DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

Thesis Abstracts

CONCEPTUAL DESIGN TOOLS FOR THE NPS SPACECRAFT DESIGN CENTER

Michael N. Abreu-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Astronautical Engineering-September 2001
Advisor: Brij N. Agrawal, Department of Aeronautics and Astronautics
Second Reader: Joseph Aguilar, Aerospace Corporation
Christopher Taylor, Aerospace Corporation

The thesis surveys and develops spacecraft design techniques and tools involving the integration of collaborative/concurrent engineering (CE) for spacecraft design, specifically in the areas of spreadsheet and CAD/CAE software, for the NPS Spacecraft Design Center (SDC). The applicability of solid modeling to the spacecraft design process is also explored. A previous class design is modeled using a solid modeling tool and the results compared against the time and effort required for the original. In addition, two CE software tools obtained from commercial and university sources are installed in the SDC, improved, documented if necessary, and evaluated. The capabilities are evaluated with regard to learning curve, CE and their utility to the curriculum. A User's Guide for one of the software tools is written, as no documentation existed for it prior to this thesis. In addition, procedures for spacecraft design utilizing the SDC are developed in order to enhance student design capabilities and further their educational experience.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spacecraft Design Techniques, Collaborative/Concurrent Engineering

PERFORMANCE AND SPACE BORNE APPLICATION ANALYSIS OF THE HIGHER ORDER CYCLOSTATIONARY BASED CLASSIFIER

Brian K. Bailey-Captain, United States Air Force
B.S., Carnegie Mellon University, 1994
Master of Science in Astronautical Engineering-December 2000
Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics
Charles W. Therrien, Department of Electrical and Computer Engineering
Second Reader: Tri T. Ha, Department of Electrical and Computer Engineering

Testing of the Higher Order Cyclostationary Based Classifier (HBC) is conducted to evaluate system operational performance. Utilizing Higher Order Cyclostationary (HOCS) analysis techniques, the HBC is designed to automatically detect and classify communication and radar signals contained in input signal samples. While test results utilizing earlier data were inconclusive on the effectiveness of the system, a more rigorous testing for Binary Phase-Shift Keying (BPSK) modulation scheme is herein carried out. The results of the HBC analysis reveal a system which experiences difficulty in performing modulation detection and classification of the input data at signal-to-noise ratios above 10 dB. The HBC automatic band-of-interest detector also shows evidence of interfering with accurate signal classification results. Recommended improvements to the algorithms and interface are presented to address these and other observed trends. An application of the HBC system to the Naval Research Laboratory's Pre-Configured Interface Payload (PCIP) program are assessed for space borne testing of the HBC system.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software, Sensors, Modeling and Simulation

KEYWORDS: Cyclostationary, Cyclostationarity, Digital Signals, Signal Classification, Signals Intelligence (SIGINT), Spacecraft Payload Integration, Pre-Configured Interface Payload (PCIP)

ADAPTIVE MULTI-LAYER LMS CONTROLLER DESIGN AND ITS APPLICATION TO ACTIVE VIBRATION SUPPRESSION ON A SPACE TRUSS

Timothy A. Barney-Lieutenant, United States Navy
B.S., Eastern Michigan University, 1993
Master of Science in Mechanical Engineering-June 2001
Advisors: Young S. Shin, Department of Mechanical Engineering
Brij N. Agrawal, Department of Aeronautics and Astronautics

This thesis develops an adaptive controller that actively suppresses a single frequency disturbance source at a remote position and tests the system on the NPS Space Truss. The experimental results are then compared to those predicted by an ANSYS finite element model. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss. Experimental and analytical results both demonstrate reductions to the level of system noise. Vibration reductions in excess of 50dB were obtained through experimentation and over 100dB using ANSYS, demonstrating the ability to model this system with a finite element model. This thesis also proposes a method to use distributed quartz accelerometers to evaluate the location, direction, and energy of impacts on the NPS space truss using the dSPACE data acquisition and processing system to capture the structural response and compare it to known reference signals.

DoD KEY TECHNOLOGY AREA: Space Vehicles, Modeling and Simulation

KEYWORDS: Active Vibration Suppression, Piezoceramic Actuators, Impact Analysis, Adaptive Controller, LMS

THREE-COMPONENT LDV MEASUREMENTS OF CORNER VORTICES OVER SECOND-GENERATION, CONTROLLED-DIFFUSION, COMPRESSOR BLADES IN CASCADE

Todd M. Caruso-Captain, United States Marine Corps
B.S., Northeastern University, 1991
Master of Science in Aeronautical Engineering-September 2001
Advisor: Garth V. Hobson, Department of Aeronautics and Astronautics
Second Reader: Raymond P. Shreeve, Department of Aeronautics and Astronautics

A detailed investigation of the three-dimensional flow in a cascade of second-generation controlled-diffusion compressor stator blades, at off-design inlet-flow angle, is reported. Three-component fiber-optic Laser-Doppler Velocimetry (LDV) surveys were made to fully map the flow at one plane upstream of the cascade and at three planes downstream. The measurements were performed at an inlet flow Mach number of 0.22 and a Reynolds number, based on chord length, of 640,000. The inlet surveys documented the approaching flow field in detail to establish the inlet boundary conditions for numerical simulations. At the downstream planes, total velocity distributions, total turbulence kinetic energy distributions, secondary flow velocity vector and contour plots are presented. The downstream surveys confirmed the existence of secondary flow vortices produced by the end wall. Surface vector and contour plots of non-dimensional velocity and total turbulence kinetic energy detail the complex flow field, including the size and location of the corner vortex system.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: LDV Measurements, Compressor Ccascade Stall, Transonic Compressor Design, Controlled Diffusion Blading

MULTI-BLOCK PARALLEL NAVIER-STOKES SIMULATION OF UNSTEADY WIND TUNNEL AND GROUND INTERFERENCE EFFECTS

Breno Moura Castro, Brazilian Air Force
B.S., Instituto Tecnológico de Aeronáutica, Brazil, 1985
M.S., Instituto Tecnológico de Aeronáutica, Brazil, 1997
Doctor of Philosophy in Aeronautical and Astronautical Engineering-September 2001
Dissertation Supervisor: Max F. Platzer, Department of Aeronautics and Astronautics

A numerical investigation of unsteady wind tunnel and ground interference effects is carried out in the time domain to study the transonic flutter characteristics of the NLR 7301 section inside a wind tunnel and the thrust generation characteristics of a NACA0014 airfoil plunging near a ground plane. A parallelized, multi-block, deforming grid, unsteady flow-solver is coupled with a two-degree-of-freedom structural model.

For the transonic flutter problem, two types of porous-wall boundary-conditions are implemented and tested for the boundaries representing the tunnel walls. The type of porous boundary condition is found to influence significantly both steady and unsteady solutions. Results show that the free-flight flutter behavior may differ significantly from the behavior found in a porous wind tunnel because of the strong dependence on the tunnel porosity parameter and the proximity of the walls.

An analysis of the trailing edge boundary condition is performed for the airfoil in ground effect. The computations show that this boundary condition influences the solution only when non-linearities are present in the flow-field, although parameters averaged through a cycle of oscillation are not affected significantly. The same behavior is observed for the influence of the turbulence model on the fully-turbulent, unsteady computations. However, the best agreement with low Reynolds number, experimental data is obtained when the flow is assumed laminar and no turbulence model is applied.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Low Speed Aerodynamics, Transonic Flutter, Computational Fluid Dynamics

HI-FIDELITY SIMULATION AND PREDICTION OF HELICOPTER SINGLE POINT EXTERNAL LOAD STABILIZATION

George E. Ehlers-Major, United States Marine Corps
B.S., University of Nebraska-Lincoln, 1991
Master of Science in Aeronautical Engineering-September 2001
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Mark B. Tischler, National Aeronautics and Space Administration-Ames Research Center

The helicopter has been used since its early development for external transport of large or bulky loads to small austere locations. Among the problems encountered as lift capability and airspeeds increased was that of divergent load oscillations due to load aerodynamics The most problematic are the single point external loads displaying unsteady aerodynamics and coupled yaw-pendulum modes accounting for the instability of cargo containers. However, a lack of simulation models for unsteady aerodynamics renders simulation and analysis incapable of predicting the critical speeds at which such loads become unstable. This thesis attempts to provide a stabilization system for controlling the yaw degree of freedom for the single point external load. Empirical models of the yaw resistance at the hook and of the yaw moments due to vortex shedding were developed and tuned using flight test data and lab measurements. Several load stabilization systems were considered, and a horizontal and vertical tail fin assembly was selected This thesis presents simulation model improvements required for a simulation to match flight results for the load yaw, along with the design, modeling and optimization of the fin stabilization system, and a simulation assessment of the envelope expansion obtained from both passive and active stabilization.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Rotocraft, Helicopter, Aerodynamics

DESIGN AND EVALUATION OF A DIGITAL FLIGHT CONTROL SYSTEM FOR THE FROG UNMANNED AERIAL VEHICLE

Christopher H. Flood-Commander, United States Navy
B.S., United States Naval Academy, 1984
Aeronautical and Astronautical Engineer-September 2001
Advisor: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Second Reader: Oleg Yakimenko, Department of Aeronautics and Astronautics

The importance of unmanned aerial vehicles (UAVs) to current and future military operations cannot be understated. This rapidly developing field requires the ability to quickly develop and evaluate advanced control concepts. The FROG UAV serves as a test bed for advanced control and sensor projects at the Naval Postgraduate School. Previous control system projects have made use of a low performance electromechanical autopilot onboard the UAV. This autopilot imposed significant limitations on the responsiveness of the FROG. This project developed and tested an off board digital flight control system for use in lieu of the previous electromechanical device.

The digital flight controller was developed using the MatrixX rapid prototyping system and a previously validated dynamic model of the FROG. Surrogate flight control servo actuators were characterized in the laboratory and added to the plant model. Classic inner/outer loop controllers were developed for yaw damping and speed, altitude and heading control. The system was then successfully demonstrated with hardware in the loop in the lab.

The FROG was then instrumented and a command uplink latency of 170 ms was discovered. This introduced excessive phase lag into the system, which drove the flight controllers unstable. An alternate serial uplink method was developed and tested which reduced the command latency to 76 ms however the remaining phase lag resulted in limit cycle oscillation. Laboratory tests indicated that the current flight controller could withstand a maximum of 50 ms command path delay; without modification.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Unmanned Aerial Vehicles, Flight Control System, Flight Controller

TESTING AND DEVELOPMENT OF A SHROUDED GAS URBINE ENGINE IN A FREEJET FACILITY

Hector Garcia-Lieutenant Commander, United States Navy
B.S., University of California-Riverside, 1986
Master of Science in Applied Physics-December 2000
Advisors: Garth V. Hobson, Department of Aeronautics and Astronautics
Karlheinz E.Woehler, Professor Emeritus

Testing and analysis of a shrouded turbojet engine with possible application for high speed propulsion on low cost Unmanned Combat Aerial Vehicles (UCAV), Unmanned Aerial Vehicles (UAV) and missiles was the subject of this thesis. The possibility of a turbojet providing thrust at subsonic conditions and the ramjet section providing the thrust in the supersonic regime exists. The combined cycle engine (CCE) could be incorporated into a variety of applications.

The building of a new freejet facility and engine test rig at the Naval Postgraduate School enabled dynamic testing of the ongoing development of a turboramjet. The freejet facility and new engine stand performed without exception. The shrouded engine was dynamically tested in a freejet up to Mach 0.4. The engine performance measurements closely matched those predicted by a cycle analysis program, GASTURB.

Computational fluid dynamics (CFD) was used to analyze the supersonic inlet at a design point of Mach 2. The results provided by the CFD code, OVERFLOW, matched theoretical flow parameters. The intake design was slightly modified to enhance performance of shock waves in the supersonic flight regime.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Micro-Turbojet, GASTURB, Engine Shroud, Turboramjet, Sophia J450, Microturbine

SUPERSONIC FLOW FIELD VISUALIZATION STUDIES OF THE M8 =6 PRICE WAVERIDER PLANFORM

Karl Garcia-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
Master of Science in Aeronautical Engineering-September 2001
Advisor: Conrad F. Newberry, Department of Aeronautics and Astronautics
Second Reader: Garth V. Hobson, Department of Aeronautics and Astronautics

Supersonic tests of the conical flow derived M8 =6 (design) Price waverider planform were conducted using the Naval Postgraduate School wind tunnel. These tests are part of a continuing effort to study the characteristics of waverider configured vehicles. Two sting-mounted, flat-plate stainless-steel Price waverider planform models were utilized for testing in the NPS 4-inch by 4-inch cross section supersonic blowdown wind tunnel. Tests at Mach numbers of M8 =1.7, 2.8 and 4 were attempted but flowfield studies were only completed at M8 =4. Sting mount flow blockage (choked flow) prevented test section starting at freestream test Mach numbers of M8 =1.7 and 2.8. Horizontal (side-view) and vertical (top-view) mounted shadowgraph pictures and pressure sensitive paint images were taken at pitch angles of a=0°, 2° and 4°. The Mach 4 shadowgraph and pressure sensitive paint results correlate well with previous CFD results using the three-dimensional Price waverider model. The choked flow tests at M8 =1.7 and 2.8 are discussed in detail; suggestions are given for future work in this Mach number test spectrum.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Supersonic Tests, Waverider Configured Vehicles, Price Waverider Planform

INVESTIGATION OF CROSS FLOW FAN PROPULSION FOR LIGHTWEIGHT VTOL AIRCRAFT

Dean H. Gossett-Lieutenant Commander, United States Navy
B.S., Montana College of Mineral Science and Technology, 1984
Master of Science in Aeronautical Engineering-December 2000
Advisors: Max F. Platzer, Department of Aeronautics and Astronautics
Kevin D. Jones, Department of Aeronautics and Astronautics

As world population increases, road and airport congestion will become increasingly prevalent. A small, cheap VTOL aircraft which can be flown from a driveway to the workplace parking lot would reduce traffic congestion and travel time. A lightweight, single seat commuter type VTOL aircraft is envisioned as the solution to this problem. To achieve a goal of minimum weight, the aircraft aerodynamic design should be optimized for forward flight. Vertical thrust augmentation from a propulsion unit contained within the fuselage would have little detriment to forward flight aerodynamics, and the cross flow fan can be accomodated as such. Cross flow fan propulsion has not been seriously considered for aircraft use since an LTV Vought Systems Division study for the U.S. Navy in 1975. Despite an indepth knowledge of the design parameters and airflow relationships in cross flow fans, the existing data supports the hypothesis that with further development the thrust efficiency and thrust-to-weight ratio could improve to the point where this thrust producing method is viable. This study investigates the incorporation of rotary engine powered cross flow fan propulsion in a hypothetical lightweight VTOL aircraft and concludes that cross flow fan propulsion is viable but only with further investigation of power plant technology and fan design parameters and relationships.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: VTOL, Cross Flow Fan, Ducted Propeller

A NUMERICAL STUDY OF FUEL-OPTIMAL LOW-EARTH-ORBIT MAINTENANCE

Lawrence E. Halbach-Major, United States Air Force
B.A.E.M., University of Minnesota, 1988
Master of Science in Astronautical Engineering-December 2000
Advisors: I. M. Ross, Department of Aeronautics and Astronautics
Fariba Fahroo, Department of Mathematics

This thesis studies the fuel optimal periodic reboost profile required to maintain a spacecraft experiencing drag in low-earth-orbit (LEO). Recent advances in computational optimal control theory are employed, along with a Legendre-Gauss-Lobatto Pseudospectral collocation code developed at the Naval Postgraduate School, to solve the problem. Solutions obtained by this method are compared against a previous study. Key issues were checking the optimality of the solutions by way of the necessary conditions and the behavior of the solution to changes in the thruster size. The results confirmed Jensen's findings of propellant savings of one to five percent when compared against a middle altitude Forced Keplerian Trajectory (FKT). Larger savings are predicted if compared against a finite-burn Hohmann transfer with drag. The costates estimates compared favorable against necessary conditions of Pontryagin's Minimum Principle. Analysis of the switching function yielded periods of thrust-modulated arcs. The optimal thrust profile appears to be a thrust-modulated burn to raise the orbit followed by an orbital decay and a terminating thrust-modulated arc. For a sufficiently low thrust-control authority, the switching structure includes a maximum thrust arc. Indirect optimization techniques to confirm these findings were unsuccessful.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Orbital Mechanics, Optimization, Optimal Control Theory, Orbit Maintenance

TELEMETRY SYSTEMS ANALYSIS AND DESIGN

William K. Ham-Lieutenant, United States Navy
B.S., Texas Tech University, 1993
Master of Science in Astronautical Engineering-December 2000
Advisor: Brij Agrawal, Department of Aeronautics and Astronautics
Second Reader: Norm Sorensen, National Reconnaissance Office Chair Professor

The Navy has a valuable opportunity to improve its own products and operations efficiency by showing its future leaders and designers how to design effective and viable telemetry, tracking, and commanding (TT&C) systems, and their operation. One system is the FLTSAT military communications constellation of spacecraft, one of which has been a static display at the Naval Postgraduate School (NPS) until June, 2000. The primary objective was to make this spacecraft operational and thus provide a new operational spacecraft laboratory for other NPS students. This thesis may also be used as a primer for the space engineering or space operations student regarding TT&C systems design. Great effort has been taken to document and discuss current design practices and standards adopted by DoD laboratories, test facilities, and operation centers. A TT&C system designed for a spacecraft incorporating all the traditional subsystems (payload, thermal, structural, power, TT&C, attitude control) is included.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Other (Communications)

KEYWORDS: Space Vehicles, Communications

UNMANNED AERIAL VEHICLES AND SPECIAL OPERATIONS: FUTURE DIRECTIONS

Gregory K. James-Major, United States Army
B.S., University of Washington, 1988
Master of Science in Defense Analysis-December 2000
Advisor: Gordon H. McCormick, Special Operations Academic Group
Second Reader: E. Roberts Wood, Department of Aeronautics and Astronautics

Advances in computing, miniaturization, imaging, and data transmission technologies are precursors to a more important role for UAVs in warfare. UAVs are likely, first, to revolutionize the way reconnaissance and surveillance are conducted, second, to increase the capabilities of small units, third, to join manned platforms in the conduct of assault and attack missions, and finally help provide the numerous nodes necessary to facilitate both the digital connectivity and swarming forces envisioned in future network-centric formations.

This thesis focuses on answering six questions:

-What missions can UAVs perform?
-What missions should UAVs perform?
-What type of UAV is appropriate for each mission?
-How can SOF use UAVs?
-Who should own the UAV (from a SOF perspective)?
-What level of control is required and where?

Results include what UAV missions and types could support special operations, which of these should be performed by UAVs organic to special operations, and which should be performed by the Services' UAVs, as well as recommendations for future command and control of UAVs supporting special operations. Results are presented in matrix form for easy correlation of related factors. The thesis concludes with a twenty-year prognostication of UAV development and recommends areas for future study.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Command Control and Communications, Electronic Warfare, Sensors

KEYWORDS: Unmanned Aerial Vehicles, UAV, Special Operations Forces, SOF, Future of Warfare

HARDWARE INTEGRATION OF PARACHUTE GUIDANCE, NAVIGATION, AND CONTROL FOR THE AFFORDABLE GUIDED AIRDROP SYSTEM (AGAS)

James G. Johnson-Lieutenant Commander, United States Navy
B.S.E.E., United States Naval Academy, 1985
M.A., Naval War College, 1996
Master of Science in Aeronautical Engineering-September 2001
Advisors: Isaac I. Kaminer, Department of Aeronautics and Astronautics
Oleg A. Yakimenko, Department of Aeronautics and Astronautics

This study is a continuation of a previous work concerning the Affordable Guided Airdrop System (AGAS), a parachute structure that integrates low-cost guidance and control into fielded cargo air delivery systems. This thesis sought to integrate the previous studies and algorithms into developmental prototypes for test and evaluation (DT&E). Several objectives and tasks were completed in the course of this research and development. A RealSim(r) executable on an Integrated Systems, Incorporated (ISI) AC-104 real-time controller integrated actual Vertigo(r), pneumatic muscle actuators (PMAs) into the MATRIX-X. The environment simulation model used in the previous work to validate, analyze and improve the simulation model. A ground station utilizing the model's control algorithms, a downlink of platform position and attitude data, and a Futaba(r) Pulse Code Modulated uplink demonstrated controlled guidance of a round cargo parachute (G-12). This system evolved as an RS-232 serial control RF modem uplink replaced the PCM control. After evaluating, validating, and improving the algorithms using the ground station control algorithm was written in C-code for incorporation into an autonomous system. The results from the drops were then analyzed in the MATRIX_X (r) to further improve the model and qualitatively evaluate

improved control strategies. Conclusions and recommendations for further study were drawn from this project.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Affordable Guided Airdrop System, AGAS, Parachute Guidance, Navigation and Control

EXPERIMENTAL INVESTIGATION OF LOW SPEED FLOW OVER FLAPPING AIRFOILS AND AIRFOIL COMBINATIONS

Osama Mohamed Kamal Mohamed Mahmoud-Major, Egyptian Army
B.S., Military Technical College, Cairo, Egypt, 1989
M.S., Military Technical College, Cairo, Egypt, 1994
Doctor of Philosophy in Aeronautical and Astronautical Engineering-September 2001
Dissertation Supervisor: Max F. Platzer, Department of Aeronautics and Astronautics

A wind tunnel investigation of low speed flow over flapping airfoils and airfoil combinations was performed using flow visualization and laser Doppler velocimetry. Specifically, three cases were studied: A NACA0014 airfoil oscillating in a sinusoidal plunge mode, A NACA0014 airfoil oscillating in a sinusoidal plunge mode near a ground plane, and two NACA0014 airfoils arranged in a biplane configuration and oscillating in counterphase in a sinusoidal plunge mode. The plunge amplitude-to-airfoil chord ratio was 0.4, the reduced frequency of oscillation was 1.0 and the Reynolds number based on airfoil chord was set at 8760.

Conditionally sampled measurements of the axial flow velocity were taken at numerous flow held points providing detailed information about the flow features generated by this type of flapping motion. These measurements were complemented by time-averaged flowfield data and by visualization of the instantaneous flow held at various points during the flapping cycle. Furthermore, the thrust generated by the sinusoidal plunge motion was measured with a laser range. The results show that vortex shedding occurs both from the airfoil leading and trailing edge.

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Low Speed Flow, Flapping Airfoils, Axial Flow Velocity, Low Speed Aerodynamics

EVALUATION OF THE USE OF GPS-AIDED WEAPONS TO ATTACK MOVING TARGETS

Randolph L. Mahr-Commander, United States Navy
B.S., United States Naval Academy, 1983
Master of Science in Aeronautical Engineering-March 2001
Advisor: Russell W. Duren, Department of Aeronautics and Astronautics
Second Reader: Morris R. Driels, Department of Mechanical Engineering

The current intelligence gathering and strike decision infrastructure is optimized to handle geographically and temporally fixed targets. When tasked to respond to targets that require near immediate engagement, however, the system is stressed to the limit of its capability. When these time sensitive targets are capable of relocating, the process of rapidly applying lethal force becomes even more complicated. This thesis examines the problems associated with attacking a moving target using low cost GPS-aided standoff weapons, without an integrated weapon seeker. It begins with a discussion of the history and evolution of the Navy's ability to attack time sensitive moving targets, and provides the description of a system that could address shortcomings noted. MATLAB(Simulink(was used to develop a model to simulate the proposed system, and determine the responses to various combinations of identified error sources. The results of the research showed that the type of system proposed is technically feasible.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Command, Control, and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Other (Time Critical Strike)

KEYWORDS: GPS, Weapon, Modeling, CEP, Time Sensitive Targets, Command Control and Communications, Conventional Weapons, Sensors, Modeling and Simulation, Time Critical Strike, Stand-off Weapons

MICROELECTROMECHANICAL SYSTEMS FOR SMALL SATELLITE APPLICATIONS

Elizabeth Sei Okano-United States Navy
B.S., United States Naval Academy, 1994
Master of Science in Astronautical Engineering-June 2001
Advisors: Rudy Panholzer, Space Systems Academic Group
Brij Agrawal, Department of Aeronautics and Astronautics
Second Reader: Alfred N. Sorensen, National Reconnaissance Office/
Aerospace Corporation Chair Professor

Microelectromechanical systems (MEMS) have been developing for the past few decades, but recent spaceflight demonstrations have highlighted the potential of this technology as an attractive paradigm shift in how aerospace systems should be developed, maintained and used as the dawn of a new space age emerges. MEMS will generate a revolution in the way people see and control tomorrow's satellites by combining technological advances in sensors, actuators, reactionary systems, spacecraft attitude control systems, information processing and storage with the miniaturization of these components. MEMS will enable the realization of decentralizing satellites and, therefore, create a paradigm shift in the conceptual operation and development process of how people think about using satellites. The vision of what can be achieved from space is no longer bound by what an individual satellite can accomplish, rather, a number of much smaller cooperating satellites can share the functionality at a lower cost in development and production. This thesis will validate the concept of MEMS and its applicability to space and conclude by examining possible paths that the Naval Postgraduate School microsatellite, NPSAT1, can take to reducing subsystem mass and power through the use of MEMS components.

DoD KEY TECHNOLOGY AREA: Sensors, Other (Microelectromechanical Systems)

KEYWORDS: Micromlectromechanical Systems, MEMS, Nanosatellites, Microsatellites, NPSAT1, Gyroscopes

ANGULAR RATE ESTIMATION FOR MULTI-BODY SPACECRAFT ATTITUDE CONTROL

William J. Palermo-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Astronautical Engineering-June 2001
Aeronautical and Astronautical Engineer-June 2001
Advisor: Brij N. Agrawal, Department of Aeronautics and Astronautics
Second Reader: Harold A. Titus, Department of Electrical and Computer Engineering

Spacecraft with high performance attitude control systems requirements have traditionally relied on imperfect mechanical gyroscopes for primary attitude determination. Gyro bias errors are connected with a Kalman filter algorithm that uses updates from precise attitude sensors like star trackers. Gyroscopes, however, have a tendency to degrade or fail on orbit, becoming a life-limiting factor for many satellites. When errors become erratic, pointing accuracy may be lost during short star gaps. Unpredictable gyros degradations have impacted NASA spacecraft missions such as Skylab and Hubble Space Telescope as several DoD and ESA satellites. An alternative source of angular rate information is a software implemented real tie dynamic model. Inputs to the model from internal sensors and known spacecraft parameters enable the tracking of total systemangular momentum from which body rates can be determined. With this technique, the Kalman filter algorithm provides error corrections to the dynamic

model. The accuracy of internal sensor and input parameters determine the effectivenes of this angular rate estimation technique. This thesis presents the background for understanding and implementation of the technique into a representative attitude determination system. The system is incorporated into an attitude simulation model developed in SIMULINK to evaluate the effects of dynamic modeling errors and sensor inaccuracies. Results are presented that indicate that real time dynamic modeling is an effective method of angular rate determination for maneuvering multi-body spacecraft attitude control systems.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Dynamic Gyro, Kalman Filter, Attitude Determination, Rate Estimation, Star Trackers, Attitude Simulation, Multi-body Dynamics, Quaternion, MATLAB, SIMULINK

PRELIMINARY DESIGN CODE FOR AN AXIAL STAGE COMPRESSOR

Rizwan R. Ramakdawala, DoD Civilian
B.S., University of Maryland, 1994
Master of Science in Aeronautical Engineering-September 2001
Advisor: Raymond P. Shreeve, Department of Aeronautics and Astronautics
Second Reader: Garth V. Hobson, Department of Aeronautics and Astronautics

Current two-dimensional preliminary design codes use structured programming, which is rigid and does not allow the user to vary parameters easily. This study uses object-oriented programming to allow the user to vary all selectable parameters in a familiar Windows operating environment. The programmed design is based on the assumptions of axial and free-vortex flow between blade rows, simple radial equilibrium, and a thermally and calorically perfect gas. The program allows a fan or core stage design and uses an open architecture to facilitate upgrades and extensions.

Using the Naval Postgraduate School's (NPS) transonic compressor design as input, the preliminary design code output was compared to the detailed throughflow design of the transonic compressor. The results agreed reasonably well with detailed throughflow design. With some minor improvements this code can easily be used to develop a preliminary design that can be optimized to the user's requirements.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Axial and Free-Vortex Flow, Transonic Compressor, Axial Stage Compressor

TARGETING AND FIRE CONTROL SYSTEM ANALYSIS OF THE NEW TURKISH ATTACK HELICOPTER "THE AH-1Z KINGCOBRA"

Gokhan Lutfu Reyhan-First Lieutenant, Turkish Army
Master of Science in Aeronautical Engineering-March 2001
Advisors: Russ Duren, Department of Aeronautics and Astronautics
Alfred W. Cooper, Department of Physics

In May of 1997, the Turkish Military issued a Request for Proposal for the purchase of 145 attack helicopters. Turkey has chosen Bell Helicopter's KingCobra as its attack helicopter. The major difference between the USMC version of AH-1Z and the Turkish version KingCobra is the Targeting and Fire Control System. Bell Helicopter Textron has chosen Lockheed Martin to develop and build a new targeting system, the Target Sight System (TSS). The TSS will contain Lockheed Martin's 3-5µm midwave staring array FLIR. On the other hand, the Turkish Secretariat for Defense Industries (SSM) has chosen Aselsan ASELFLIR-300T that contains an 8-12µm longwave scanning second-generation FLIR.

A comparison of range performance for these two systems has been made using the TAWS Field Performance Model. Since the physical parameters on these specific FLIRs are proprietary, the FLIR92 Simulation Model is used to generate performance parameters. These parameters are expected to represent the general characteristics of the two systems. The resultant data is used in the TAWS Field Performance Model to predict the range performances.

The results have showed that the staring array midwave FLIR has longer ranges in the scenarios given in this thesis. This may not represent the real performance of the systems.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Sensors, Other (Thermal Imaging Systems)

KEYWORDS: Thermal Imaging Systems, Targeting, Fire Control Systems, Forward Looking Infrared, FLIR, TAWS, KingCobra, Attack Helicopter, Infrared

EXPLOITATION OF NATIONAL SENSORS FOR TERRAIN CATEGORIZATION (U)

Charles S. Seitz-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1982
Master of Science in Astronautical Engineering-March 2001
Advisors: Richard C. Olsen, Department of Physics
Brij N. Agrawal, Department of Aeronautics and Astronautics

Abstract is classified.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors, Other (Intelligence, Indications and Warning (I&W))

KEYWORDS: Sensor Fusion, Multispectral Imaging, Imagery Intelligence, TERCAT

SIMULATION OF GUIDED AEROASSISTED MANEUVERS FOR PLANETARY MISSIONS

Christopher M. Senenko-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994
Master of Science in Astronautical Engineering-December 2000
Advisor: I. M. Ross, Department of Aeronautics and Astronautics
Second Reader: S. E. Matousek, Jet Propulsion Laboratory

Aeroassisted maneuvers are distinguished from purely propulsive maneuvers in that aerodynamic forces are used to assist in orbital maneuvers of spacecraft. These types of maneuvers can vary from aerocapture to direct entry. The NASA Solar System Exploration Program lays the foundation for the future of interplanetary exploration using various versions of these aeroassisted maneuvers. The computer program ACAPS, designed at the Naval Postgraduate School, was developed for the Jet Propulsion Laboratory (JPL) to conduct high-level mission design for exploration missions to Mars. The primary research objective of this thesis was to upgrade the previous version of ACAPS, to produce a tool that provides new capabilities in support of the Solar System Exploration Program. The secondary research objective of this thesis was to provide direct support to JPL mission planners. The first major upgrade was the incorporation of additional planets which allows for simulation at Venus, Saturn, Neptune, and Titan. The second focus of work was the incorporation of guidance to include ballute guidance and the Apollo derived Mars Precision Lander guidance algorithm. This thesis also documents how these upgrades were used to support future missions to Venus, Neptune, Saturn and Titan; particularly in the possibilities of using ballutes.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Aerocapture Simulation (ACAPS), Aeroassist, National Aeronautics and Space Administration (NASA), Jet Propulsion Laboratory (JPL), Mars Sample Return (MSR) Mission, Mars Micromission, MATLAB, SIMULINK, Ballute, Parachute

DETONABILITY OF HYDROCARBON/AIR MIXTURES USING COMBUSTION ENHANCING GEOMETRIES FOR PULSE DETONATION ENGINES

Neil G. Sexton-Lieutenant, United States Navy
B.S., United States Naval Academy, 1995
Master of Science in Applied Physics-June 2001
Advisors: Christopher M. Brophy, Department of Aeronautics and Astronautics
James V. Sanders, Department of Physics
Second Reader: David W. Netzer, Department of Aeronautics and Astronautics

This research studied combustion enhancing geometries and shock reflection on generating a hydrocarbon/air detonation wave in a combustion tube. Ethylene was used as a baseline fuel to determine the preferable geometries. Propane was then used in later testing because of its combustion similarities with heavy hydrocarbon fuels such JP5, JP8, and JP10. Three criteria were used to measure the effectiveness of the combustion enhancing geometries: ability to generate a detonation, wave speed, and time for shock formation. The evaluated geometries included flow-restricting orifice plates and a Schelkin spiral. The shock reflection was accomplished by a vertical fence (large orifice) placed in the last fourth of the tube length. The optimum geometry was found to be the orifice plate used in conjunction with the spiral. Detonations occurred when using ethylene in this configuration, but did not develop when using propane. Because propane's overall reaction rate is slower than that of simpler fuels, more large- and small-scale turbulence to further enhance combustion needs to be generated to create a detonation wave in a short distance when using complex hydrocarbons, such as propane.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Detonation, Pulse Detonation Engine, Deflagration to Detonation Transition, DDT

COMPUTERIZED BALLISTIC MODELING OF THE COMANCHE TAILFAN SHROUD

Allen H. Stephan-Captain, United States Army
B.S., United States Military Academy, 1991
Master of Science in Aeronautical Engineering-December 2000
Advisors: E. Roberts Wood, Department of Aeronautics and Astronautics
Donald A. Danielson, Department of Mathematics

The U.S. Army has contracted Boeing-Sikorsky to develop the RAH-66 Comanche, a new, armed reconnaissance helicopter that features stealth technology designed to improve survivability when operating in hostile environments. Ballistic testing is required on the Comanche prior to fielding. Computer based simulations are being employed in order to reduce requirements for expensive live-fire testing. This thesis uses a computer program called Dytran from MacNeal-Schwendler to simulate the effects of an explosive round detonating in the Comanche tailfan shroud. Six test cases involving explosions with varying amounts of explosive energy, or specific internal energy, are evaluated. From these tests, a curve showing the percentage of structural failure versus the specific internal energy is plotted. Assuming that 20% structural failure of the model equates to a catastrophic failure, this analysis shows that the analyzed section of the Comanche tailfan shroud can withstand an explosion with a specific internal energy of 2.58 * 1010 in2/sec2. Any potential threat rounds with specific internal energies greater than 2.58 * 1010 in2/sec2 will pose serious threats to the Comanche.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Comanche, Ballistic Modeling, Dytran, Tailfan Shroud

A COMPUTATIONALLY EFFICIENT ALGORITHM FOR DISTURBANCE CANCELLATION TO MEET THE REQUIREMENTS FOR OPTICAL PAYLOADS IN SATELLITES

Christian Giorgio Roberto Taranti-First Lieutenant, Brazilian Air Force
B.S., Technological Institute of Aeronautics, Brazil, 1994
Doctor of Philosophy in Electrical Engineering-September 2001
Dissertation Supervisors: Roberto Cristi, Department of Electrical and Computer Engineering
Brij N. Agrawal, Department of Aeronautics and Astronautics

Vibration control is a very important issue in satellites. The new high-resolution digital imaging devices are especially sensitive to vibrations. Antennas used in laser communications also require a very quiet environment so that their performance is not degraded. The Stewart platform is capable of isolating an optical payload from the noisy spacecraft bus. Until recently, only passive methods were used in all vibration isolation applications. Recent advances in Digital Signal Processing techniques made the development of vibration control algorithms possible, but these usually require large computational power. This work explores using a computationally efficient vibration-isolation method for optical payloads by using hexapods. The method suppresses the vibration at the assigned frequencies and does not affect unassigned frequencies if the plant is linear.

The mathematical analysis includes convergence analysis and the effect of unassigned frequencies in the output. The computational requirements of the algorithm is evaluated and is compared to the Multiple-Error Least Mean Square. The method is very robust to nonlinearities; its performance is comparable to the Multiple-Error Least Mean Square with a fraction of the computational time and memory requirements. It also requires very little plant knowledge. Theoretical results are verified through simulations using a Single-Input/Single-Output plant and a nonlinear hexapod model. The controller was also experimentally validated in two different hexapods and the performance was found to be similar to or better than the performance obtained with the Multiple-Error Least Mean Square method when a noisy reference signal is used.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Vibration Control, Optical Payloads in Satellites, Disturbance Cancellation

REMOTE NANOSATELLITE FORMATION DESIGNS WITH ORBIT PERTURBATION CORRECTIONS AND ATTITUDE CONTROL/PROPULSION SUBSYSTEM CORRELATION

Stephen D. Tomlin-Lieutenant, United States Navy
B.S., Rensselaer Polytechnic Institute, 1994
Master of Science in Astronautical Engineering-June 2001
Advisor: Brij N. Agrawal, Department of Aeronautics and Astronautics
Second Reader: Alfred N. Sorenson, National Reconnaissance Office/
Aerospace Corporation Chair Professor

The innovative idea of distributing the functionality of current larger satellites among smaller, cooperative satellites has been sincerely considered for assorted space missions to accomplish goals that are not possible or very difficult to do with a single satellite. Additionally, the utilization of smaller satellites is maximized within formations and clusters to conduct missions such as interferometry and earth-sensing. This paper presents a methodology to describe, populate and analyze numerous formation designs employing the use of Hill's equations of motion to describe a formation's dynamics. These equations of motion are then programmed into a MATLAB code to produce Cartesian elements for input into a Satellite Tool Kit((STK) simulation that demonstrates numerous possible cluster formation designs. These simulations are then used to determine ?V requirements for overcoming LEO-type perturbations that were modeled within STK's High Precision Orbit Propagator (HPOP).

Finally, components from two subsystems [Attitude Determination and Control (ADCS) and Propulsion], using the ?V calculations from the simulation analysis and current advances in MicroElectroMechanical systems (MEMs) and nanosatellite technology, are presented based on a mass constraint of 10kg for the entire satellite.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion, Space Vehicles, Modeling and Simulation

KEYWORDS: Satellite Formation, Orbit Dynamics, STK, Nanosatellite, and Satellite Propulsion

ANALYSIS OF TRACKING AND IDENTIFICATION CHARACTERISTICS OF DIVERSE SYSTEMS AND DATA SOURCES FOR SENSOR FUSION

Dean A. Wilson-Lieutenant Commander, United States Navy
B.S.A.E., Virginia Polytechnic and State University, 1990
Master of Science in Aeronautical Engineering-June 2001
Advisors: Russell Duren, Department of Aeronautics and Astronautics
Gary Hutchins, Department of Electrical and Computer Engineering

In the Command and Control mission, new technologies such as 'sensor fusion' are designed to help reduce operator workload and increase situational awareness. This thesis explored the tracking characteristics of diverse sensors and sources of data and their contributions to a fused tactical picture. The fundamental building blocks of any sensor fusion algorithm are the tracking algorithms associated with each of the sensors on the sensor platform. In support of this study, the MATLAB program 'fusim' was written to provide acquisition managers a tool for evaluating tracking and sensor fusion algorithms.

The fusim program gives the user flexibility in selecting: sensor platforms, up to four sensors associated with that platform, the target types, the problem orientation, and the tracking algorithms to be used with the sensors. The fusim program was used to compare tracking algorithms in a multiple sensor/multiple target environment. Specifically, the Probabilistic Data Association Filter, the Interacting Multiple Models Filter, the Kalman Filter and the Constant Gain Kalman Filter were evaluated against multiple maneuvering, non-maneuvering, and fixed targets. It is recommended that this study be continued to evaluate advanced tracking and data association techniques, to expand the program to allow attribute tracking and identification, and to study the Human-Machine Interface aspects of sensor fusion.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors, Command Control and Communications, Computing and Software

KEYWORDS: Data Fusion, Sensor Fusion, Tracking, Tracking Algorithms, Kalman Filter, Probabilistic Data Association, PDA, Interacting Multiple Models, IMM, Simulation

ANALYSIS OF A MAGNETIC THREE-AXIS STABILIZED ATTITUDE CONTROL SYSTEM FOR THE NPSAT1 SPACECRAFT

Todd A. Zirkle-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994
Master of Science in Space Systems Operations-September 2001
Advisor: Michael Spencer, Department of Aeronautics and Astronautics
Second Reader: Barry Leonard, Department of Aeronautics and Astronautics

The NPSAT1 satellite uses an active magnetic torque rod system, with a magnetometer for attitude determination, to maintain 3-axis stabilization, with a slightly gravity gradient friendly structure.

This thesis will examine the performance of three combinations of programs and simulation models for the NPSAT1 satellite attitude control system. The models include a magnetic control law with a reduced order estimator to generate torque commands to achieve spacecraft nadir pointing and a magnetic rate (Bdot) control law to reduce spacecraft angular rates. The performances of two Bdot mode switching designs are compared. Also, a case is made for the benefits of priming the system's reduced estimator prior to mode switching.

All of the control methods analyzed appear to be valid control methods to achieve three-axis attitude stabilization using only magnetic torquers for active control. The most efficient control method analyzed incorporates a hand-off method from a magnetic rate (Bdot) control loop to a magnetic control loop. The results of this analysis indicates that the best use of this method is to perform the Bdot hand-off following the achievement of a predetermined combined angular rate.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: NPSAT1, Attitude Control System