DEPARTMENT SUMMARY

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 committees, namely, Aerodynamics, Structures, Propulsion, Flight Mechanics and Controls, and System Design. Both aircraft and spacecraft are involved. Present Departmental endeavors are described below.

Aerodynamics

HIGH-ANGLE-OF-ATTACK MISSILE AERODYNAMICS: In support of the Missile Division of the Naval Air Warfare Center, Professors Platzer and Tuncer developed a three-dimensional Navier-Stokes solution for an advanced blended airframe missile configuration.

FLAPPING WING PROPULSION: In support of the Naval Research Laboratory, Professors Platzer and Jones are performing experimental and computational studies to explore flapping wing propulsion for micro-air vehicles.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/UNIVERSITY SPACE RESEARCH ASSOCIATION (NASA/USRA) ADVANCED DESIGN PROGRAM: The primary focus of the NASA/USRA Advanced Design Program for aeronautical systems under Professor Newberry is the innovative design of deck-launched waverider configured aircraft. However, conventional aircraft, helicopter, and missile system designs were also completed. Research efforts involving interplanetary waverider-configured spacecraft using aero-gravity-assist and the LoFlyte (Mach = 5) configuration supported design class products.

TOPICS RELATED TO ROTORCRAFT AND VERTICAL FLIGHT: The rotary wing program led by Professor Wood has five areas. These are: (1) sponsored research support of the Army's principal program, the RAH-66 Comanche helicopter. The prototype helicopter is now undergoing engineering flight development at Sikorsky's test center in West Palm Beach, FL; (2) research in ground and air resonance of soft-inplane hingeless rotor systems to eliminate the instability without requiring heavy and costly blade dampers; (3) technical support of McDonnell Douglas and SatCon Technology for application of higher harmonic control for improved rotor performance; (4) advanced engineering upgrades for rotorcraft in Special Operations Warfare; and (5) NOTAR=AE research using a 1/4 scale remotely piloted helicopter, the NPS Hummingbird I. In addition, NPS received two full scale OH-6A flightworthy helicopters from the Army National Guard in October 1995. One of the helicopters will be removed from flying status and serve as a baseline model for helicopter structural dynamics research. In this area, Professor Wood, Professor Gordis (Department of Mechanical Engineering), and Professor Danielson (Department of Mathematics) 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.

ENHANCED HELICOPTER MANEUVERABILITY: Professors Chandrasekhara, Platzer, and Jones are performing experimental and computational studies to investigate the fundamental fluid flow physics of compressible flow separation and dynamic stall onset over fixed and variable geometry airfoils, leading to innovative flow control methods. These studies are partially supported by the Army Research Office. Also, in support of the Army Research Office, Professor Chandrasekhara is performing experiments to develop flow control schemes by dynamically deforming the leading edge of an airfoil for prevention of flow separation.

Structures

P-3 ORION LIFE EXTENSION PROGRAM: Professor Wu is developing a life extension program. The strategy is to develop fatigue data for the aluminum alloy used in P-3 structures. Data collection is underway. Studying constant amplitude fatigue and spectrum fatigue will make up the second phase of testing. Results of these testing phases will be compared such that a methodology for spectrum life prediction will be available. Verifications will be performed on new samples subjected to a load history entirely in the laboratory. This will allow a lead time to forewarn any refurbishment in the fleet.

Propulsion

ADVANCED AIRCRAFT ENGINE AND MISSILE PROPULSION STUDIES: Professor Shreeve is working on a transonic fan design and validation. Experimentally, the goal is to install a new stage in the NPS transonic compressor test rig and evaluated it. Professors Shreeve and Hobson are working on an experimental validation of off-design compressor stall prediction for controlled-diffusion (CD) blading; they also are working on UAV propulsion technology, examining the potential performance of alternate engines for application in Predator and Global Hawk class UAVs. Professor Hobson is working on non-intrusive, laser Doppler velocimetry (LVD) measurements of turbine tip-leakage flows with the intent to transfer the measurement technique to operational turbines.

PLUME AFTERBURNING SUPPRESSION AND PULSE-DETONATION ENGINES: Professor Netzer and Dr. Brophy (National Research Council Post-doctoral Research Associate) are working to determine the effects of solid propellant rocket motor exhaust particulates and nozzle geometry on the suppression of plume afterburning and to obtain effective nozzle geometries which do not adversely affect thrust. Also, they are experimentally determining the combustion requirements for sustainment of full strength detonations and the detonation characteristics of liquid-fueled, pulse detonation engines.

Flight Mechanics and Controls

ADVANCED AVIONICS TECHNOLOGY: Over the past several years under the Naval Air Systems Command (NAVAIR) sponsorship, Professor Kaminer has embarked on the development and evaluation of GPS/INS integration systems. In particular, progress has been made in the development of the uniform framework for the INS/GPS integration using Kalman Filtering. The work is ongoing and strives to unify various approaches to the development of INS systems and their integration with GPS using Kalman Filtering.

CLOSED-LOOP PITCH CONTROL EFFECTOR SIZING: In this project Professor Kaminer developed a new optimization tool for obtaining the closed loop tail sizing criteria for HSCT. In particular, the tool is capable of determining the maximum cg travel for a given HSCT tail volume subject to a variety of disturbance recovery and closed loop constraints as well as structural mode considerations. The disturbances considered included vertical gust and sinusoidal inputs. The closed loop constraints included the effect of feedback specifications, such as MIL STD 1797 Level I and II flying qualities requirements. Furthermore, the HSCT actuator amplitude and rate constraints were accounted for. Moreover, the tool has the option of including the structural mode considerations.

PASSIVE SENSOR-BASED CONTROL OF NONLINEAR AUTONOMOUS SYSTEMS: The objective of this proposal is to investigate sensor fusion architectures and mathematical algorithms required to support autonomous vertical take off and landing (VTOL) of uninhabited combat air vehicles on ships using passive sensors. Preliminary results were obtained by Professors Kaminer and Duren on the synthesis of time-varying and nonlinear filters that integrate vision, GPS, and inertial sensors to provide an accurate estimate of ship's position with respect to the aircraft as well as of the ship's inertial velocity.

FY97 ENGINEERING AND TECHNICAL SUPPORT FOR UNMANNED AIR VEHICLE-JOINT PROGRAM OFFICE (UAV-JPO) PHASE II CONTRACT EFFORT: Under the UAV-JPO, Professor Kaminer has provided engineering and technical support to UAV JPO in managing the Phase II of the SBIR proposal "Low-Cost Fault Tolerant Controls for Unmanned Air Vehicles." The project was kicked off at NPS in November 1997.

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 control technologies and to address relevant issues of aerodynamics and flight mechanics. A program supporting technology development for future UAVs was begun in 1997. Professors Howard, Shreeve, Kaminer, and Duren conducted studies of recuperative engine cycles of bus architecture for a common UAV architecture, and improved airframe aerodynamics. For the aerodynamic study, a panel method computer program was used to model the Predator

Unmanned Aerial vehicle at its trim flight condition. Basic stability-and-control characteristics were identified for future modeling.

INTEGRATED GUIDANCE AND CONTROL FOR AIR VEHICLES: This work by Professor Kaminer addresses the problem of integrated design of guidance and control systems for autonomous vehicles (AVs). In fact, a new methodology for integrated design of guidance and control for autonomous vehicles has been developed. 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 Frog at the NPS UAV Lab.

DEVELOPMENT OF TAIL SIZING CRITERIA FOR A SUPERSONIC TRANSPORT: Professor Kaminer is also 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 rewrite 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. This technique is being currently integrated into a tail-sizing tool to be used by McDonnell Douglas.

SPACECRAFT ATTITUDE CONTROL AND SMART STRUCTURES: In this program, under the supervision of Professor Agrawal and in response to DoD requirements, the emphasis is on the development of improved control techniques for the attitude control of flexible spacecraft and vibration and shape control using smart structures. Improved control techniques have been developed using the technique of input shaping in conjunction with PWPF thrusters to minimize structural vibrations. A finite element model has been developed to analyze composite plates with piezoelectric actuators. Analytical techniques to determine optimum actuator voltages to minimize surface error were developed. Smart Structures Laboratory, consisting of vibration isolation platform, space truss, proof mass actuator, fiber optic, shape memory ally, and piezoelectric actuators is under development.

ASTRODYNAMICS: In support of DoD's role to develop advanced concepts in maneuverability for future space missions, Professor Ross' research in astrodynamics is focused on theoretical and numerical aspects of modeling, analysis, simulation, guidance, and control of nonlinear dynamical systems such as those encountered in, but not limited to: (1) synergetic maneuvers for military space planes; (2) stability and control of single and dual-spin spacecraft; and (3) near-Earth-object interception. The research has lead to the development of a refined Energy-Sink theory that has resolved a long-standing debate on the stability of dual-spin spacecraft. In addition, Professor Ross has developed two space maneuvers: one called aerobang that achieves rapid, minimum-fuel orbital plane-changes for a space plane, and another called a singular orbit transfer which achieves suboptimal performance by continuos thrusting. Recent advances have utilized singular optimal control theory to endo-atmospheric space flight, and periodic optimal control theory to low-Earth-orbit maintenance. The application of periodic optimal control theory has provided minimum-fuel solutions to the stationkeeping problem. Currently, Professor Ross and his associates are working on developing an advanced guidance algorithm for the orbit maintenance of low-Earth-orbiting spacecraft. Research is also continuing on a space mission design project for minimizing energy requirements for deflecting Earth-crossing asteroids.

System Design

MULTI-DISCIPLINARY DESIGN OPTIMIZATION: Under a Cooperative Research and Development Agreement with the Boeing Company Professors Platzer and Jones are contributing to the development of advanced multi-disciplinary analysis and design methods for subsonic transport aircraft.

In spacecraft design, under Professor Agrawal's supervision, a military communications satellite which would provide enhanced communications capacity has been considered. Also, four spacecraft laboratories have been developed, namely, FLEETSATCOM, spacecraft testing, spacecraft dynamics and control, and spacecraft design.

JOINT STAND-OFF WEAPON CAPTIVE AIR TRAINING MISSILE (JSOW CATM) PROJECT: This project 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 by Professors Lindsey, Biblarz, Kaminer, and Scrivener 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 STAND-OFF WEAPON UNITARY CAPTIVE AIR TRAINING MISSILE (JSOW-CATM) CONCEPTUAL DESIGN: On this project Professor Kaminer was responsible for the issues related to the JSOW CATM avionics system and for the development of cockpit steering commands requirements for the carriage aircraft. The work accomplished includes development of the preliminary functional requirements for JSOW CATM avionics as well as development of JSOW 6DOF nonlinear simulation and guidance and control system for a typical JSOW profile.

AIRCRAFT COMBAT SURVIVABILITY AND AIR DEFENSE 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 developing the 11 week graduate level course AA 3251, “Aircraft Combat Survivability,” in 1978 and teaching it twice a year since then; (2) by writing a textbook in aircraft combat survivability, “The Fundamentals of Aircraft Combat Survivability and Design,” published by the American Institute of Aeronautics and Astronautics (AIAA), 1985; (3) by conducting over 15 short (one week) and several shorter (three day) courses in survivability since 1978, (4) by developing the NPS/NAVAIR Survivability and Lethality Assessment Center (SLAC); and (5) by conducting a variety of studies on the survivability of U.S. aircraft. In CY 1997, the majority of efforts were devoted to: (1) the transmission of AA 3251 by Distance Learning to the NAWC-AD and NAWC-WD during the winter quarter; (2) the continued development of the second edition of the AIAA survivability textbook; and (3) six Master’s theses on the survivability of aircraft. Two of the theses used MOSAIC to study the effects of flare dispensing on the survivability of the SH-60A helicopter, and two of the theses examined the effects of on-board ECM on the survivability of aircraft against proximity-fuzed SAMs. One thesis developed a robust methodology for determining the synergistic effects of combining radar signature reduction with on-board ECM, and one thesis presented the current technology for reducing the vulnerability of modern fixed-wing tactical aircraft.

AIRCREW-CENTERED SYSTEM DESIGN (ACSD): The primary focus of the Aircrew-Centered System Design project has been the preliminary definition of attributes and characteristics of ACSD. A working group within AIAA has been established to address ACSD issues and two related sessions were held at the Ist World Congress in Los Angeles. Additional sessions are planned.