MASTER OF SCIENCE
IN
SPACE SYSTEMS OPERATIONS

PRIMARY SPACE EDUCATION
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The purpose of this thesis is to identify a joint educational track to facilitate the development of a joint military Space Cadre. This thesis includes an analysis of educational courses that currently address the unique needs of each individual service component for space operations education. This thesis will focus on identifying the commonality of educational course material across the services and recommending a joint educational track, which supports the individual needs of each service while still allowing Officers to serve in joint space billets without undue additional education. The establishment of this joint level of education with respect to the needs of each service and the interaction between them, will help balance the critical need to operate in a joint environment and share limited resources.

KEYWORDS: Space Cadre, Space Education, Rumsfeld Commission

MODELING THE PROPULSION INSTRUMENTATION ELECTRONICS SUBSYSTEM FOR SPACECRAFT-ENVIRONMENT INTERACTIONS ON TECHSAT 21
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With the trend towards designing smaller satellites, alternative propulsion systems must be explored. Electric Propulsion is a maturing technology that holds a great deal of promise due to the small propellant mass fraction. This reduction in propellant, compared to bi-propellant systems, increases potential payload mass. Various methods of modeling the contamination effects on satellites from Electric Propulsion are being researched. Ion, Electron, Solar Cell, Photometer and Radiometer sensors will be modeled, tested and integrated on an Air Force Research Lab experimental satellite (TechSat 21). The effects will then be measured through the interactions between the Propulsion Instrumentation Electronics (PIE) interface, the sensors and the spacecraft main controller bus. Simulation and modeling of the sensors will be performed on a laptop using LabVIEW. Using this data, the PIE will then be evaluated by comparing the expected versus actual results. Testing will culminate with an end-to-end test between the PIE, its controller that simulates the spacecraft bus and the sensor simulator laptop. Data acquisition devices will be used to compare the analog currents and voltages to and from the sensors with that from the PIE.

KEYWORDS: Sensor Simulators, Spacecraft-Environment Interactions, TechSat 21

HUMAN DISORIENTATION AS A FACTOR IN SPACECRAFT CENTRIFUGE DESIGN

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Weightlessness is the major contributing factor behind the degradation of bone mass, muscle tone, and aerobic capacity during long-term space missions. With the loss of bone mass progressing at up to two percent per month, long duration and interplanetary missions shall remain the sole duty of robotic explorers until sufficient countermeasures are developed.

Several countermeasures are either in use, or under development to alleviate this problem. Exercise is currently used to reduce the severity of bone loss and muscle atrophy. Exercise has proven ineffective despite the fact two hours of daily exercise together with elaborate apparatus have been devoted to simulating the load of Earth's gravity. Drug therapy and other, more exotic, countermeasures are also under consideration, but the side-effects of these other treatments and the fact that they do not directly address the root cause of the negative effects of weightlessness means that they may only reduce, not cure, those problems. Only artificial gravity addresses the root cause, weightlessness itself.

This thesis addresses the need to balance the effects of Coriolis on human disorientation with the engineering costs of constructing a centrifuge for human occupation in space.

KEYWORDS: Artificial Gravity, Centrifuge Model, Centrifuge Simulator, Human Disorientation, Human Factors, Spacecraft Centrifuge, Vestibular Model, Vestibular Simulator

REMOTELY SENSED DENSITY MEASUREMENTS OF VOLCANIC SULFUR DIOXIDE PLUMES USING A SPECTRAL LONG WAVE INFRARED IMAGER

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This thesis examines the process of detecting and quantifying volcanic SO_2 plumes using the Airborne Hyperspectral Infrared Imager (AHI) developed by the University of Hawaii. AHI was flown over Pu'u'O'o Vent of Kilauea Volcano in Hawaii to collect data on SO_2 plumes. In conjunction with these observations, data were taken with the Hawaii Volcano Observatory's Correlation Spectrometer (COSPEC) and University of Hawaii's FLYSPEC. These are ultraviolet remote sensors with a successful history of monitoring volcanic SO_2 plumes at ~0.3 μ. AHI is a LWIR pushbroom imager sensitive to the 7.5 – 11.5 μ region. Spectral analysis and mapping tools were used to identify and classify the SO_2 plume in both radiance and emissive space. MODTRAN was used to model the radiance observed by the sensor as it looked to the ground through an SO_2 plume. A spectral library of radiance profiles with varying ground surface temperatures and SO_2 concentrations was developed, and the AHI data fitted to the varying model profiles. Reasonable values of SO_2 emission were obtained, though the values directly over the vent obtained by AHI were much higher than those obtained by the UV sensors some distance away.

KEYWORDS: Hypersepctral, Airborne Remote Sensing, Long Wave Infrared (LWIR), Ultraviolet (UV), Sulfur Dioxide, Gas Detection, Volcanic Plumes, Airborne Hyperspectral Infrared Imager (AHI), FLYSPEC

A COMPARATIVE STUDY OF THE PROSPECTIVE SOLAR CELLS FOR NPSAT1

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The Naval Postgraduate School's next satellite to be launched will be the technology demonstration experiment NPSAT1 in 2006. This satellite will be laden with some of the school's top research projects including on orbit solar cell I-V curve testing. The designers of this satellite were presented with three types of solar cells with which to power their satellite: silicon, gallium arsenide, and triple junction cells. This thesis evaluates those three types of cells on the merits of their advertised and tested efficiency, cost, performance, and reaction to radiation experiments. Although the triple junction cells have already been selected to provide solar power to the onboard experiments, the background justification for such cells is warranted.

KEYWORDS: NPSAT1, solar cells, solar simulator, LINAC

A STUDY OF THE VULNERABILITY OF COMMERCIAL IMAGING SATELLITES TO COMMERCIAL LASER TECHNOLOGY (U)

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(U) The focus of this thesis research project has been to determine whether of not current on-orbit commercial imaging satellites (both foreign and domestic) are vulnerable to blinding or degradation by commercially available lasers. Second, upon completion of the vulnerability analysis, the following assessment was conducted. The assessment determined whether or not the necessary hardware, software and satellite ephemeris data (i.e. lasers, mount, telescope, pointing and slewing software etc.) were readily available without restrictions via purchase or other means. Finally, the likelihood of fielding this type of offensive space control system was closely coupled to development and operational costs. The final research question was to determine if an offensive space control system could be developed and fielded for under five hundred thousand dollars.

(U) The calculations, experimental methods, findings and recommendations can be found in the classified thesis document.

KEYWORDS: Commercial Imaging, Laser, Charge-Coupled Devices, Space Control, Satellite Vulnerabilities, Offensive Counterspace

ANALYSIS OF THE AERODYNAMIC ORBITAL TRANSFER CAPABILITIES OF A WINGED RE-ENTRY VEHICLE

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The ability to perform an inclination change maximizes the maneuverability of an orbiting space vehicle. Most maneuvers utilize a combined plane change and orbital transfer to the new orbit. This costs more in terms of energy and fuel than an in-plane change of orbits. The amount of ΔV and fuel required for such an energy-intensive inclination change exceeds the benefit of performing the maneuver. However, this paper demonstrates that a winged re-entry vehicle, based on the currently proposed X-37, has the necessary thrust to change planes and then perform an in-plane transfer to achieve a new orbit. Using SIMULINK™ and LABVIEW™ simulation tools, this research found that the use of the aerodynamic lift of a winged re-entry vehicle produced more than 12° of inclination change with the minimal ΔV achievable. Through small orbital maneuvers and atmospheric re-entry, the aerodynamics of the lift vector demonstrated that the spacecraft retained sufficient energy to prevent perigee collapse using an orbital regulation code to control throttle setting.

KEYWORDS: Winged Re-entry Vehicle**,** Orbital Mechanics, Orbital Transfer, Perigee Collapse, Orbital Regulator, Aerodynamic Forces, Fuel Optimal, Inclination Change

TIMELINES REQUIREMENTS FOR SAM AND CRUISE MISSILE LAUNCH SIGNATURE CUED THREAT WARNING (U)

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(U) Launch detection cued threat warning offers the possibility of increased situational awareness for U.S. aircraft and warships that routinely operate in missile threat envelops. Evolving SAM and ASCM tactics and technologies may minimize the effectiveness of traditional tactical threat warning systems. Current launch detection warning systems were designed for strategic warning. As such, their designed response time was less than the missile time of flight of a strategic threat system. If launch detection systems are to be designed to support tactical systems, their design response time must similarly work within the missile time of flight of tactical threat systems. Current requirements studies define this timeline as "real time" or "near real time." The purpose of this paper is to more exactly define what these terms mean in selected SAM threat and ASCM threat scenarios. These values can then serve as the basis of timeliness reporting requirements for any system that will use launch detection cued threat warning in support of tactical platforms.

KEYWORDS: SAM, ASCM, SAM Threat Warning, ASCM Threat Warning, Missile Warning

FEASIBILITY OF SCRAMJET TECHNOLOGY FOR AN INTERMEDIATE PROPULSIVE STAGE OF AN EXPENDABLE LAUNCH VEHICLE

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The single largest contributor to the cost of putting objects into space is that of the launch portion. The currently available chemical rockets are only capable of specific impulse (I_{sp}) values on the average of 300-350 seconds, with a maximum of 450 seconds. In order to improve the performance of the current families of launch vehicles, it is necessary to increase the performance of the rocket motors, and conversely the amount of propellant/oxidizer carried.

The purpose of this thesis was to determine the feasibility of employing SCRAMJET technology for an intermediate propulsive stage of an expendable launch vehicle. This was motivated by the fact that SCRAMJETS offer a very high propulsive efficiency when compared to conventional chemical rockets. The incorporation of a SCRAMJET engine into the configuration "stack" of an expendable launch vehicle, offers the promise of increased payload mass fraction or an increase in the number of attainable orbital profiles. Analytical tools were developed using open-source software to identify launch trajectories for the SCRAMJET-enabled rocket configurations, and to determine how these would differ from conventional launch profiles. The effects of incremental increases in configuration lift and drag coefficients due to the SCRAMJET stage was analyzed. It was determined that incorporation of SCRAMJET Technology into an expendable rocket configuration offered marked improvement in performance, reduction in total launch weight, and increase operational flexibility when compared to a similarly sized conventional chemical rocket.

KEYWORDS: Launch Vehicle, SCRAMJET, Pressure Gradient, Launch Profile, Launch Trajectory, Lift, Drag, Efficiency, Intermediate Stage Propulsion, Axis-Symmetric

OVERVIEW AND VULNERABILITY OF RADIO DETERMINATION SATELLITE SERVICE (RDSS) SYSTEMS (U)

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(U)Radio Determination Satellite Service (RDSS) is a system that provides geolocation via radio determination using two or more spacecraft in geosynchronous orbit. Developed in the early 1980s the GEOSTAR System for providing RDSS was to supply this capability, as well as two-way packet messaging, on a national or continental-wide basis. However, with the cancellation of Selective Availability for GPS Standard Positioning Service users, the potential competition from Iridium, and the ubiquity of cellular service GEOSTAR as a commercial entity became defunct, filing for bankruptcy in 1990. Nevertheless, the GEOSTAR concept and its technology still remain viable options for countries and organizations that do not wish to rely on GPS or GLONASS. Military and commercial entities have begun using GEOSTAR RDSS-like systems on a progressively larger scale. With the emergence of increased foreign interest in RDSS and the GEOSTAR architecture, the need to understand and determine vulnerabilities and insecurities of this technology, and the opportunities this presents, are paramount to the continued success of intelligence operations.

KEYWORDS: Radio Determination Satellite Service, GEOSTAR, TWINSTAR, Beidou, Navigational Satellites, Blue Force Tracking, Smart Transport, Asset Tracking

A COMPARATIVE ANALYSIS OF RADIATION EFFECTS ON SILICON, GALLIUM ARSENIDE AND GAINP$_2$/GAAS/GE TRIPLE JUNCTION SOLAR CELLS USING A 30 MEV ELECTRON LINEAR ACCELERATOR

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Many improvements have been made in the design and manufacture of high efficiency solar cells. The need to understand the behavior of these new types of solar cells is crucial to the procurement of future space systems, both commercial and military. This thesis studies the results of irradiating three commonly used solar cells with 30 MeV electrons using the Naval Postgraduate School Linear Accelerator. A comparison of the performance characteristics of the three cells is made using commonly accepted parameters and notes the differences in trends and failure modes. Additionally, the affect of current annealing is investigated.

KEYWORDS: Solar Cells, Silicon, Gallium Arsenide, Multi-Junction, Triple-Junction, Radiation Effects, Annealing