

MASTER OF SCIENCE IN SPACE SYSTEMS OPERATIONS

RADIANT GOLD: AN ALTERNATIVE CUEING ARCHITECTURE FOR NAVAL THEATER BALLISTIC MISSILE DEFENSE PROGRAMS

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The Theater Ballistic Missile Defense (TBMD) problem is complex and dynamic, requiring the use of space-based sensor system information to enhance mission success. The central purpose of this thesis is to examine the potential of the cueing architecture that results from using a Navy Tactical Exploitation of National Capabilities (TENCAP) sponsored research and development program's concept, termed RADIANT GOLD. The program delivers JTAGS processed data derived from national sensor systems to an AEGIS ship. To this end, this project had three goals. First, model and simulate the cueing architecture under varying degrees of complexity and exploring a diverse set of data dissemination methodologies. Secondly, to examine data derived from a demonstration of the RADIANT GOLD architecture in a recent Fleet Battle Experiment and compare the performance of the architecture to simulation. Lastly, to provide a subjective analysis of RADIANT GOLD and other architectures.

The results from the research indicate that an Extremely High Frequency (EHF) satellite communications network is a suitable method to deliver time critical TBM data. Additionally, the Global Broadcast Service network is an appropriate alternative to EHF. Research also suggests that the RADIANT GOLD architecture is suitable to support the entire spectrum of TBMD operations.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Command, Control, and Communications, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Theater Ballistic Missile Defense, Cueing, Defense Support Program, Theater Event System, Joint Tactical Ground Station, Aegis Weapon System, Navy Area Defense, Navy Theater Wide Defense Modeling and Simulation, Fleet Battle Experiment, Global Broadcast Service, Extremely High Frequency Satellite Communications

FEASIBILITY STUDY ON THE UTILIZATION OF SATELLITE INFRARED IMAGERY IN THE DETECTION OF SUBMARINE GENERATED SIGNALS

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Anti-submarine warfare is an area that has grown in complexity over the past decade. There has been growing interest in submarine capabilities as well as increased investments in submarine technologies exhibited by potentially adversarial nations. It is evident that the U.S. must continue to develop its ASW

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surveillance capabilities if it is to keep pace with the emerging submarine threat. Acoustic sensors have historically been the primary means of detecting, localizing and tracking submarines. With ASW operations shifting to acoustically challenging littoral regions and submarines becoming much quieter, it is evident that non-acoustic sensors need to be developed to complement acoustic sensors. Submarine motions both below and above the ocean surface create disturbances that can be detected in the infrared spectrum. This thesis examines the feasibility in exploiting these IR signatures by looking at factors surrounding the satellite, the submarine and the ocean environment. It makes assessments in the detectability of these IR signatures and further assesses the tactical significance of this type of data. The primary objective of this thesis is to determine if the utilization of satellite IR sensors as ASW detectability assets will contribute to the development of the overall tactical ASW picture.

DoD KEY TECHNOLOGY AREA: Space Vehicles, Sensors

KEYWORDS: Non-Acoustic, Anti-Submarine Warfare, Satellite, Submarine

**THE WARFIGHTERS' COUNTERSPACE THREAT ANALYSIS (WCTA): A FRAMEWORK
FOR EVALUATING COUNTERSPACE THREATS**

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The authors present an evolutionary approach to evaluating the counterspace threat in support of Department of Defense (DoD) decisionmakers. The goal is to present a process that decisionmakers can readily utilize to accurately assess the level of the counterspace threat originating within their Area of Responsibility (AOR). It is particularly useful as the state of affairs change within the AOR. The authors examine the necessity to utilize space to achieve information dominance, strengths and weaknesses of present Counterspace Threat Models, DoD's increasing dependence on space assets, DoD's reliance on commercial space systems to meet future requirements, and potential adversaries' awareness of the dependence of U.S. forces on space systems.

Conclusions stress that the threat is comprised of two essential elements an opponent's willingness to employ a counterspace tactic (their intent) and the opponent's ability to develop the necessary tools to employ a counterspace tactic (their capability). The authors believe that the "*intent*" component of the threat changes more rapidly than the present models can easily accommodate. Therefore, a process, such as the one presented in this thesis, will enable DoD decisionmakers that experience many of the changes of "*intent*" first hand to rapidly and accurately assess the threat as the condition changes within the AOR.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Battlespace Environments, Command, Control and Communications, Electronic Warfare, Directed Energy Weapons, Modeling and Simulation

KEYWORDS: Counterspace Threats, Counterspace Threat Assessment, Counterspace Threat Assessment Framework

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THE IMPACT OF THE INTEGRATED BROADCAST SERVICE (IBS) ON THE FORCE OVER-THE-HORIZON TRACK COORDINATOR (FOTC) PROCEDURES

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The Integrated Broadcast Service (IBS) will provide parallel dissemination of over-the-horizon tracking data to DDG, CG, and CV, possibly resulting in conflicting Common Tactical Pictures. What will be the impact of IBS on U.S. Navy Force Over-The-Horizon Track Coordinator (FOTC) procedures? Specifically, how will IBS change how Battle Group (BG) Commanders conduct FOTC operations and what recommended changes should we consider in doctrine, tactics, techniques, and procedures; i.e., Naval Warfare Publication (NWP), and Operational Tasking Message (OPTASKS)? Should the FOTC direct all platforms in the BG, other than the FOTC, to filter all but Theater Ballistic Missile (TBM) data and force everyone to continue to rely on FOTC broadcast for the tactical picture? Should the FOTC allow and encourage each ship to develop their own picture using their direct near real-time access to over the horizon data? These questions must be answered to ensure successful integration, training, and maintainability of warfighting capabilities with the intelligence and information provided by the IBS to the U.S. Navy's combat platforms. The purpose of this thesis is to provide an overview of the IBS and FOTC, address these concerns, and provide a possible course of action.

DoD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Integrated Broadcast Service (IBS), Force Over-The-Horizon Track Coordinator (FOTC), Command and Control Warfare (C2W), Command, Control, Communications, Computers and Intelligence (C4I), Over-The-Horizon-Targeting (OTH-T)

APPLICATIONS OF THERMAL HYPERSPECTRAL IMAGERY FOR SPECIFIC MATERIAL IDENTIFICATION

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Thermal infrared spectral imagery provides the opportunity to perform material identification on targets. The Aerospace Corporation's SEBASS High Altitude Research Project (SHARP) collects thermal imagery data in both midwave infrared (MWIR) and longwave infrared (LWIR) regions of the electromagnetic spectrum. This thesis explored the ability to perform specific material identification of targets from SHARP acquired LWIR data from the DESERT RADIANCE III exercise conducted in Yuma, Arizona in February 1999. Data were atmospherically compensated using both an in-scene method (ISAC) and an empirical line method (ELM). The ELM was needed due to the lack of in-scene blackbodies, which limited the performance of ISAC. After calibration, an inverse minimum noise fraction rotation was used to correct a noticeable calibration error in the data. Alpha residual and emissivity normalization methods were used to separate emissivity from temperature. Both alpha residual and emissive data sets were analyzed using the spectral angle mapper algorithm. Spectral angle results were poor for alpha residuals, therefore only the emissive data was further examined using the spectral matched filter algorithm and the K-Means classification method. Only results from the spectral matched filter demonstrated an ability to positively identify materials based on specific thermal emissivity.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Remote Sensing, Hyperspectral, Thermal Imagery, Specific Material Identification, SHARP, DESERT RADIANCE III, Spectral Imagery

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GLOBALSTAR: A NATIONAL SECURITY PERSPECTIVE

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It is expected that LEO-based satellite mobile telephony will thrive in the global marketplace of the 21st century. There are large portions of the world that could reap significant benefit from a satellite communication system such as the GLOBALSTAR. The worldwide communication services of the GLOBALSTAR provide a means to enhance the command and control capabilities of government and military leadership throughout the world. The application of the GLOBALSTAR to U.S. National Security issues deals with the impact of satellite mobile telephony upon the communication structure of U.S. National and foreign entities. Analysis of the GLOBALSTAR and its impact to U.S. National Security provide insight into what modifications need to be implemented to the existing Command, Control, Computers, Communications, Surveillance and Reconnaissance (C4ISR) Systems of the United States to accommodate emerging technologies that have the potential to revolutionize the way the world communicates.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Sensors, Space Vehicles

KEYWORDS: Satellite Mobile Telephony, Satellite Communications

VULNERABILITY AND IMPACT ANALYSIS OF RADIO FREQUENCY INTERFERENCE ON MILITARY ULTRA HIGH FREQUENCY SATELLITE COMMUNICATIONS

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As the U.S. military focuses more attention on information warfare and obtaining knowledge superiority on the battlefield, communications capabilities are becoming a critical element to military readiness. Ultra High Frequency Satellite Communications (UHF SATCOM) provides the military with unique capabilities that communication systems operating in other spectrum bands cannot. UHF SATCOM is the primary means of interoperability with Allies. Not only are these systems inexpensive and light enough to be man-portable but they can also operate through weather and foliage. Unfortunately, UHF SATCOM systems are extremely susceptible to radio frequency interference (RFI). The military's vulnerability to UHF SATCOM RFI is caused by technical, regulatory and operational factors.

This vulnerability manifests itself in terms of impact of RFI on UHF SATCOM and corresponding degradation of military operations. RFI is responsible for an approximately 25% decrease in UHF channel availability. Consequently, users often experience intermittent or complete circuit outages. Unfortunately, there is a severe deficiency in the services' ability to identify, geolocate and resolve RFI sources. When the factors and operational costs are analyzed together and reviewed as a whole, the vulnerability of our military's UHF SATCOM to RFI cannot be underestimated. This thesis provides recommendations for mitigating the military's vulnerability, eliminating deficiencies in resolution capability, thereby decreasing the impact of RFI on military readiness.

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

KEYWORDS: Military Satellite Communications, Radio Frequency Interference, Ultra High Frequency Communications

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SPACE-BASED COMPUTER NETWORK OPERATIONS (CNO)

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This abstract is classified.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software

KEYWORDS: Internet, Satellite Operations, Computer Network Operations, Space-based Computer Network Operations

TARGET DETECTION AND SCENE CLASSIFICATION WITH VNIR/SWIR

SPECTRAL IMAGERY

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Spectral imagery provides a new resource in remote sensing, which can be used for defeating camouflage, concealment and detection, as well as terrain categorization. A new sensor, the Night Vision Imaging Spectrometer (NVIS), provides VNIR/SWIR (0.4-2.5 μ m) spectra, which are used to study such applications. NVIS has a nominal GSD of 0.5-1.5 meters in operational modes utilized for this work, which make the data well suited for studying mapping and classification algorithms. Data taken at Ft. A.P. Hill on April 29, 2000 are studied here.

A Principal Components Transformation was performed on the NVIS data. From this new data set, target spectra were collected for use in classification algorithms. The NVIS data was converted from radiance to reflectance in two different ways: Empirical Line Method and Internal Average Relative Reflectance. Using this data, various standard algorithms were performed. It was found that while none of the algorithms correctly classified all of the selected targets, the Mahalanobis Distance and Mixture Tuned Matched FilterTM algorithms were the most successful.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Sensors

KEYWORDS: Hyperspectral, NVIS, Remote Sensing, Imagery, Electro-Optical Sensing

MANUAL DIFFERENTIAL CORRECTION (MANDC)

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This thesis is a partial analysis of the Naval Space Command Manual Differential Correction (MANDC) software program. Through a process called Differential Correction, data collected from space surveillance radar observation stations is synthesized with previously composed element sets to maintain accurate orbital object position information. The Automatic Differential Correction (AUTODC) software program is central to this process. Unfortunately, AUTODC fails to converge 1.5% of the time. These failed observations are forwarded to MANDC for lengthy manual manipulation by the watchfloor operators. This thesis will provide an analysis of the MANDC program.

DoD KEY TECHNOLOGY AREA: Computing and Software

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KEYWORDS: Nonlinear Least Squares, Differential Correction

TRANSITIONING TO THE UNIFIED CRYPTOLOGIC ARCHITECTURE

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The National Security Agency/Central Security Service (NSA/CSS) is the nation's center for excellence for signals intelligence (SIGINT) and information assurance products and services. To sustain the nation's SIGINT capabilities, the NSA/CSS has begun a period of rapid change that will transform the way it performs the SIGINT mission to cope with the exploding information technology of today and tomorrow. One of the documents that chart the course for the NSA/CSS is the Unified Cryptologic Architecture. This thesis investigates both the systems engineering approach used in the Unified Cryptologic Architecture and the documents that detail the NSA/CSS transformation in order to postulate recommendations to support the transformation process.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Cryptologic Architecture, Business Plan, Signals Intelligence, Access Providers, Technology Forecast

REVISED TOMAHAWK PLANNING IN AN ANTI-GPS ELECTRONIC WARFARE ENVIRONMENT

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This study reviews the manner in which the Tomahawk Land Attack Missile (TLAM) Block III utilizes the Global Positioning System (GPS) to navigate and includes threats that may be employed to thwart GPS and consequently TLAM. The study incorporates current TLAM tactics to counter jamming and interference in an electronic warfare environment and utilizes the GPS Interference and Navigation Tool (GIANT) to create and analyze two scenarios with varied terrain features. The results of the scenarios culminate with a planner thought process for revised planning in an anti-GPS Electronic Warfare (EW) environment.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation

KEYWORDS: Tomahawk, Mission Planning, Global Positioning System, Electronic Warfare

A SURVEY AND ANALYSIS OF GEOLOCATION PROCESSORS

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Geolocation of electromagnetic emitters is a processing intensive endeavor. Numerous signal data processing systems have been developed to accomplish this difficult task. These systems utilize different hardware configurations, software tools, and processing algorithms, with each system possessing varying capabilities and limitations. Many current programs and projects require the employment of these processing suites, necessitating the selection and possible modification of the most suitable system. This

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thesis document provides a survey and analysis of the currently available signal processing systems and discusses in depth the associated deployment, hardware, software, algorithm and development issues. The analysis provides a unique resource, heretofore lacking, for interested parties to utilize when tasked with the selection of a processing system that will meet their mission specific requirements.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Geolocation, Signal Processing

NON-IMAGING DETECTION AND TRACKING OF MOBILE TARGETS

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In August, 1999, observations with a non-imaging satellite revealed an aircraft (not in afterburner) flying over the ocean. Although this initial detection was made quite by chance, a specialized sensor configuration was devised, and several additional aircraft observations were performed. The precise parameters required for such remote detection are still unclear due to the processing and analysis limitations of current system algorithms. Nevertheless, the successful collections made thus far do provide valuable insight into the phenomenon behind these observations. Furthermore, they point to specific hardware and software shortcomings which may be improved in the near future. This thesis includes a full explanation of the sensor and processing systems, a compilation of accomplished collections, and a thorough analysis of data. It explains the current status of this emerging capability and identifies the steps that are necessary to make remote aircraft detection and tracking into a tactical tool in the future.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors

KEYWORDS: Aircraft Detection and Tracking, Space Sensors

INTEGRATION OF MARITIME SHIPPING TECHNICAL DATA INTO A COMMON DATABASE FOR USE IN A GRAPHICAL DISPLAY

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Maritime Situational Awareness has been an important part of the overall shipping picture since the beginning of high seas exploration. Both military and civilian professionals have desired the knowledge of what ships are in their vicinity and what ships will be in their vicinity in the near and distant future. A common database will enhance the integration of multiple data sources into an accurate display of past, present, and future shipping tracks. In the past, shipping professionals relied on one or two sources to provide them with a picture of the maritime situation. Advancing technologies of the present and future allow and will allow for an increased number of data options to assist in providing a display of the shipping picture. This thesis will describe the generation, integration, and correlation of multiple sources of maritime shipping data into a common database. Examples presented show the application of the database and the display to the ship-tracking problem.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors

KEYWORDS: Maritime Situational Awareness, Database, Graphical Display

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A STUDY OF THE FEASIBILITY AND APPLICABILITY OF SHAPE CONTROLLED SPACE BASED INFLATABLE MEMBRANE STRUCTURES

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Inflatable structures used for space applications offer mass, volume, and cost savings to spacecraft programs, allowing larger space structures to be built. For certain space applications, there are advantages to using large structures. For example, antennas achieve higher gains when they are increased in size. Higher gains equate to higher data throughputs. Therefore, inflatable structures offer improvements in performance to certain types of spacecraft components.

Environmental factors induce surface errors on large inflatable structures. This degrades performance, especially for inflatable antennas. To reduce this degradation, active and passive control systems can be used to sense errors and control the shape of the antenna. One method of applying an active and passive control system is by using piezoelectric films that are either attached to or are part of the inflatable structure.

The research performed for this thesis explored the theoretical performance of a large inflatable space-based antenna via spreadsheet analysis and the physical performance of a piezoelectric film via laboratory experimentation. For the laboratory experiment, the film was attached to a drum and varying internal pressures and voltages were applied. Also, in order to validate the experimental results, an analytical model was created using MSC/PATRAN and MSC/NASTRAN software.

DoD KEY TECHNOLOGY AREA: Other (Communications)

KEYWORDS: Piezoelectric Film, Inflatable Structure, Antennas, Communications, Satellite Development

THE ROLES AND REQUIRED CAPABILITIES OF FUTURE NATIONAL SIGINT SYSTEMS

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National systems provide critical signals intelligence (SIGINT) support to both military commanders and national-level decisionmakers during peacetime, wartime, and contingency operations. This thesis explores how changes in the global technological environment are necessitating changes in the roles and required collection capabilities of future national SIGINT systems. It is imperative that future national SIGINT systems be tailored to the future signals environment, and be developed in the context of the overall SIGINT effort of multiple access providers detailed in the *Unified Cryptologic Architecture*. This thesis provides an estimate of the future SIGINT environment from a technological point of view, analyzes the roles that should be assigned to national systems, and develops collection-related requirements for the future national SIGINT architecture. Furthermore, this thesis briefly describes currently projected national SIGINT systems, focusing on collection-related shortcomings relative to future requirements. Finally, a brief outline is provided of possible evolutionary changes that have the potential to meet the future SIGINT collection requirements.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Other (Intelligence)

KEYWORDS: Signals Intelligence, Electronic Intelligence, Collection Requirements, Access Providers, Technology Forecast, National Systems