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DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS RESEARCH PROGRAM

Research in the Department of Aeronautics and Astronautics is focused on topics of critical importance to military users. Typically, research activity resides in the Department's five technical groups, namely, Aerodynamics, Structures, Propulsion, Flight Mechanics and Controls, and System Design. Both aircraft and spacecraft are involved. Present Departmental endeavors are described below.

AERODYNAMICS

ENHANCED AIRCRAFT MANEUVERABILITY STUDIES

In support of the Naval Air Warfare Center, Aircraft Division, Professors Platzer and Hebbar performed water tunnel tests to investigate the effect of Reynolds number on the vortical flow over double-delta wings at high angles of attack.

HIGH-ANGLE-OF-ATTACK MISSILE AERODYNAMICS AND HYPERSONICS

In support of the Naval Air Warfare Center, Weapons Division, Professors Platzer and Tuncer are developing solutions for the flow over missile configurations in steady and unsteady subsonic high angle of attack flight using Navier-Stokes and panel code modelling.

NASA/USRA grant funding was available to Professor Newberry to improve the aeronautical design program at the NPS and to encourage the configuration development of tactical waverider aircraft. This funding has provided the aeronautical design laboratory with a variety of hardware (SGI workstation, PC, color printer) and software (design reference books, design synthesis codes, miscellaneous supplies). Design team reports and conference papers have been generated to document research activity supporting the configuration development of carrier capable tactical waverid er aircraft of interest to the DoN, ARPA, DoD and NASA. NASA Ames Research Center has also provided reimbursable funding for this waverider research.

BOUNDARY LAYER CONTROL

Professor Platzer is performing systematic water tunnel tests, supported by the Office of Naval Research, to explore the effectiveness of a new boundary layer and flow separation control method for drag reduction and lift enhancement.

TOPICS RELATED TO ADVANCED ROTORCRAFT

A program led by Professor Wood has five areas. First, research continues to be conducted on the unsteady aerodynamics related to higher harmonic control (HHC). HHC is an active control system concept which promises reduced helicopter vibrations, lower rotor noise levels and improved helicopter performance. Recent NPS research based on the results from the 1984 NASA/Army/McDonnell Douglas OH-6A HHC flight test program shows that a reduction in rotor power results due to the unsteady wake shed by the rotor with HHC turned on. In this area, NPS is teamed with SatCon Technology and McDonnell Douglas Helicopters to conduct rotor whirl tests this year at the MDHC facility. Rotor power a hover will be measured with HHC "off" and HHC "on" to quantify the amount of power reduction to be expected with an HHC system. The OH-6A rotor hub and blades for these tests will be provided by NPS. Second, research is being conducted on the no tail rotor (NOTAR) concept which uses circulation control aerodynamics (Coanda) effect to counter the torque from the helicopter's main rotor in place of a conventional tail rotor. This research is being carried out using the NPS "Hummingbird", a 1/4-scale remotely piloted helicopter with a NOTAR tailboom designed and built at NPS. Third, real-time flight simulation is being carried out for the Navy's SH-60B helicopter under sponsorship from NAWC, Patuxent River, Md. The simulation makes use of FLIGHTLAB, a unique computer software program developed by Advanced Rotorcraft Technology that permits detailed modelling of aircraft to a level never before considered possible including many higher order and non-linear effects. Fourth, NPS received two full scale OH-6A flightworthy helicopters from the Army National Guard in October. One of the helicopters will be removed from flying status and serve as a baseline model for helicopter structural dynamics research. In this area, Profs. Wood (AA), Gordis (ME), and Danielson (MA) are being funded by the Army RAH-66 Comanche office to provide a backup NASTRAN dynamic model of the Comanche to be used for exploring potential vibration problem areas, should they surface from the current RAH-66 flight test program being conducted by Sikorsky and Boeing at Wes t Palm Beach, Florida. The laboratory OH-6A helicopter provides a baseline model for training students in this program. That, is NPS students get experience in helicopter vibration testing by conducting vibration tests of the OH-6A here. Test results a re correlated against a finite element model of the OH-6A which has been provided the school by MDHC. Following this work, the students have the background to apply their training to analysis of the Army's new RAH-66 Comanche helicopter, which first flew on January 4, 1996, and which will be involved in flight tests to expand its flight envelope throughout the rest of this year. The second OH-6A helicopter will be maintained on flight status and used for research on helicopter noise and vibrations, and instruction in helicopter flight testing.

ENHANCED HELICOPTER MANEUVERABILITY

Professors Chandrasekhara, Platzer and Tuncer are performing experimental and computational studies on the dynamic stall characteristics of helicopter blades. Experiments are being carried out to develop practical adaptive-geometry techniques for controlling flow separation. Also, Navier-Stokes methods are being developed to predict the formation of separation bubbles on the onset of dynamic stall. These studies are partially supported by the Army Research office.

STRUCTURES

FAILURE AND LIFE PREDICTION FOR ADVANCED COMPOSITE AND AGING ALUMINUM VEHICLE STRUCTURES

Increased use of composites structures in all weapons platforms requires that there be developed reliable predictive methods for failure and probable structural life. Professor Wu has undertaken this fundamental problem using an analytical approach which separates fiber, matrix and interface mechanisms, and uses carefully controlled experiments to establish necessary statistical strength and life data. A unique new laboratory for composites has been established at NPS and the first successful research results have now been reported.

STRUCTURAL & DYNAMIC ANALYSIS AND DESIGN OF SPACECRAFT

Professor Scrivener and two NPS students helped conduct a 2 axis shock and vibration test on the Ya-21 TOPAZ II unit at Sandia National labs in September 1994. The students, performed a finite element analysis on a model of the TOPAZ II structure, and correlated the experimentally determined frequencies with those predicted by the model. The match was very close, and it was concluded that the test had excited all the relevant modes of the structure, and that the model was a good indicator of the actual behavior of the unit. In addition to advising a thesis in 1994 on the analysis and design of the adaptor fitting for PANSAT, Professor Scrivener also advised a thesis on the structural analysis and design of the EPS housing and circuit boards for PANSAT. The design is currently being implemented by the PANSAT engineers. This thesis work explored the static and dynamic behavior of the EPS housing and circuit boards, and determined the physical properties of the printed circuit board material through experimental methods. Also performed was a finite element analysis of th e components and the assembly to compare the behavior of a more complex model to that of the simplified one used for hand calculations.

PROPULSION

ADVANCED AIRCRAFT ENGINE AND MISSILE PROPULSION STUDIES

Currently in its second phase, the goals of the third phase of the (tri-service, government/industry) Integrated High Performance Turbine Engine Technology (IHPTET) Program can only be reached by achieving very significant performance and weight advances in each of the engine components. Advancing fan and compressor and turbine aerodynamics (to allow higher-blade loading) is the fo cus of the work of Professors Shreeve and Hobson at the Turbopropulsion Laboratory. The general approach is to use the laboratory's exceptional experimental facilities to validate CFD codes being developed for use in advanced design. The off-design and stalling behavior of controlled-diffusion compressor blading is being measured in a very large-scale subsonic cascade wind tunnel. The alleviation of shock boundary-interaction losses is being studied in a transonic blow-down wind tunnel model simulation of the flow through fan passages. A new stage designed by NASA using 3D CFD codes is being prepared for evaluation in the transonic compressor rig. Pressure sensitive paint has been developed as a diagnostic for the rotor flow. The details of flow in the tip region of high speed turbines is to be studied using, as a tool, the Space-Shuttle Main-Engine fuel-pump turbine and an annular cascade. Two- and three-dimensional traversing Laser-Doppler Velocimeter (LDV) systems have been developed for velocity field mapping. The development of successful diagnostic techniques to resolve small- scale, three-dimensional effects near to walls is necessary to achieve the goals of this and the IHPTET program.

Professor Netzer's work at the Combustion Laboratory is directed at several missile and gas turbine areas; (1) development of a small,low cost, long-range, combined-cycle motor for lethal UAV or helicopter, (2) fuel additive effects on plume IR signature of liquid rocket motors and gas turbine engines, (3) effects of particulates on supersonic shearlayer mixing and plume IR signature (ONR), (4) combustion behavior of high energy liquid and solid fuels, (5) optimization of inlets and fuel distribution for liquid-fuel ramjets (NAWCWD) and (6) development of liquid fuel injection for a pulse-detonation engine. Professors Biblarz and Netzer have been developing an instrument for the on-line determination of soot concentration within the test cell environment (NAWCAD).

FLIGHT MECHANICS AND CONTROLS

UNMANNED AIR VEHICLE (UAV) TECHNOLOGY

In support of the DoD's role in the development of UAVs, Professor Howard has developed a UAV flight research laboratory at NPS using several flight platforms for the development and testing of flight controls and flight mechanics applications. The broad goal is to develop innovative technologies and flight-control techniques applicable to UAVs, including HAE (high altitude endurance), Tactical, and Vertical Takeoff and Landing (VTOL) configurations. The design, construction and testing of a full-scale VTOL UAV has been initiated. The current focus, jointly with Professor Kaminer, is on the development of autonomous guidance, navigation and control of a conventional air vehicle to validate the technology prior to extension to the VTOL platform. Flight testing of the avionics, airborne sensors, and datalinks is underway. Professors Howard, Kaminer and Netzer are also investigating a lethal UAV concept for the detection and destruction of ballistic missiles prior to launch.

IMPROVING AIR VEHICLE CONTROLS & MILITARY APPLICATIONS OF NEURAL NETWORKS

Integrated Guidance and Control and Plant Controller Optimization for Air Vehicles.

In his work, Professor Kaminer addresses the problem of integrated design of guidance and control systems for autonomous vehicles (AVs). In fact, we have developed a new methodology for integrated design of guidance and control for autonomous vehicles. The methodology proposed leads to an efficient procedure for the design of controllers for AVs to accurately track reference trajectories defined in an inertial reference frame. This methodology was applied to the design of a tracking controller for the Unmanned Air Vehicle Bluebird at the NPS UAV Lab and to the Autonomous Underwater Vehicle Marius at the Instituto Superior Tecnico of Lisbon, Portugal. Furthermore, we are working on the development of closed loop criteria for tail sizing criteria of commercial supersonic aircraft using newly developed integrated plant/controller design methodology. The key idea is to rewrit e the tail sizing and feedback requirements as Linear Matrix Inequalities. In particular, the effects of feedback specifications, such as MIL STD 1797 Level I and II flying qualities requirements, and of actuator amplitude and rate constraints on the maximum allowable cg travel for a given set of tail sizes were considered. A static state feedback controller was designed as a part of the tail sizing process.

Following work on the X29 controller, Professor Collins has extended his work on neural networks to two important Navy problems. In the first, neural networks are being developed to identify transient sonar signals. In the second, neural network technology is being applied to ionospheric modeling and to PMA operator training.

ATTITUDE CONTROL, MANEUVER & SMART STRUCTURES

In this program, under the supervision of Professor Agrawal and in support of DOD, the emphasis is on the development of improved control techniques for attitude control of flexible spacecraft using thrusters and vibration control and antenna shape control using smart structures technology. Pulse-Width Pulse-Frequency (PWPF) modulator thruster control parameters were analyzed to minimize interaction with flexible spacecraft structures. Analytical model to optimize the locations of piezoceramic actuators to minimize beam shape error was developed. A finite element model for laminated composite plate with piezoceramic actuators using higher order shear deformation theory was developed.

ASTRODYNAMICS

Astrodynamics is the study of the motion of natural and artificial bodies in space. In support of DoD's role in the prediction and control of spacecraft motion, Professor Ross conducts research in the area of trajectory maneuver and optimization, singular control and mission design. A "bang-bang" maneuver called aerobang was developed by Professor Ross for the purpose of minimizing propellant use for orbital plane-change maneuvers. He and his students have mapped the efficacy regions for the maneuver and are currently working on optimizing the trajectory. Under Professor Ross' guidance, a team of students designed single- and dual-burn maneuvers for low-Earth-orbit maintenance. In support of the Air Force Space Command, another team of students, guided by Professor Ross and Hall (at AFIT), are currently working on mission design for near-Earth-orbit interception. Finally, Prof. Ross has developed a refined Energy-Sink Theory that has lead to the resolution of a decade-old debate on the stability of Dual-Spin spacecraft.

SYSTEM DESIGN

MULTI-DISCIPLINARY DESIGN OPTIMIZATION

Under a Cooperative Research & Development Agreement (CRADA) with the McDonnell-Douglas Corporation, Professor Platzer is contributing to the development of advanced multi-disciplinary analysis and design methods for subsonic transport aircraft.

In Spacecraft Design, Under Professor's Agrawal's supervision, two design projects were completed: Tomography Satellite System and EHF Communications Satellite. The mission of the Tomography Satellite System was to provide a "near real time" map of the ionosphere. Two different radio waves are sent by the satellite sim ultaneously and the relative delay of the signals determines electron content along the path of the signal. EHF communication satellite in a highly elliptical orbit provided EHF communications for the mobile tactical users above 650 N latitude, the area not covered by geosynchronous satellites.

JSOW CATM Project

Professor Lindsey is leading a multi-disciplinary project which involves the preliminary conceptual development of a Captive Air Training Missile (CATM) to be used in fleet operations for training pilots in the use of the Joint Stand-Off Weapon (JSOW) missile. A Concept of Operations for the CATM has been written, from which functional requirements are to be drawn up. Exploratory work on the conceptual design is to be done in (1) airframe structural design and weight estimation; (2) aerodynamic analyses for flight loads and contour shaping for minimum drag; (3) flight simulation of the JSOW by the CATM carrier aircraft; and (4) exploration of communications between the CATM on the carrier aircraft and the data link pod on the control aircraft.

Joint reimbursable funding has been obtained by Professor Newberry to determine the attributes and parameters of aircrew-centered system design. This funding has been channeled through NWAC/China Lake for the purpose of defining the system design procedur es and methodology for aeronautical systems which maximize the effectiveness of aircrew performance during manned missions.

AIRCRAFT COMBAT SURVIVABILITY AND LETHALITY ASSESSMENT

Professor Ball originated the study of aircraft combat survivability at NPS in 1974 and has provided technical support for the Naval Air Systems Command (NAVAIR) and the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS); (1) by writin g a textbook in aircraft combat survivability ("The Fundamentals of Aircraft Combat Survivability and Design", published by the American Institute of Aeronautics and Astronautics (AIAA) in 1985), (2) by conducting over 15 short and shorter courses in surv ivability since 1978, (3) by developing the NPS/NAVAIR Survivability and Lethality Assessment Center (SLAC), and (4) by conducting a variety of studies on the survivability of US aircraft and the lethality of US air defense systems. In FY 1995, the major ity of efforts were devoted to; (1) the continued development of the second edition of the AIAA survivability textbook, (3) the continued development of the SLAC, primarily through the addition of MOSAIC, a computer program that models the flyout of an in frared missile toward an aircraft ejecting flares, and (4) three MS degree studies on the survivability of aircraft. Two of the studies used MOSAIC to study the effects of flare dispensing on the survivability of the P-3 Orion and F-14A Tomcat aircraft ag ainst infrared missiles. The third study examined the effects of digital avionics systems on the survivability of modern tactical aircraft.