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics, Sensors

KEYWORDS: Unmanned Aerial Vehicles, Avionics, Sonic Altimeter

PERFORMANCE ENHANCEMENTS TO JOINT ARMY/NAVY ROTORCRAFT ANALYSIS
AND DESIGN (JANRAD) SOFTWARE AND GRAPHICAL USER INTERFACE (GUI)
William L. Hucke-Lieutenant Commander, United States Coast Guard
B.S.O.E., United States Coast Guard Academy, 1984
Master of Science in Aeronautical Engineering-June 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Robert L. King, Department of Aeronautics and Astronautics

The Joint Army/Navy Rotorcraft Analysis and Design (JANRAD) computer program was developed at the Naval Postgraduate School to perform performance, stability and control, and rotor dynamics analysis during preliminary helicopter design efforts. This thesis is the continuation of a previous work in which a Graphical User Interface (GUI) was developed and implemented as the front end to the JANRAD program. Due to the complexity of the GUI design, only the performance module of JANRAD was completed by the prior student. This thesis expands the capabilities of the performance module, and the JANRAD code, by adding graphical output of performance results, improved rotor sizing capabilities, resources for user defined blade elements and non-linear blade twist, airfoil meshing capabilities, and additional reference airfoil data corrected for compressibility effects. It also contains the basic architecture for the stability and control module GUI. Additionally, utilizing actual I.JH-60A Black Hawk airfoil and test flight data as inputs, JANRAD version 5.0 was run to validate

---

its output with the test flight results, and those produced in a prior thesis by JANRAD version 3.1 (1995). Excellent agreement was demonstrated in all flight regimes. Utilizing airfoil data corrected for compressibility effects, high altitude runs resulted in much better correlation with test flight results than those experienced in 1995 using uncorrected airfoil data. A JANRAD Users Guide was updated and is included as Appendix A to this thesis.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Helicopter, Graphical User Interface, Performance, Preliminary Design, Stability and Control, UH-60A, JANRAD

VULNERABILITY REDUCTION TECHNOLOGY FOR ROTARY WING AIRCRAFT

Christopher A. Keane-Captain, United States Marine Corps
B.S., Marquette University, 1989
Master of Science in Aeronautical Engineering-June 1998
Advisor: Robert E. Ball, Department of Aeronautics and Astronautics
Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

Aircraft Survivability is made up of two elements, aircraft susceptibility and aircraft vulnerability. Susceptibility is the inability of an aircraft to avoid being damaged by the elements of an enemy's air defense, and vulnerability is the inability of an aircraft to withstand the damage caused by the enemy's air defense. This thesis is written as a tool for the designer of future military helicopters and tiltrotor aircraft. The vulnerability of modem rotary wing aircraft, the vulnerability reduction concepts, and the technologies used to reduce vulnerability are examined. This thesis describes the threats that may be encountered by modern aircraft, the damage that those threats can cause, the aircraft component/system kill modes, the Loss of essential functions, and concludes with a vulnerability reduction checklist for the designer of rotary wing aircraft.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Rotary Wing Aircraft, Vulnerability, Reduction Concepts, Aircraft Survivability

IDENTIFICATION OF RANDOM LOADS IMPINGING ON THE RAH-66 COMANCHE HELICOPTER EMPENNAGE USING SPECTRAL ANALYSIS

Patrick H. Mason-Major, United States Army
B.S., Georgia Institute of Technology, 1986
Master of Science in Aeronautical Engineering-June 1998
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Donald A. Danielson, Department of Mathematics
Joshua H. Gordis, Department of Mechanical Engineering

The Army RAH-66 Comanche Helicopter is currently undergoing developmental flight testing. The empennage of the aircraft is experiencing buffeting where the horizontal and vertical tail vibrate at resonant frequencies. These high buffet loads are manifested in higher than anticipated fitting loads, particularly on the tail, and vibrations in the crew stations and at the nose cone where the targeting sensors are located. Significant effort has been devoted to identifying the sources of excitation and the nature of the structural response. This thesis determines the location and magnitude of empennage vibratory airloads. Because the nature of the excitation is a random function, spectral analysis is used. To obtain the loads, a three-step process was utilized. First, from aircraft differential pressure transducers and accelerometers, the spectral content of the response and excitation was determined Then, using a NASTRAN model modified to replicate the flight test aircraft, frequency response functions were determined between selected points on the aircraft's tail and the accelerometers. Finally, using this information, a solution was obtained for the vibratory airloads. Having provided information on the

nature of the driving forces, structural modifications can be made that move the natural frequencies away from the frequencies of the applied airloads.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: RAH-66 Comanche Helicopter, Random Vibrations, Comanche Tail Section, Structural Analysis, Spectral Analysis, NASTRAN Analysis

DYNAMIC SYSTEM IDENTIFICATION AND MODELING OF A ROTARY WING UAV FOR STABILITY AND CONTROL ANALYSIS

Matthew D. McEwen-Major, United States Marine Corps
B. S., San Diego State University, 1985
Master of Science in Aeronautical Engineering-June 1998
Advisor: Russ Duren, Department of Aeronautics and Astronautics
Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

This thesis presents a method for the dynamic system identification and simulation model development of a small rotary wing Unmanned Aerial Vehicle (UAV). Using aerodynamic parameterization and linear state-space modeling techniques, the Bergen Industrial UAV was modeled for computer simulation to analyze its inherent stability and control characteristics. The NIPS designed JANRAD software was utilized to determine the stability and control derivatives used in the simulation model. The identification of the UAV dynamic model will aid in the development of closed-loop controllers capable of autonomous UAV control. The fidelity of the simulation model was verified by comparing the simulation responses with data collected from on-board sensors during test flights.

DoD KEY TECHNICAL AREA: Air Vehicles

KEYWORDS: Unmanned Aerial Vehicles, Stability and Control, Modeling, Simulation, System Identification, Helicopter, JANRAD