MASTER OF SCIENCE IN ASTRONAUTICAL ENGINEERING

COMPARATIVE ANALYSIS OF SELECTED RADIATION EFFECTS IN MEDIUM EARTH ORBITS

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Satellite design is well developed for the common Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) and Highly Elliptical Orbits (HEO), i.e., Molniya, cases; Medium Earth Orbit (MEO) satellite design is a relatively new venture. MEO is roughly defined as being altitudes above LEO and below GEO. A primary concern, and a major reason for the delay in exploiting the MEO altitudes, has been the expected radiation environment and corresponding satellite degradation anticipated to occur at MEO altitudes. The presence of the Van Allen belts, a major source of radiation, along with the suitability of GEO and LEO orbits, has conventionally discouraged satellite placement in MEO. As conventional Earth orbits become increasingly crowded, MEO will become further populated.

This thesis investigates the major sources of radiation (geomagnetically trapped particles, solar particle events and galactic cosmic radiation) with respect to specific Naval Research Laboratory (NRL) designated MEO (altitudes between 3,000 nautical miles (nmi) and 9,000 nmi; inclination angle of 15 degrees). The contribution of each of these components to the total radiation experienced in MEO and the effects of the expected radiation on a representative spacecraft are analyzed in comparison to a baseline LEO orbit of 400 nmi and 70 degrees inclination. Dose depth curves are calculated for several configurations, and show that weight gains from necessary expected shielding are not extreme. The radiation effects considered include proton displacement dose and solar cell degradation.

KEYWORDS: Radiation, Medium Earth Orbit, Space

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Battlespace Environments

DESIGN OF AN ATTITUDE DYNAMICS AND CONTROL SUBSYSTEM FOR A MEDIUM EARTH ORBIT SATELLITE

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The Department of Defense has a continuing need for satellite communications to satisfy the demand for information exchange for strategic, operational, and tactical warfighters. There is currently a Deputy Undersecretary of Defense for Space (DUSD (Space)) transition planning effort to develop a satellite communications architecture for the 2007-2010 time frame. During this time all three current satellite systems; UFO, DSCS, and MILSTAR, are expected to degrade rapidly. As part of the DUSD - Space effort the U.S. Navy was tasked to form a Mobile Users Study to establish a framework for completing the detailed requirements and engineering work needed to develop the UHF/Mobile User transition plan. Then,

as part of the Navy effort, the Naval Postgraduate School's Astronautical Engineering class SE-61 under Professor Brij Agrawal's guidance designed a proposed medium Earth orbit communications satellite. This thesis is a design of the Attitude Dynamics and Control Subsystem for the subject medium Earth orbit MUS communications satellite. The thesis describes and explores the five major steps in designing an Attitude, Dynamics, and Control Subsystem. It also focuses on key ADCS related areas that are peculiar to a MEO satellite as compared to a GEO satellite.

KEYWORDS: Attitude Dynamics and Control Subsystem, ADCS, Medium Earth Orbit, MEO, Satellite Design, Spacecraft Design, Communications Satellite

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

A MILITARY UHF COMMUNICATIONS SATELLITE DESIGN FOR THE USER ON THE MOVE

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Initial proposals for commercial PCS at L/S band were based on LEO and MEO satellites; some more recent commercial initiatives have been based on GEO satellites with large deployable antennas to provide low data rate services to handheld units. This thesis addresses the feasibility of a UHF military satellite design capable of providing service to handheld units. More specifically, this thesis focuses on the key payload design aspects and technology considerations required to design a GEO satellite with a large deployable antenna that forms multiple beams, and employs on-board signal processing to demodulate and route signals between beams. Several design excursions based on cutting edge technologies in their final stages of R&D are discussed (e.g., Digital Beam Forming, and Turbo coding) along with their system impacts.

KEYWORDS: Satellite Personal Communications, Communications on the Move, Processing Payload, Digital Beam Forming, Waveform Coding, Spacecraft Design

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

ENVIRONMETAL TESTING OF THE PETITE AMATEUR NAVY SATELLITE (PANSAT)

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Any complex and expensive system requires testing to ensure adequate performance. Communications satellites require extensive testing for two additional reasons: they operate in an environment considerably different from that in which they were built and, after launch, they are inaccessible to routine maintenance and repair. The objectives of testing is not necessarily to duplicate the space environment but to approach it sufficiently so that any spacecraft that passes the tests will operate successfully in its designed space environment. The major features of the space environment that are difficult to simulate exactly are zero gravity, high vacuum, solar radiation, particle radiation and extreme temperatures. This document describes the environmental test program and the test results for the PANSAT program. PANSAT is the acronym for the Petite Amateur Navy Satellite, which is a small communications satellite under development by the Space Systems Aca-

demic Group at the Naval Postgraduate School. PANSAT subsystems were subjected to thermal vacuum and random vibration testing as part of the overall environmental test program. Satellite launch, as a Shuttle secondary payload via the Space Transportation System (STS) Small Self-contained Payload (SSCP) program, is planned for October 1998.

KEYWORDS: Environmental Testing, PANSAT, Spacecraft Testing

DoD KEY TECHNOLOGY AREA: Space Vehicles

A PATCHED-CONIC ANALYSIS FOR OPTIMALLY DEFLECTING EARTH-CROSSING ASTEROIDS

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The threat of collision between an asteroid or a comet and the Earth has been well documented. Mitigation of such a threat can be accomplished by destruction of the threat or by perturbing the threat object into a safe orbit. Following a summary of proposed mitigation techniques, this thesis investigates the impulse required to safely perturb a threatening Earth-Crossing Asteroid (ECA). While previously published analysis included only two-body approximations to the impact geometry, this thesis adds the effect of the Earth's gravitational field to more closely approximate reality. The results indicate that third-body effects are strongest on ECA's in a nearly circular heliocentric orbit, where the minimum required DV can be several times larger than that calculated using two-body approximations. To determine the minimum DV required for mitigation, MATLAB®'s sequential quadratic programming (SQP) algorithm is applied to a constrained optimization problem. Third-body effects were added to a previously published two-body optimization by modifying the boundary conditions. With knowledge of the minimum DV requirements, the capability of current impulsive mitigation technology is analyzed. For asteroids of median density in co-planar orbits, a single 24 Mt nuclear explosive impulse applied earlier than 3 years before impact can effectively mitigate a threat with diameter of 6 km. The capability significantly decreases with shorter warning times.

KEYWORDS: Earth-Crossing Asteroid, Near-Earth Object, NEO Hazard Mitigation, Deflection, Asteroid, Comet, Impact Hazard, Optimum

DoD KEY TECHNOLOGY AREA: Space Vehicles

HYPERSPECTRAL POLARIMETRY FOR SATELLITE REMOTE SENSING

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The study of polarization of reflected light and its angular dependence is well documented. However, most measurements have been panchromatic in nature, i.e., they were taken over a broad wavelength region. A few polarization measurements have examined polarization at several specific narrow wavelength bands. These measurements can be classified as multi-spectral. Thus, previous efforts to characterize an object using polarization have not investigated a hyperspectral polarization signature.

This thesis determines the hyperspectral polarization signature of several common materials that are significant to the military. A range of materials was examined including camouflage fabrics, military paints, rubber, plastic, taggant, and glass. It is shown that a hyperspectral polarization signature, when combined with a hyperspectral reflectance signature may enhance present capabilities to detect, classify, and identify objects of military significance. This technique appears especially promising for dark objects, shiny surfaces, synthetic fabrics, and unpainted metal.

This combined approach could be realized in a hyperspectral polarimetric imaging satellite. The utility of designing such a sensor and many key design considerations are examined. Preliminary analysis suggests sensor designs for low earth and geosynchronous orbiting spacecraft may be feasible. Sensor data rate and signal-to-noise ratio will be the limiting factors in these designs.

KEYWORDS: Hyperspectral Imagery, Polarization, Polarimetry, Satellite Remote Sensing

DoD KEY TECHNOLOGY AREA: Sensors

THERMAL ANALYSIS OF PANSAT

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The thermal control system of a spacecraft is designed to maintain all spacecraft components within their specified operating temperature limits throughout all phases of a spacecraft's mission. In order to verify and aid in such a design process, a thermal analysis of the system must be conducted. A thermal model of the spacecraft is used to simulate its behavior under given thermal environments and boundary conditions so that temperature predictions can be made.

The focus of this thesis is to develop and analyze thermal models of PANSAT which describe its thermal behavior while it is in orbit and also prior to its insertion in its orbit (while it is still in the shuttle). The results of these analyses will serve to help in the thermal design and performance of PANSAT. This thesis completes the thermal model prerequisites of the STS 95 space shuttle mission hitchhiker program for PANSAT. The emphasis of this thesis is to develop a model that will allow the prediction of the temperatures of all the electrical components including the temperature sensitive electrical components of PANSAT such as batteries over a complete orbit of the satellite.

KEYWORDS: Thermal Analysis, Spacecraft Thermal Control

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation