



Calhoun: The NPS Institutional Archive

Administrative Publications

Annual Reports

2014-11-10

2014 Annual Report

Monterey, California; Naval Postgraduate School

<http://hdl.handle.net/10945/48149>



Calhoun is a project of the Dudley Knox Library at NPS, furthering the precepts and goals of open government and government transparency. All information contained herein has been approved for release by the NPS Public Affairs Officer.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

<http://www.nps.edu/library>

2014 ANNUAL REPORT

10 NOVEMBER 2014



NAVAL RESEARCH PROGRAM
NAVAL POSTGRADUATE SCHOOL

The information within this report is unlimited distribution, and has been prepared by:

Naval Postgraduate School
Naval Research Program
Research & Sponsored Programs Office
699 Dyer Road, Bldg 234
Monterey, CA 93943
NPS_NRP_POC@nps.edu

Provided by:

President, NPS: Ronald Route, VADM (USN), (Ret)

Provost, NPS: Dr. Doug Hensler

Dean of Research, NPS: Dr. Jeffrey Paduan

NPS NRP Program Manager: Rodman Abbott, CAPT, USNR (Ret.)

NPS NRP Deputy Program manager: Lt Col Mark Raffetto

NPS NRP National Capital Region Representative: Robert Osterhoudt, CAPT, USN (Ret.)

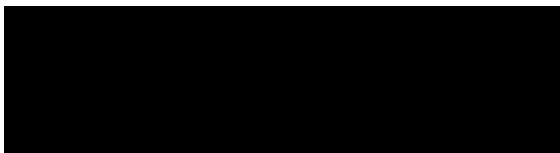
Message From the Dean of Research

The Research and Sponsored Programs Office is pleased to support the Naval Research Program (NRP) in the first complete fiscal year of the program. The NRP was championed by former Program Manager, Dr. Alejandro Hernandez. Through his management, the program has strategically embedded itself as a cornerstone of the mission of the Naval Postgraduate School (NPS), conducting research that “increase[s] the combat effectiveness of commissioned officers of the Naval Service to enhance the security of the United States...[which] supports the needs of Navy and Department of Defense while building the intellectual capital of Naval Postgraduate School faculty.” Results of the research sponsored within FY14 have already made significant contributions in the Department of the Navy (DON), providing input to key operational decision-makers and in areas that support cost savings in a fiscally constrained environment. Secretary of the Navy (SECNAV)-funded research “support[s] the Navy in reaching well-informed, objective decisions on strategic, operational, and programmatic issues through collaborative research.”

This report highlights salient features and activities across the spectrum of NPS research activities conducted on behalf of both Navy and Marine Corps topic sponsors during the 2014 fiscal year. Each of the 90 research projects’ executive summary included herein outlines key results. While most of the summaries detail final results, some projects have multi-year project lengths and, therefore, progress to date is reported.

The NRP is one critical component of the NPS research portfolio. Under the stewardship of the NPS president, it utilizes direct funding to assist the naval community while also informing NPS students and faculty about the latest operational questions. Looking forward to FY15, the program management will be under the direction of Mr. Rodman Abbott. His leadership will build upon the program foundation that has been laid down in FY14. My hope is that the naval communities will join with me in the continued support and contribution of the Naval Research Program.

Sincerely,



Dr. Jeffrey Paduan

NPS Dean of Research

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

Message From the Dean of Research	i
Naval Research Program Overview	1
Background	1
Organization	1
Mission and Goals	2
Program Administration	3
Accomplishments	3
FY14 Research Highlights	4
Navy	4
Marine Corps	5
N1: Personnel	7
Make Goal: A Training System for Naval Recruiting District Leaders	7
International Navies' Policies for Women Faculty	7
Assessing the Potential of Virtual Worlds for Navy Training and Education NPS	9
Individual Reservist Affiliation Motivators and Objections	12
Navy Recruit Attrition Prediction Modeling	12
NETC Acquisition Planning Framework for Managing Training Delivery Requirements	13
Limitations of IA and IT Security Policies in Naval Learning	14
XAPI and HTML5 in Naval Learning	15
Evaluating the Financial Effectiveness of Marketing and Advertising on Recruiting Outcomes	16
Future Navy Recruiting Strategies: Development of the Concepts, Practices, Processes and Procedures to Recruit Generations Z and Alpha	17
Developing Cost Effective Distributed Learning Strategies for Educating Naval Officers	18
Integrating Men and Women Within Naval Special Warfare Teams	20
Effects and Return on Investment for Regional Training Pilot	21
Improved Forecasting Methods for Naval Manpower Studies	21
Developing a Market-Based Compensation System	23
Utilizing Non-Cognitive Measure for Navy Selection, Classification and Duty Assignments	24

Who Uses Tuition Assistance? Variations in Tuition Assistance Use Due to Demographic Characteristics and Job Requirements.....	25
Women in the Navy: What is the Correct Staffing Level to Maximize Retention?.....	25
Littoral Watch Bill Innovations.....	27
Informing Shipboard Readiness Metrics to Include Physical and Cognitive Fatigue Estimates	29
21st Century Retention Challenges for The Navy: Generational Changes, Attitudinal Effects, and Their Impact on Operations	30
SAPR Best Practices, Fleet Communication Strategy, and SAPR Website Analysis.....	31
The Performance of Hispanics in the Military: A Look Across Services and Into the Civilian Labor Market	35
N2/N6: Information Dominance	37
Establishing and Maintaining Semantic Interoperability Under Denied, Disconnected, Intermittent and Limited Telecommunications Conditions	37
Data Compression/Transfer Afloat Using Efficient XML Interchange (EXI) Standards.....	38
Naval Tactical Cloud Data Science and Analytics for Leveraging Meteorological and Oceanographic Tactical Data	39
Cyber Threat Detection and Cyber Hunting	40
Support to Fleet Experimentation.....	41
Using UAS to Sense the Physical Environment and Predict Electromagnetic System Performance.....	43
Underwater Experimentation Arena for Development Testing and Evaluation of Autonomous Capabilities	45
Developing Cyber Skills in Information Dominance Corps Officers	45
A Secure Lifecycle Framework for Shipboard Machinery Control System Development	46
Lifecycle Methodology for System of Systems Capability and Integration Analysis.....	52
Sea Cyber Test Range for Assured C2 Networks and Systems	53
3D Simulation Database for NPS C4ISR Research and OPNAV Capability Analysis	55
Planning for Climate Change	56
Methods of Finding Malicious Files by Cross-Drive Forensic Comparison of Times	58
Mobile User Objective System Applications In Support of the Tactical Warfighter	59
Mobility and Cloud: Operating in Intermittent, Austere Network Conditions	63
Improving Data Fusion Beyond DCGS-N INC 2	64
Bridging the Naval Postgraduate School and Naval Oceanography to Accelerate Warfighter Capabilities.....	66

N3/N5: Plans & Strategy	69
Exploring North Atlantic Treaty Organization—China Military Collaboration.....	69
Chinese Naval Expansion into the Indian Ocean.....	70
Strategic Engagement With Tier One Countries: Track II Strategic Dialogue	71
Regional Stability Models and Civil Affairs in the Maritime Domain	72
Strategy and Innovation Cycle.....	73
N4: Material Readiness & Logistics	75
Optimal Operating Policies for Hybrid Wind/Fossil Fuel Energy Systems	75
Reduction of Aviation Fuel Consumption Through Slot Management	75
Accelerating Navy Energy Culture Change	77
Alternative Fuel Usage Practices.....	77
Developing a New Paradigm for High Energy Density Capacitive Energy Storage.....	78
N8: Integration of Capabilities & Resources	81
Capability Modeling and Assessment for Offensive Swarm Unmanned Aerial Systems.....	81
Developing Synthetic Theater Operations Research Model Analytic Utility.....	82
Unmanned Surface Vessels Anti-Submarine Warfare Employment.....	84
N9: Warfare Systems	87
Optimized Naval Aircraft Capital Investment Planning	87
Enhancing Medical Capabilities for Disaggregated Operations	89
Radar Technology Study.....	90
FA-XX Long-Term Cost and Technology Risk	91
ASN (RDA): Research, Development, & Acquisition.....	93
Modernizing Test and Evaluation Procedures to Support Navy Open Architecture.....	93
3D Modeling and Visualization of Allied Special Weapons Handling Site.....	94
High Energy Laser Weapon Physics-Based Analysis for Naval Platforms	98
Department of the Navy Online Fraud Protection Riding on an Integrated Business Intelligence Foundation.....	99
High Energy Laser Employment in Self Defense Tactics on Naval Platforms.....	100
United States Marine Corps.....	103
United States-Mexico Security Development Partnership Project.....	103
Enabling Marine Aviation Digital Interoperability	103
United States Marine Corps Distribution in the Battlespace	104
Mobile Ad-hoc Network Node Monitor	105

Leveraging Mobile Ad-hoc Network and Mobile Devices in Ship-to-Objective Maneuver and Expeditionary Marine Air-Ground Task Force Operations	106
Expeditionary Unified Marine Corps Enterprise Network Information Technology Service Architecture	108
Big Data: A Low Cost Alternative to Data Warehousing	109
Analysis of Marine Corps Renewable Energy Planning to Meet Installation Energy Security Requirements	110
Efficient Intelligence Processing from Large Networks.....	112
Quantifying the Human Domain and Operationalizing Social Network Analysis Targeting.....	112
A Cost Analysis for Life Cycle Preventative Maintenance, Administrative Storage and Conditions-Based Maintenance for the U.S. Marine Corps Medium Tactical Vehicle Replacement.....	115
High Power Microwave Weapon Identification System.....	115
Mid-Wave Infrared Signaling Tool for Enhanced Targeting Safety and Situational Awareness.....	117
Multidisciplinary Studies Support for the U.S. Marine Forces Reserve.....	120
Readiness and System Cost Trade-Off and Management Tool	124
Evaluating the Oracle Platform as a Decision Support Platform.....	125
What Are The Optimal Maintenance Intervals for Preventative Maintenance Checks on Marine Corps Equipment?.....	126
U.S. Marine Corps Logistics Force Structure and the Pacific Pivot	127
Plant Utilization at Marine Corps Logistics Command	131
Over the Air Light Communication	133
Trusted Hand-Held	135
Leveraging Commercial Off-the-Shelf/Government Off-the-Shelf to Extend Wireless Voice and Data Throughout Amphibious Ready Group Vessels, Particularly Within Well-Decks	136
Handheld Devices for Rapid Request Generation.....	137
Digitalizing Consumption Across the Operational Spectrum.....	139
U.S. Marine Corps Sexual Assault Data Analytics.....	140

Naval Research Program Overview

The Naval Postgraduate School (NPS) Naval Research Program (NRP) is funded by the Secretary of the Navy (SECNAV), and supports research projects for the Navy and Marine Corps. The NRP research projects are comprised of individual research teams, where projects are conducted and expertise is developed, and then maintained, on behalf of the Navy and Marine Corps. The NPS NRP serves as a launch-point for new initiatives, which posture naval forces to meet future challenges. The primary mechanism for obtaining NPS NRP support is through participation at the bi-annual spring and summer NPS Naval Research Working Group/Thesis Research Working Group (NRWG/TRWG) research meetings for the Navy and USMC sponsored respectively. The annual spring meeting is a joint Navy and Marine Corps sponsored event; and the summer meeting is a Marine Corps-only event. Both research meetings bring together sponsors and faculty members to discuss potential research initiatives.

Background

The NRP was established in 2013 to leverage the expertise and experience of NPS' multidisciplinary faculty and naval (Navy and Marine Corps) student body to complete relevant, cost-effective research that addresses operational issues for the Naval community*. Naval research, analyses topics, and focus areas are sponsored by numerous agencies within the DON. The NPS NRP has developed as a standardized, systematic vehicle to leverage NPS multidisciplinary faculty and student research capabilities in response to demand signals across the DON. It serves to execute research that adds value to the Department of the Navy through research efforts (RDT&E funding) at NPS. The NPS NRP in no way replaces the traditional, independent, external research development processes used by NPS faculty (e.g. Broad Area Announcements, Requests for Proposals), but rather is intended to complement those efforts.

*Other Federal Agency sponsors may choose to participate in the NPS NRP working groups with their own funding.

Organization

The organization of the NPS NRP is based upon an annual research-topic solicitation process that helps merge DON research requirements with NPS faculty researchers and students who have unique expertise and experience within the DON, creating opportunities for NPS to actively contribute to real-world issues within the DON by providing relevant, high-quality, and timely research. The process starts annually with the convening of the NRWG on site at

NPS each spring. The TRWG co-convenes one of its two bi-annual meetings with the NRWG. The working groups create a forum for open discussion between NPS faculty, students, and DON topic sponsors.

The NPS NRP also draws ideas from a Topics Review Board (TRB) comprised of senior military and/or civilian representatives from each of the responding operational command/activities, headquarters, or systems commands. The TRB also includes a senior leader from NPS. The USMC executes and establishes a parallel Executive Review Board (ERB) process to conduct the same service-level research-topic exploration. TRB and ERB recommendations are forwarded to the NPS president for concurrence and coordination with the Vice Chief of Naval Operations and Assistant Commandant of the Marine Corps. The review boards conduct thorough reviews of proposed topics and research, to ensure funding is available to support topics with the highest priority within the DON.

Mission and Goals

The mission of the NPS NRP is to facilitate a continuum of Navy and Marine Corps research projects for the purpose of meeting current and future naval research requirements, integrating NPS faculty into the total naval Research and Development (R&D) capability space, and disseminating the knowledge and expertise gained to NPS students. The goals of the NPS NRP are to:

- become a recognized partner from which naval R&D organizations seek out research in response to short, medium, and long-term time frame requirements
- develop a ready pool of faculty research expertise to address these requirements
- offer a venue for NPS students to identify thesis research opportunities in areas directly relevant to naval challenges and research needs
- become the recognized leader for providing cutting-edge graduate education for naval officers that includes research complementary to the U.S Navy's and USMC's R&D requirements.

The NRP supports the awareness that “an active academic research program is vital to the quality of education provided to students, the attraction and retention of exceptional faculty members, and the provision of real-time, directly relevant deliverables to government sponsors (SECNAVINST 1524.2c dtd 21 Oct 2014),” and is postured to fulfill this DON requirement. The NPS NRP convenes the annual NRWG/TRWG as a forum for communicating, reviewing, validating, prioritizing and recommending research-topic challenges for consideration. Other topic solicitation methods may be employed in coordination with NRWG and TRWG to maximize the breadth and scope of research topics. The process includes opportunity for faculty dialogue with topic sponsors; faculty proposed responses to proposed

topics that match academic interests and capabilities; and review, validation, and prioritization of matched topics against the most pressing joint requirements.

Program Administration

The NPS NRP is directed through NPS' Research and Sponsored Programs Office. The Dean of Research (DOR) at NPS is designated as the lead agent and is responsible for NRWG execution, routing of post-TRB research requirements to NPS faculty and sponsors,, and program management of the NPS NRP. The NPS NRP Program Office includes a program manager, deputy program manager, and small staff who is delegated the responsibility for day-to-day program management of the NRWG, as well as program and individual research project oversight on behalf of the DOR. The NPS NRP Program Office coordinates and liaises with NPS NRP designated points of contact/Program Area Manager (PAM) counterparts from the various research sponsors.

Accomplishments

FY14 NRP Overview: The NPS NRP represents a strategic statement about the tangible and intangible value that NPS provides the entire naval community. It has proven to be a significant integration vehicle for partnering naval sponsors and NPS researchers to deliver cost-efficient results. The NRWG and TRWG are the manifestation of this integration process. Over 50 Navy and Marine Corps organizations throughout the naval community have actively supported opportunities to engage NPS faculty and students through participation in two NRP-sponsored events: The FY14 TRWG, which involved representatives from 12 USMC agencies; and FY14 NRWG, which included 49 USN and USMC agencies. To date, the NRP has collected over 500 potential and current research topics through these events, while funding 90 of them. Embedding the NRP into the fabric of the NPS strategic planning process enables the school to rapidly respond to current and future "compass swings" in naval research requirements.

As a result of NRP's operations, NPS research is more directly aligned with the naval community than in prior years:

- In FY14, NPS received \$12.1M, which it translated into 90 distinct U.S. Navy and Marine Corps projects that cover the entire OPNAV staff, Fleet Forces, ASN (RDA), SSP, and Marine Corps functional organizations.
- One-hundred percent of FY14 projects are directly traceable to the Navy's Strategic Plan and/ or the Marine Corps Expeditionary Force 21 Concept.
- The NRP has mobilized the NPS faculty to focus more of their research on naval issues. A total of 145 faculty (66 tenured professors, 86 non-tenured academics,

and three military faculty) from all four academic schools have joined the NRP effort, highlighting NPS' campus-wide commitment to naval research.

- Cross-campus, inter-departmental research partnerships represent 26 of the 90 projects. They provide an advantage from the application of integrated perspectives and resulting multidisciplinary approaches.
- The NRP enjoys robust student engagement, leveraging the students' previous operational experience and new-found knowledge from graduate studies. There are currently 122 thesis students collaborating with faculty on 61 of the 90 projects.

FY14 Research Highlights

Navy

- N81 has fully incorporated NPS-derived techniques in experimental designs for computer simulations. Application of these breakthrough concepts to the study of the Synthetic Theater Operations Research Model (STORM) has resulted in determining its sensitivities to input parameters. The NPS research team has developed tools for extracting the appropriate data from the simulation and analyzing results. The value of this effort is confirmed, as it is now the only research effort that N81 identifies for itself under the NRP for FY15, requesting a focus on continued efforts. STORM is positioned to be the premier Navy and Marine Corps simulation tool.
- A project focused on high-energy laser employment in self-defense tactics on naval platforms has already produced a solid-state laser database and new tactical, agent-based model the Navy can utilize for future evaluation of solid state laser improvements, new tactical situations, and new mission analyses.
- NPS has developed risk-based processes that provide systematic answers to the question of "how much testing is enough?" based on risk tolerances and analysis that identifies the worst-case impact of a failure of each ASN (RDA) software component. This quantitative process tests the mission- and safety-critical modules more thoroughly than those where failure has less impact.
- NPS' continuing development of its Multi-level Assessment and Evaluation (MLA&E) methodology to support the fleet-experimentation program run by NWDC continues to pay dividends. The FY14 MLA&E effort has produced higher than usual fidelity of results from exercise data. These results will help add increased accuracy to a model of the specific operational threads (SAG vs. SAG scenario) and to architectures that support the model.

- Attacks on Machinery Control Systems (MCS) transitioned from hypothetical demonstrations to reality with the discovery of the Stuxnet worm in June 2010. Security for naval machinery-control systems could be similarly problematic. Based on early analysis, a related NRP project has developed a set of documents that can be used to guide the development of highly trustworthy machine-control systems for N2/N6.
- NPS has investigated for N1 the statistical properties of forecasting quantities related to end-strength by pay grade and rating for sailors in the U.S. Navy. NPS found that PMA score, AFQT score, number of months at sea, and the proportion of test takers to vacancies are significant predictors of promotion from E4 to E5 in the HM rating.
- NPS research supported the OPNAV N1/N2N6 project P14-0236 Lifecycle Methodology for System of Systems Capability and Integration Analysis. This project has provided model integration with SPAWAR 5.0 Executable Architecture Requirements Model (ExARM) for OPNAV Portfolio Health Assessment (PHA).
- Using data collected from the Defense Manpower Data Center between 2002 and 2012, an NPS logistics regression analysis has suggested that the proportion of females in an occupation has a statistically significant effect on retention for all male regressions and females in some of the broad occupational categories examined.

Marine Corps

- At the TRWG 14-2 out-brief in August 2014, representatives from six sponsors specifically lauded the NRWG/ TRWG as the only venue where sponsors across services and domains can meet to discuss issues outside the formal studies process. Interactions with researchers helped shape problem statements for current issues, and were identified as one of the greatest benefits of the TRWG. One of the sponsors expressed the desire to leverage NPS via the NRP to support an upcoming \$0.5 billion dollar Milestone-C decision, which signifies the value and faith sponsors are willing to place in the NRP.
- NPS researchers have leveraged current information technology solutions combined with modern communications architecture to provide a proof-of-concept for USMC intelligence collection in tandem with C2 functions in distributed operations. At the current level of technological maturity, it is possible to support a data-rich environment on the tactical edge of Marine Corps units

while operating under the austere conditions outlined in EF21 and the *Vision & Strategy 2025* document.

- The Marine Corps is currently investing in renewable energy (RE) projects in an effort to meet the SECNAV's stated goal of 50% RE by FY2020. However, the current investment strategy involves a few major projects that boost the Corps' overall RE generation but fails to address energy security concerns at over one-half of Marine Corps installations. NPS researchers helped demonstrate that by including the cost of interruption at each installation, the net present value of investment in RE to meet these installations' energy security needs is positive at 19 of the 20 installations studied.
- NPS researchers are developing a conceptual prototype of a metamaterial sensor to serve as a main element for a system to identify and store the spectral signature of USMC High Power Microwave Weapons (HPMW), even if the target system is damaged or destroyed. Metamaterials studies have definitely shown resonant behavior consistent with similar metamaterials in other frequency bands, such as THz. NPS has observed some oscillatory behavior in the frequency spectra and have attributed it to the thickness of the metal layers being smaller than optimal. Subsequent generations of these devices should be made with metal layers thicker than the skin-depth at GHz frequencies.
- The Marine Corps recognizes that its reserve forces are critical to its success. The ability of the Marine Forces Reserve (MARFORRES) to augment and reinforce active Marine forces with trained and ready personnel comes at a time of tighter budgets and an increasingly challenging mission environment. An NRP-supported project, Optimal Location of Marine Forces Reserve Units by Demographics (Salmeron and Dell) in conjunction with a student thesis by Captain Paul Brisker (USMC), developed the Marine Corps Reserve Optimizer (MCRO), an optimization tool to aid Marine Corps Forces Reserves in the task of geographically situating their subordinate units with respect to demographics.
- The two most important criteria for USMC weapons system-performance—readiness (or operational availability, Ao), and cost—are often in conflict. One may increase Ao by increasing costs, or reduce costs by decreasing Ao. NPS has developed a prototype decision-support-model to conduct readiness and system life-cycle cost-tradeoff analysis for the Joint Light Tactical Vehicle program office.

N1: Personnel

Make Goal: A Training System for Naval Recruiting District Leaders

Researchers: Jonathan Alt, Jeffrey Appleget, Quinn Kennedy, Erik Johnson, LT Lee Sciarini, Christian Darken, and Jesse Huston

Student: Capt. Taylor Williams

Recruiting individuals to serve in the military continues to be a challenging and resource-intensive effort. As budgets are reduced, the Naval Recruiting District (NRD) needs to produce quality recruits at prescribed levels in order for the Navy to maintain the force. The Make-Goal game is intended to assist NRD leaders in learning to efficiently allocate resources to accomplish this task. This research will:

- Assess the current Make-Goal game as an instructional system in order to develop a set of recommended improvements,
- analyze data available from the sponsor to develop an empirical model to use within the game to determine player outcomes,
- implement a browser-based version of the improved game, and
- conduct pilot testing of the improved game using students at the Naval Postgraduate School.

This project is currently in progress, with completion and final project deliverables anticipated in June 2015.

International Navies' Policies for Women Faculty

Researchers: Kathryn Aten, Mark Eitelberg, and Captain Michael Smith

Students: Capt. Charles Drennan, LT Audra Vance, LCDR Nathalie Kocis, and Capt. Kimberly Sonntag

Objective: Retention of talented and qualified military members is critically important to maintaining a mission-ready U.S. Navy. The U.S. Navy is increasing female presence in previously restricted career paths while enhancing opportunities for women to join and stay in service. Learning best practices from allied foreign navies will help the U.S. Navy as it

evaluates its existing policies and programs to attract and retain the most talented and qualified women. This study catalogs and compares the policies, programs, and practices of selected nations to identify best practices and assess the relevance and potential value of such policies, programs, and practices in attracting and retaining highly-qualified women for the U.S. Navy. This study addresses the following research questions:

- What policies and practices are used by other navies to increase or sustain retention of women?
- What policies and practices employed by other navies can potentially assist the U.S. Navy in its effort to attract and retain highly-qualified women?
- What has been learned from integrating women from non-traditional career paths across international navies; and what policies and practices are found most effective in supporting the transition?

Process: NPS researchers co-developed a template and spreadsheet with N134W for assessing and comparing policies related to women in the navies of the following nations: United States, Australia, Brazil, Canada, Sweden, United Kingdom. The data and comparison focus on the following areas of policy and practice:

Pregnancy and Childbirth Maternity Paternity Adoption In-Vitro Fertilization/Assisted Reproductive Technologies Surrogacy/Egg Harvesting Operational/Adoption Deferment Marriage Dual-Military Couples Divorce Single Parenting Mentoring Habitability	Deployments Gender Differences/Disparities Limitations for Women Closed Occupations Assignment Physical Standards Combat High-Ranking Positions (Promotion) Accession Rates Career Path and Development Traditional/Non-Traditional Freedom of Choice Promotion Milestones Other Policies
---	--

Milestones and Preliminary Analysis: Responses to request for information from N134W have been received from five nations, as well as the U.S. Comparative analysis and report-writing have commenced. Three student projects are in progress or completed, which will contribute to the final findings and recommendations.

Preliminary analysis points to the critical importance of policies, programs, and practices that assist all members in balancing career and family. These are key to retaining all service members, particularly women. Balancing work and life demands are particularly challenging

for military women based on cultural expectations, traditional roles, organizational demands, and other factors. Future policies need to focus on smoothing the transition of women into non-traditional career paths. The experiences of other nations are informative and potentially useful.

Future Directions: Preliminary analysis suggests a need to focus future research, resources, and policy initiatives on work-life balance for achieving optimum retention objectives. Additional studies should explore service members' understandings and requirements for achieving work-life balance and the options available in the context of a military career. Studies of underlying reasons for similarities and differences between nations' policies—including the effects of cultural, religious, regional, political, and demographic factors unique to nations—would also assist the U.S. Navy in better understanding the experiences and successes of allied navies.

Assessing the Potential of Virtual Worlds for Navy Training and Education NPS

Researchers: Kathryn Aten, and Marco DiRenzo

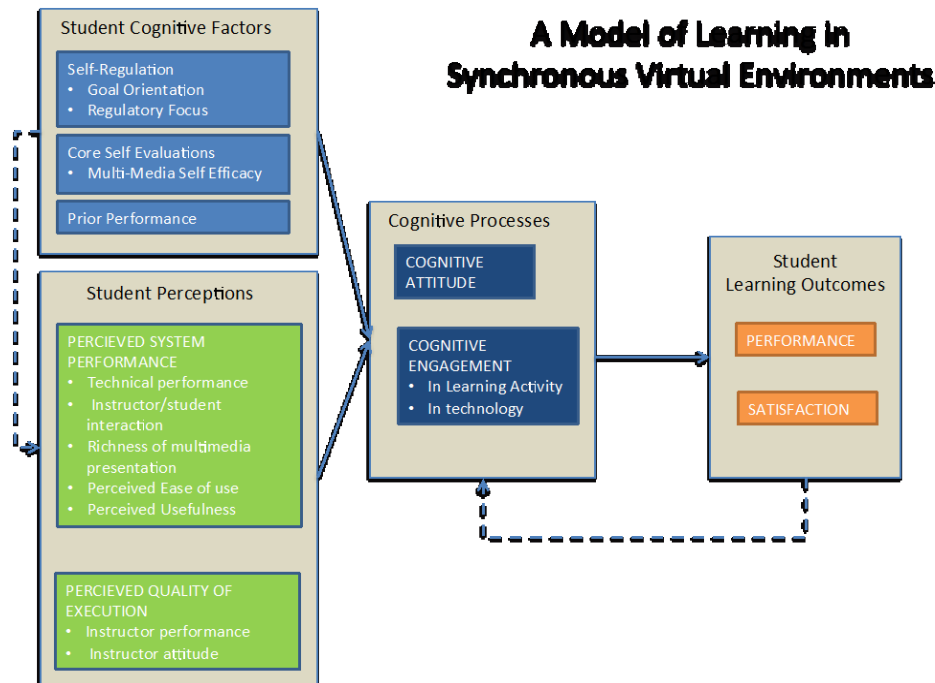
Student: LT William Spears

Although virtual worlds offer the potential to reduce training costs while maintaining student engagement, implementing technology-mediated training and communication has proven challenging. Failures are often associated with cognitive and psychological factors, including an unwillingness to adopt communication technologies. Successful adoption of virtual-world training will require an understanding and management of cognitive and psychological barriers. The objective of this study is to assess the role of cognitive and psycho-social factors on performance and satisfaction outcomes of training conducted in the Submarine Learning Center's (SLC) virtual schoolhouse (VSH).

Process: NPS researchers joined a team supporting a test of the SLC's virtual schoolhouse at Fleet Anti-Submarine Warfare Training Center. Instructors in San Diego, CA, taught and assessed three, seven-day modules of the A-130-0061 Surface Common Airborne Undersea Sensor Software (CAUSS) Functional Segment (SCFS) course. In each module, 12 students were trained (six in the traditional face-to-face facilities and six in the VSH). Participants were given pre-, mid- and post- training surveys and post-training interviews to assess cognitive and psychological factors. Performance outcomes were assessed by the instructors using existing written and practical exams. Using these assessments, NPS researchers will identify

relationships between outcomes, and cognitive and psycho-social factors, and make recommendations to support the reduction of training costs through technology.

Preliminary Analysis of Model Development: Researchers identified variables likely to affect student outcomes. The resulting Model of Learning in Synchronous Virtual Environments served as a framework for the remainder of the study.



Preliminary Analysis of Interview Data: Overall, students found learning in the VSH to be similar to learning in the face-to-face setting. Students found it easy to learn to use the VSH and most students stated they would attend training in a virtual setting if given the opportunity in the future. The following statement is exemplary of many students' conclusions, "I was a little bit worried about when I first did this [that]...we would get more knowledge ...in the [traditional] classroom... I feel like I learned almost more than what I would have learned normally in the classroom."

Students noted some differences between face-to-face and virtual learning, including advantages and disadvantages. Many students noted the overall advantage of the VSH would be an improvement to their quality of life and work-family balance. Advantages more specific to learning included: unique tools/learning aids, increased access to the lab, and benefits of the virtual space. General disadvantages noted by students included a lack of face-to-face interaction, emphasizing the added difficulty of communicating through technology, and technology mishaps, such as excessive lag. Specifically, several students noted that they preferred the access they had to PPT slides in the face-to-face setting where they were able to move through the slides at their own pace while the instructor was lecturing.

Advantages of the Virtual Schoolhouse: Students noted advantages related to quality of life and learning, specific to the virtual setting. Advantages included support of improved quality of life, availability of unique tools, learning advantages of the 3D environment, and increased access to the lab.

Disadvantages of the Virtual Schoolhouse: The primary disadvantage noted in interviews was the lack of face-to-face interaction. Several students noted that many people prefer face-to-face interaction. Others noted difficulties of technology-mediated communication, though several noted that the difficulties could be overcome.

Preliminary Conclusions: Preliminary analysis of the interviews suggests that acceptance of the technology by instructors and students will be critical to successful implementation of training utilizing virtual worlds. Actions to improve acceptance include the following:

- Roles and expectations of behavior during virtual training must be clearly outlined.
- Opportunities for interaction with instructors must be explained (i.e. group-chat, private-chat, voice).
- Instructors need instruction and practice in how to adapt their teaching to the virtual setting (i.e. speak more slowly, articulate actions, articulate visual cues).
- Students need instruction in how to adapt their communication in a virtual setting (i.e. how to signal the instructor).

Reporting: LT William Spears completed MBA project included a detailed review of the literature and development of the conceptual model. Preliminary results have been presented at the Western Academy of Management Conference and an academic paper co-authored by Kathryn Aten, Marco DiRenzo and LT William Spears is planned. The SLC will brief Mr. Scott Lutterloh, along with RADM White, and will prepare a comprehensive engineering report. NPS will brief Navy Education and Training sponsors when the analysis is complete. Results will also be briefed as part of a Virtual Workforce Conference at the end January 2015.

Further Research: This exploratory field-study is expected to provide general conclusions, suggestions for practice, and recommendations for future study. The benefits of exploratory field studies are that they allow initial exploration with relatively low risk. However, such studies typically involve a relatively small number of participants and constraints to the design. This study was based on a small number of students, in one course, in one location and the imperative to educate sailors was given priority. Results should be replicated with larger numbers of students, in varied courses, across geographic distance with more extensive experimental controls. In particular, a test must be conducted in which training begins in the virtual world and students are in separate locations rather than cubicles. Future

studies should investigate which features/tools of virtual worlds are most and least valued by Navy students and instructors? And, how should learning activities be designed to best take advantage of virtual worlds?

Individual Reservist Affiliation Motivators and Objections

Researchers: Kathryn Aten, and Marco DiRenzo

Across the reserve force there are communities, occupational fields, and grades with persistent manning shortfall in non-obligor populations. Non-obligor reservists are volunteers with each individual reservist having well-developed a rationale and reasons for affiliating and not affiliating with a reserve unit. Monetary methods are the primary incentive employed to induce reservists to affiliate and fill billets with shortfalls. Money has had a positive impact, but the utilization of monetary incentives is not based upon a deep understanding of the underlying individual reservist's motivations. A study which develops a deeper understanding of individual non-obligor reservist's motivations and rationale for affiliating with reserve units would allow for more efficient targeting of monetary methods and the development of non-monetary incentives that address an individual's objections which are not influenced by money.

This project is currently in progress, with completion and final project deliverables anticipated in June 2015.

Navy Recruit Attrition Prediction Modeling

Researchers: Samuel E. Buttrey, and Lyn R. Whitaker

Background: Since 1984, the Navy has screened recruits using the Recruit Quality Matrix. This assigns one of three levels to each recruit based on his or her percentile score on the Armed Forces Qualification Test and their educational background. In this research, we construct a statistical model to predict recruit attrition within the first term, based on information available to the recruiter. Such a model might best be used as an inventory management, rather than screening, tool. That is, the factors that are associated with success are well known, but the Navy should not turn away applicants because others with similar attributes have been less successful in the past. Instead, the Navy can use models like these to

determine the likely number of attritions by rating, age, and so on, and have a better idea of how many new recruits will be needed.

Process: We received from DMDC, in the form of Active Duty Master File and Military Entrance Processing Command, data numbering of some 250,000 records. A substantial data cleaning effort was followed by the use of logistic regression to model the probability of attrition for each recruit. The models were built using 80% of the data from sailors recruited in 2006-2008 and evaluated both on the remainder of the 2006-2008 data, and also on the data for the set of recruits from 2009.

Findings and Conclusions: The logistic regression models developed here are more useful in establishing attrition probabilities than the three-level recruit quality matrix. As an aid to their interpretation and use, we demonstrate a scorecard analogous to the popular credit score that consumers receive from Equifax, Experian, and TransUnion.

Recommendations: Credit scores are widely used and understood. By assigning an integer score to each sailor, we think we can make the management of the inventory of sailors more understandable. If the Navy moves from the three-level current system to a numeric substitute, it will be easier to estimate the numbers of recruits undergoing attrition. These models might be made even more accurate by the inclusion of non-cognitive (e.g. personality test) scores, and expanded to other outcomes beyond attrition.

NETC Acquisition Planning Framework for Managing Training Delivery Requirements

Researchers: Rudy Darken, and Perry McDowell

The Naval Education and Training Command (NETC) requires an acquisition planning tool to assist them in managing the myriad of training systems and assets the Navy needs to meet its individual training mission. They recognize the importance of developing this tool on a framework that is based on the science of learning (SoL) that will allow them to systematically develop high quality training systems, but also to link the design to trained performance and then to link trained performance to demonstrated skill in the Fleet. This effort will develop that framework. We will begin by assessing the current state of NETC processes and will build a SoL framework that modifies that process leading the way to eventual tools for NETC acquisition managers.

This project is currently in progress, with completion and final project deliverables anticipated in May 2015.

Limitations of IA and IT Security Policies in Naval Learning

Researcher: Arijit Das

Background: Naval Learning is moving away from the traditional client-server technology to a distributed model. This will mean content resides on several servers and will be combined and presented to the learner, as well as on devices of various form factor—namely desktops, laptops, thin-clients, zero-clients and smart devices. Tracking is decoupled from the server and is moving to the client using technologies like JavaScript/AJAX and Service Oriented Architecture. Tracking data is stored in legacy Shareable Content Object Reference Model and non-legacy formats.

All of these innovations give rise to concerns from the Information Assurance (IA) community. Can one provide a new production environment with servers, clients, and networks that comply with DOD IA policies, at the comfort level of existing architecture (client-server)?

Process: The problem was broken down into client-security and server-security. On the server-side, the NPS researchers had prior experience hosting Naval Research portals on the military network (unclassified and classified enclaves). On applying that knowledge to Naval Learning servers, not much of a difference was found. DOD guidelines were clear even though implementation might differ from site to site. Tech professionals in the DOD community can handle the deltas. NPS used a virtual platform (of servers, firewalls, routers) to test these policies and kept a dialogue with the NPS server IA community (ITACS-IA) as a fact-check.

On the client-side, the team looked at iOS and Android using the virtual PC technology from VMWare. The assumption was to use a CAC enabled smart device and move the credentials to a virtual PC, from where Navy learning was launched. The browser screen running was mirrored via client software (Horizon View) on the smart device. Several vendor products were thus tested that had been given the DOD 'okay'.

Findings and Conclusions: NPS has a pool of DOD researchers who, along with students, provide a good intellectual base to test IA policies (applicable to Naval Learning). Several client and server technologies were tested that lead to a Master of Science Information System thesis, while more testing needs to be done.

Recommendations: A sustained year-by-year partnership is needed to keep a continued effort. Hiring of tech savvy personnel will increase the value added to this research.

XAPI and HTML5 in Naval Learning

Researcher: Arijit Das

Background: This research looks at aspects of Naval Learning technology which is currently based on the client-server architecture. Learning content is stored in the server, and is sent to learners. Learners are consuming the content on designated computers connected to the servers in a dedicated manner. The server content uses a format known as SCORM (Shareable Content Object Reference Model). Tracking of the learning occurs within the context of the server and client. The content is mostly an Adobe Flash file, which limits what browsers can play it.

This model is now changing, wherein content now needs to be stored in a distributed manner (on several servers). That content has to be aggregated and sent to a learner in one single client application. The content is now no longer just SCORM compliant, but compatible with several different formats. The client has the ability to move from a dedicated desktop to a laptop, smart-device, thin-client, zero-client or even a smart-phone. There is also an effort to create content that is written using HTML5/CSS, which can then be consumed by most browsers. Finally, distributed content has to be tracked on the client devices and stored in legacy (SCORM) and non-legacy formats.

There are efforts from ADLNet (Advanced distributed Learning Network) to look at new directions in Naval Learning. NPS researchers are trying to create a lab to test these new technological innovations, have students look at them as thesis research topics, and incorporate their experience from the field.

Process: The first step in creating a lab is to have a virtual environment to build and re-build servers and test new ideas. This platform was available to the NPS researchers from prior effort and was used in this research. Next, the sponsors were asked to present their concerns, which lead to looking at work done by ADLNet and trying to test it in the lab. Researchers from ADLnet visited NPS to give us a better understanding of their technology.

The initial product from ADLNet that was tested was the decoupling of the tracking using xAPI (Experience Application Programming Interface) which uses Javascript/AJAX (as a SOA or Service Oriented Architecture) to track distributed learning. Content can come from various

servers to one client and be tracked on any server. Next, the tracking was stored back from xAPI format to legacy SCORM complaint format, or any other.

Findings and Conclusions: NPS has a pool of DOD researchers who, along with students, provide a good intellectual base to test innovations (applicable to Naval Learning). Only one aspect, namely tracking, was looked at in a MSCS thesis, while more thesis research needs to be done.

Recommendations: A sustained year-by-year partnership is needed to keep a continued effort. Hiring of tech savvy personnel will increase the value added to this research.

Evaluating the Financial Effectiveness of Marketing and Advertising on Recruiting Outcomes

Researchers: Robert Eger, and Amilcar Menichini

Students: Lt. Tim Didjurgis, and Lt. Tim Henderson

As stated in the Navy Recruiting Command's, *Recruiting Force 2020 Strategy*, (Commander Navy Recruiting Command, 2012), the mission of Navy recruiting is to "Recruit the best men and women for America's Navy to accomplish today's missions and meet tomorrow's challenges." One of the three overarching goals articulated in the *Recruiting Force 2020 Strategy* is to increase an emphasis on measuring success and return on investment.

As a major component of the Navy' recruiting strategy, marketing and advertising (M&A) plays a very important role in achieving recruitment outcomes for the Navy (Mehay and Stoker, 2011). In the current budgetary environment, enlistment contracts are indicated as the outcome metric for M&A investments. Difficulty in measuring the direct effects of M&A is due to the uncertainty associated with isolating specific causes of the desired outcomes (Bicksler and Nolan 2006; McGlocking 2013). Given the singular metric focus, additional outcomes affected by M&A spending may be underutilized in the budgetary process. Other outcomes affected by M&A investments include enlistment leads, awareness, branding, image, officer applications, niche market efforts (such as nuclear power, chaplain, medical, dental, reserve officer, technical enlisted rates, and war challenges—including SEAL, EOD, Diver, Air Rescue). The utilization of these additional outcomes can provide a universal approach in measuring the success and effectiveness of M&A investments.

The goal of this research is to provide a methodology and model in measuring effectiveness of M&A investments. To achieve this goal, we begin by exploring the current context addressing two research questions:

- How does the Navy Recruiting Command (NRC) quantify the effectiveness of its M&A investments on enlistment contracts, officer applications submitted, and additional outcomes such as enlistments leads, officer program leads, awareness, and tracking?
- Which data/metrics could NRC use to determine the effectiveness of M&A?

After exploring current approaches and measurement availability, we seek to understand metrics external of NRC by addressing the following research question:

- What tools/metrics does private industry employ to quantify their investment in M&A? Could any of those metrics be adapted to Navy Recruiting?

Upon completion of both the internal and external metrics associated with M&A, we derive a cost effectiveness model for NRC's M&A investments. Our goal is to use a weighting methodology to allow for environmental uncertainty associated with each identified outcome.

This project is currently in progress, with completion and final project deliverables anticipated in May 2015.

Future Navy Recruiting Strategies: Development of the Concepts, Practices, Processes and Procedures to Recruit Generations Z and Alpha

Researchers: Ronald D. Fricker, Jr., Samuel E. Buttrey, and Jonathan K. Alt

Objective: The objective of this research is to identify potential future research strategies for recruiting the millennial and post-millennial generations. Based on information from the other United States armed services, three allied nations, best practices in corporate America, and the academic literature, this research will provide forward leaning practices and actionable recommendations to the Commander, Navy Recruiting Command in order to improve and best align Navy Recruiting practices for the millennial and post-millennial generations.

Background: Over the past decade, United States the Navy's Naval Recruiting Command has developed and fielded resources intended to conduct operations more effectively and efficiently. However, the basic recruiting model, which is largely based around the physical interaction of Navy recruiters with potential recruits, has remained fundamentally unchanged for decades. This model places active duty recruiters in recruiting stations throughout the country, tasks the recruiters to produce a particular quota of new recruits to meet a monthly goal, and has them process their potential and new recruits via Military Entrance Processing Stations. However, it has been said that the millennial and post-millennial generations differ from past generations in that they are tech-savvy, connected, multi-taskers who want instant gratification, collaboration, transparency, and career advancement.

Process: The methodology used in this research is largely qualitative. It includes assessing, compiling, and evaluating the published literature on military recruiting and the millennial generation, as well as all unpublished service and recruiting command-specific information. It also involves interviewing subject matter experts in the services' recruiting commands and the Royal Navy and Australian Defence Force recruiting commands.

The specific research tasking is to:

- Assess the literature on trends in the millennial and post-millennial generations with a focus on how well current and previous recruiting efforts align with how these generations are likely to want to interact with Navy recruiting.
- Identify and evaluate past alternative recruiting efforts with an emphasis on assessing the quantitative evidence (if any) of performance.
- Pose possible future recruiting strategies for the Navy along with rigorous quantitative methods for evaluating the performance of the various strategies and their components.

Findings and Conclusions: Research to be completed 30 November 2014.

Developing Cost Effective Distributed Learning Strategies for Educating Naval Officers

Researchers: William R. Gates, Lisa Lindsey, Doug Brinkley, and Marigee Bacolad

Student: LCDR Kyle Alcock

Background: There is growing interest in providing distributed learning (DL) opportunities for naval officers unable to attend NPS. NPS has been a leader in DL education, being early adopters of video conferencing, Elluminate, hybrid programs, and other DL methodologies. Since NPS has entered the DL world, there have been significant developments in DL methodologies throughout civilian educational institutions. This research will examine the current DL programs within NPS and across other civilian institutions, explore the costs and benefits of alternative methodologies, and propose new DL methodologies for Naval officers, as appropriate.

Process: This research involves three tasks:

- Examine the costs and benefits of DL education to better understand the relative value, strengths, and weaknesses of DL versus resident education (RE).
- Examine the trend of blended DL in postgraduate education to identify best practices and how those best practices differ across disciplines and degree/certificate programs.
- Examine student characteristics and student performance, including DL and RE, to identify predictors of student success in both DL and RE, and understand how NPS can ensure student success (selection criteria, transition support, etc.).

Findings and Conclusions by task:

- We have completed a literature review concerning the advantages and disadvantages of various DL approaches. The literature indicates that one critical element is the extent of student/instructor engagement. We will deploy a survey of NPS DL and RE students to see how engagement varies across pedagogies.
- We are surveying DL programs at other universities to identify best practices by discipline. We are conducting a model course-development effort within NPS' Graduate School of Business and Public Policy (funded separately) that will employ the latest in DL approaches.
- We have gathered an extensive NPS student database, covering AY2006 to AY2013, for both DL and RE students and are in the process of cleaning the database. We will use this database to examine what student characteristics best predict student success in both DL and RE programs, and the similarities and differences across programs. This effort is supported by a thesis student, LCDR Kyle Alcock, Operations Research department, March 2014 graduate.

Recommendations: A final report will be provided, detailing the results of these analyses and making recommendations for resident and DL education at NPS. We will present the preliminary results at the virtual research symposium, and complete the final report based on feedback from the presentation. The start for this was delayed due to limited faculty availability. The revised schedule has been discussed with the program sponsor. We expect to complete the final report by March 31, 2015.

Integrating Men and Women Within Naval Special Warfare Teams

Researchers: Deborah E. Gibbons, Alan Nelson, and Sally M. Baho

Background: The Naval Special Warfare (NSW) Center is preparing to integrate women into training for combat roles in Joint Special Operations by 2016. At present, NSW includes all-male Sea, Air, and Land (SEAL) and Special Warfare Combatant-craft Crewmen (SWCC) teams, and all-female Cultural Engagement Units (CEUs). The SEAL and SWCC teams are designated as combat units, while the CEUs are not. Recent requirements for inclusion of women in combat units have raised questions about feasibility, process, and effectiveness of integrating women into the SEAL and SWCC units. Women have already proven their competence in integrated operations, as CEUs often work together with SEAL and SWCC teams. Each type of unit brings distinct and necessary capabilities to NSW missions. Some of these capabilities are directly related to the team members' sex or gender, but most are not. All three types of units have demonstrated excellence in performance of their respective tasks, and it is vital that future integration efforts maintain the diverse skill-sets represented across the different units within NSW.

Study Goals and Methods: This study developed strategies to provide equal opportunities for both men and women, while supporting unerring performance of unique and challenging tasks by members of each of the three types of NSW units. Our research focus was on team development and performance within and among NSW units. This required that we assess potential challenges to successful training and placement of women in special operations teams, and to explore options for addressing those issues. In addition, we identified strengths that women bring to special operations teams, and explored ways to leverage those strengths through integration of men and women in NSW training and operations. Our focus was on SEAL, SWCC, and CEU team development, and on existing and potential integration within and among these units. Our approach included extensive review of literature about teams, assessment of non-American militaries' approaches for integrating women, and

interviews with SEALs, SWCCs, CEU members, trainers, and military personnel who have participated in gender-integrated military environments. The report, when completed, will incorporate findings from all of these sources and provide recommendations for streamlining the integration process.

Findings and Conclusions: We have identified many concerns about gender integration in military settings, based on literature review and interviews. We have also identified a few benefits and obtained advice from people who have had experience in military gender integration. Most of the concerns can be addressed by preparing leaders, managing communications, and establishing pre-conditions for success.

Recommendations: Recommendations will include actions that can be taken to streamline the integration process, facilitate group cohesion, support incoming women without singling them out, and maintain or increase NSW's overall performance capacity.

Effects and Return on Investment for Regional Training Pilot

Researchers: Alan Jaeger, and Brendon Applegate

The Asia Pacific Hand program is a Navy initiative to build operationally relevant regional proficiency in officers newly assigned to the Asia Pacific AOR. Candidates who are new to the region and en-route to their duty station attend Naval Postgraduate School Department of Security Affairs for 12 regionally-focused credit hours and receive a master's certificate. The program goal is to provide varying levels of sustained and enhanced education over the course of a career. Participation in the program is determined by coded billet requirements. This research will determine return-on-investment for this program by assessing training results to-date, in terms of overall value and effectiveness, and will provide recommendations based on identified results.

This project is currently in progress, with completion and final project deliverables anticipated in May 2015.

Improved Forecasting Methods for Naval Manpower Studies

Researchers: Robert Koyak, and Lyn Whitaker

Student: LCDR Sean McCrink

Background: We investigate the statistical properties of forecasting quantities related to end-strength by pay-grade and rating for sailors in the U.S. Navy. Specifically, we focus on the Hospital Corpsman (HM) rating using data provided by the Navy Personnel Research, Studies and Technology (NPRST) that encompasses more than 50,000 sailors during a period from 1996 to 2005. This rating was considered by LCDR Sean McCrink, USN, who conducted his master's thesis research (Operations Research, June 2014) in conjunction with this project. Although LCDR McCrink investigated factors that were predictive of a sailor promoting to the next pay-grade, our focus is on loss delineated by pay grade, recognizing that sailors who are at a particular pay-grade may either (i) continue in the same pay-grade the following year; (ii) promote to the next higher pay-grade; (iii) demote to the next lower pay-grade; (iv) separate from the Navy; or (v) transfer to a different rating.

Process: Using the Career Case Manager Technologies (CCMT) data provided by NPRST, we start with LCDR McCrink's approach, which emphasized the building of a logistic regression model to predict advancement. Logistic regression is a conventional modeling approach for predicting a binary outcome variable from a set of explanatory variables. A disadvantage of this approach is the difficulty of recognizing nonlinearity and interactions among the explanatory variables. We, therefore, consider nonparametric techniques from machine-learning that are more flexible in this regard. Although the CCMT data is not current, it provides the opportunity to focus more deeply on statistical techniques in a project of limited scope such as ours.

Findings and Conclusions: LCDR McCrink found that Performance Mark Average score, Armed Forces Qualification Test score, number of months at sea, and the proportion of test-takers to vacancies are significant predictors of promotion from E4 to E5 in the HM rating. We anticipate that these variables also will play a role in predicting loss or separation at different pay-grades when our analysis is completed.

Recommendations: The CCMT data should be updated to provide the same variables up to the current year. It would be valuable to consider how well models formulated in earlier years maintain their validity for forecasting in light of changing economic circumstances and Navy decisions on sizing its manpower strata under changing budgetary circumstances.

Developing a Market-Based Compensation System

Researchers: Noah Myung, William Gates, and Peter Coughlan

Students: LCDR Eric Kelso, and LCDR Brett Williams

The goal of our research is to improve the way the U.S. Navy compensates its sailors. In particular, we designed a market-based compensation system that improves retention compensation in four dimensions: cost, quantity, quality, and the allocation of non-monetary incentives. These market-based compensations take form in various auction formats, notably a uniform-price auction. Improvement in cost refers to the reduction in cost compared to the current compensation system. Improvement in quantity means that the U.S. Navy will be able to retain the desired number of sailors instead of facing the over- or under-retention that happens in the current system. One concern with utilizing an auction format for retention is that the U.S. Navy may end up sacrificing quality by obtaining the lowest cost to retain sailors. Therefore, we also designed an auction format called the Quality Adjusted Discount (QUAD) auction which helps the U.S. Navy in controlling the quality of sailors retained. Finally, our previous research has shown that preferences for non-monetary incentives (e.g., graduate education, station of choice, etc.) vary significantly between sailors. Therefore, we further designed an auction format named the Combinatorial Retention Auction Mechanism (CRAM), which has the ability to incorporate non-monetary incentives as part of the auction. Our auction method of allocating non-monetary incentives will help in providing the right non-monetary incentive to the right person. Finally, because different auction designs may create different strategies for the participants, such as gaming the system, we designed our markets with the property that being truthful is the best option for the sailor. Attempting to game our system will generally have a less desirable outcome for the participant.

After developing various market mechanisms, we surveyed a group of officers from the naval aviation community in order to estimate the performance of our markets. Aviation Career Continuation Pay (ACCP), the retention bonus for naval aviators, has historically failed to meet stated retention goals. For fiscal year 2013, Naval Personnel Command reported that ACCP exceeded retention goals in some communities by more than 60%, while simultaneously falling over 60% short of retention objectives in others. We measured and estimated aviators' quality and willingness to stay on active duty as a naval aviator, and we compared the result of ACCP against our auction mechanisms: 1) uniform-price auction, 2) Quality Adjusted Discount (QUAD) auction, and 3) Combinatorial Retention Auction Mechanism (CRAM).

We find that by implementing a uniform-price auction, naval aviation can exactly meet 100% of its retention objectives, while reducing costs in some communities by more than \$2,200,000 in one year. Additionally, while we find no significant correlation between officer-

quality and retention-costs, we demonstrated the potential for QUAD auctions to improve upon these results by further reducing retention costs and simultaneously improving the overall quality of retained aviators. Lastly, our implementation of CRAM reveals the potential to reduce individual retention costs nearly 20% through the use of non-monetary incentives.

As this is a continuing project, we have much room for advancement. First, we are in the process of obtaining a more general set of population data to better estimate the performance of our markets. Second, we are in the process of formally and mathematically characterizing the outcomes of all three auction-mechanisms. Third, we also need to perform experiments on various ways of executing one of the market mechanisms. It is important to note that a poorly executed auction mechanism—one that does not take into account economic theory, game theory, experimental economics, and behavioral economics—can lead to a disastrous outcome.

Utilizing Non-Cognitive Measure for Navy Selection, Classification and Duty Assignments

Researchers: Elda Pema, and Simona Tick

Armed Services Vocational Aptitude Battery scores can accurately predict academic training success; it does not predict misconduct, job retention, job performance or job satisfaction. In an effort to incorporate more factors into the pre-employment job-matching process, non-cognitive factors are currently being researched with the end-state being a plan and process for best utilizing them in Navy job-matching/assignment. This research will combine data from the Defense Manpower Data Center, Personalized Recruiting for Immediate and Delayed Enlistment Modernization, Tailored Adaptive Personality Assessment System, and data from the Recruit Training Command to provide answers to questions about non-cognitive measures and job performance, retention and success.

This project is estimated to be completed by December 2014.

Who Uses Tuition Assistance? Variations in Tuition Assistance Use Due to Demographic Characteristics and Job Requirements

Researcher: Elda Pema

This study will investigate which observable background characteristics affect the likelihood of participating in the tuition assistance (TA) program. Focus on demographic characteristics will be analyzed, and econometric methods will be used to estimate systematically significant differences, and estimates on participation and success in TA courses will be reported.

Women in the Navy: What is the Correct Staffing Level to Maximize Retention?

Researcher: Dina Shatnawi

Students: LT Clinton Ceralde, and CAPT Christopher Czepiel

Background: Since the Navy's inception in 1775, males have primarily filled its fleet. In the past, the roles of women in the military were limited; however, major progress has been made to integrate women into traditionally male-dominated occupations or occupations previously closed to them. Despite the improvements made with the goal of increasing female representation, the Navy currently struggles to attract and retain women, and gender-differences in retention are much more pronounced among officers than they are for the enlisted (Defense Department Advisory Committee on Women in the Services, 2003). Furthermore, women are only half as likely to continue to serve past their initial obligation point according to the Joint Advertising Market Research and Studies Youth Poll 20 overview report (2011). Once in the Navy, it is not understood why women have a much higher propensity to exit than men given the different strategies used to retain personnel. One explanation proposed in the literature for why women leave at a higher rate than their male counterparts is job satisfaction. Studies suggest that "women report higher job satisfaction in workplaces dominated by women workers" (Bender, Donohue, & Heywood; 2005) and that job satisfaction increases as the share of females in the workplace increases (Clark, 1997; Sloane and Williams, 2000).

This study uses qualitative and quantitative research methods to identify trends regarding gender representation across occupations and retention decisions among male and female officers. The first part of this study examines whether a 'critical mass' is necessary across occupations to increase female retention in the Navy, and if so, identifies the threshold required that would reduce unintended departures at the end of their initial obligation. The second part of this study uses survey responses from Navy officers to examine perceptions and attitudes regarding gender composition of their occupation and whether they believe this influences their retention decisions.

This research was sponsored by the Navy's office of Diversity, Inclusion, and Women's Policy and is the first study that examines the relationship between critical mass and retention in the Military. The project greatly benefited from the help of the sponsor POC Jessica Milam, and assistance from LT Clinton Ceralde and Capt Christopher Czepiel, who were NPS students that assisted on this research as part of their thesis.

Process: The purpose of the first part of this study is to examine how the relative proportion of females in an occupation affects retention decisions among female officers and to determine whether a 'critical mass' is necessary across occupations to increase female retention in the Navy. To examine the relationship, data was collected from the Defense Manpower Data Center (DMDC) for fiscal years 2002-2012 on all Navy officers who had a full set of demographic and work-related information, and was observed long enough to experience their first stay-leave decision point. Logistic regressions were used to estimate the retention probabilities based on the gender composition of the occupation. The second part of this study uses survey responses from Navy officers to examine perceptions and attitudes regarding gender composition and retention decisions. The questionnaire was administered via an email invitation to over 8,000 Navy officers with a link to the LimeSurvey website if they chose to participate. The email list of potential participants was requested from DMDC and the Naval Postgraduate School for officers who were within one year of making their initial retention decision, or those within two years of having just made that decision. Because DMDC does not record the end of active obligated service date for Navy officers, we requested email addresses for active duty Navy officers that have held the rank of lieutenant junior grade (LTJG) for at least one year, or full lieutenant (LT) for less than two years. I was only able to obtain emails for officers that had active .mil or .edu accounts, which excludes those who were at sea. The survey was open from January 31, 2014 and is currently still open. As of early July, there are a total of 1,101 respondents, suggesting a response rate of less than 14 percent.

Findings and Conclusions: Using data collected from DMDC between 2002-2012, logistic regressions suggest that the proportion of females in an occupation has a statistically significant effect on retention for all male regressions and females in some of the broad

occupational categories examined. In occupations deemed 'traditionally female,' such as the Nursing Corps (which is included in the broader Medical Corps category), as the proportion of females increases beyond a particular threshold, female retention increases, however male retention decreases. In the Information Dominance field and JAG occupational category, female representation did not have a statistically significant effect on female retention, however an increase in female representation had a statistically significant effect in reducing male retention. The survey analysis reveals that in occupations that are heavily male dominated, more female officers reported that they intended to leave the Navy and that the proportion of women in those occupations is an important factor in their decision to stay. However, the number of observations in those occupational categories was too low to make any sort of statistical inference.

Recommendations: While this study provides initial insight into the relationship between female representation and retention decisions among women, it is still not entirely clear whether achieving a critical mass of female officers in each occupational category will increase female retention. The discovery of this 'retention threshold' has important policy implications of jobs previously closed to women open, however most of these jobs do not have enough observations to make any rigorous inferences quite yet. Continued data-collection and statistical-analysis are encouraged as more data becomes available and as more women enter occupations previously closed to them. There is still reason to believe that an increase in female representation could have a positive impact on female retention. Many women who are attracted to serve in the military (a male-dominated profession) seem to exhibit a preference for the military's traditionally-female occupations, however there is no evidence in the literature why this is the case. In order to develop policies for women to enter non-traditional occupations, one must understand why they choose to be in a particular occupation in the first place.

Littoral Watch Bill Innovations

Researchers: Nita Lewis Shattuck, and CDR Simonia Blassingame

Students: LT Renaldo Hollins, LT Kelly Lesczynski, LCDR Van Fitzsimmons, LCDR Michael Albrecht, LT Travis Chambers, and LT Dustin Schultz

Background: Based on what is known about human fatigue, stress levels, and physical and cognitive workloads, humans are limited in the quantity and quality of work that can be accomplished in a given period. However, recognition of these limitations has not been factored directly into the manning strategies of United States naval ships, such as the littoral

combat ship or DDG-1000 Zumwalt class destroyer. Advanced automation has been employed on these ships in an attempt to reduce the requirement for sailors; these advanced warships have opted to use automated systems in place of human crews. This reduction in manning represents a severe restriction in crew size, leaving little room for sailor fatigue or human error. However, this tradeoff comes with serious consequences. Ships have little spare capacity in the performance of its daily activities; in the event of a damage control event or combat casualty, this reduced crew size potentially places the ship and her crew at grave risk.

This study is focused on (1) assessment of the optimal assignment of the Plus-10 crew members on the littoral combat ship (LCS), determining the workload of each member of the crew for various scenarios and underway evolutions; and (2) the development and validation of models of human performance using DOD-sanctioned modeling tools to determine total-system-performance, predicted cognitive-effectiveness-levels of crewmembers using alternative watch bills; and ultimately, to provide information about the impact of minimally-manned crew configuration options for decision-makers.

Process: Data was collected onboard LCS-2 during rough water trials, Jan-Feb 2014. The data, along with task and job analysis information from subject matter experts at the LCS program office, was applied in the IMPRINT Pro FORCES modeling tool and used to create notional schedules, mission requirements, planned activities and unplanned events onboard an LCS. The rate of mission failures during regular activities and unplanned events were analyzed across various reduced manning levels. Results indicated a reduction in failures as manning levels are increased. Risk and cost-benefit analysis will have to be accounted for when ultimately determining the optimal number of sailors for the platform. The IMPRINT Pro FORCES model has been in Beta Testing stage and some software errors were identified and corrected. The basic model was built and vetted with experienced LCS crewmembers.

Findings and Conclusions: IMPRINT Pro FORCES module is a feasible tool for evaluating manning levels while accounting for fatigue and mission accomplishment of both planned activities and unplanned events. It can identify successful accomplishment of these planned activities and unplanned events, estimate distributions and time requirements for tasks, has a well-developed and validated 'trump' matrix for prioritization of activities (based on LCS SME inputs), and can yield the number of planned and unplanned activities that are projected to fail due to lack of manpower or incorrect personnel distribution.

Recommendations: The FORCES module in IMPRINT is a new software implementation that is in the Beta Test Phase and before this time, has never been used to model a ship's crew. Consequently, we have had to work closely with Alion to resolve some software challenges. However, IMPRINT Pro FORCE module has shown to be very capable and would be beneficial for the Naval vessel manpower planning process. Additional work would be required for the

government and vendor to further develop and validate the tool for total Fleet application. Ship-specific packages and sub-modules would need to be created with Alion for full-scale implementation. This would include data card collection and formal task analysis for each ship platform, data collection from subject matter experts from various program offices and crews, and validation of modules against actual crew performance on each ship platform. Additionally, further discussion and collaboration with the Navy Manpower Analysis Center would be required for full-scale model development and implementation.

Informing Shipboard Readiness Metrics to Include Physical and Cognitive Fatigue Estimates

Researcher: Nita Lewis Shattuck

Students: LCDR Stephanie Brown, LT Monica Amagna, and FORNATL Panagiotis Matsangas

Background: An extensive body of research exists, documenting the limitations on the quantity and quality of work humans can accomplish in a given time period based on human fatigue, stress levels, and physical and cognitive workloads. However, current manning and operational readiness models do not account for the physical and cognitive fatigue experienced by individual sailors. This study was designed to incorporate physical and cognitive fatigue estimates into manning and workload models of USN shipboard operations.

Process: Based on a comprehensive review of the literature regarding the connections among physical fitness levels, health, obesity, shiftwork, and sleep, we first set out to determine the prevalence of physical injuries, physical complaints, and physical and cognitive fatigue among USN crewmembers. Questionnaires were designed and administered to sailors (n=767) aboard the USS NIMITZ in conjunction with the spring 2014 Naval Physical Readiness Training to determine point prevalence estimates of physical fitness, physical injuries, and fatigue issues in the fleet. Initial data was also collected on a shore-based USN population (Naval Postgraduate School students) to serve as a comparison. Additional data collection on enlisted sailors in a shore-based unit is planned. Command resilience of USN Sailors will also be collected and compared, showing averages and standard deviations along with their work/rest schedules. Our initial operational readiness model will then be updated to include adjustable manning levels and work/rest schedules based on the results of the data collected.

Findings and Conclusions: Initial results of the shipboard questionnaire were briefed to the sponsor in September 2014, showing that over 50% of the population report experiencing at least one musculoskeletal symptom during the previous 12 months. Musculoskeletal

symptoms were more common in older crewmembers, in females, in those consuming caffeinated beverages, or taking sleep-promoting medications. Crewmembers reporting musculoskeletal symptoms also show elevated daytime sleepiness and higher levels of fatigue compared to those crewmembers without musculoskeletal symptoms. Watchstanding, body mass index (BMI), workout frequency, and consumption of energy drinks were not associated with musculoskeletal symptoms in this population.

Additional findings and conclusions will be made upon completion of the second phase of data collection.

Recommendations: Recommendations are premature at this time.

21st Century Retention Challenges for The Navy: Generational Changes, Attitudinal Effects, and Their Impact on Operations

Researcher: Anna Simons, and Anita Salem

Issues addressed: The aim of this project was to address two issues:

- How might generational differences impact retention?
- How can the Navy retain high-value personnel?

Process: We conducted a literature review, delving into both the popular and academic literatures on inter-generational trends and issues. We also conducted two sets of workshops. One set of workshops, which made use of design-thinking and future-scenario planning, was conducted on an Landing Helicopter Dock (LHD) while it was underway. We were thus able to augment our discussions with sailors and junior officers with ethnographic observations.

We next conducted a three-day long design-thinking/future-scenario planning workshop which concentrated specifically on cyber-force retention.

Findings and Conclusions: Our embarkation revealed that while some inter-generational issues are likely to affect retention, these may be fewer and different than the literature suggests. We are also likely to confirm what some of the more sophisticated literature points out—that shifts in social trends may be more significant than inter-generational differences per se. We will also note that regional and class background, educational differences, and

whether sailors and junior officers grew up in military families, seems to impact retention to a greater degree than inter-generational differences.

Recommendations: Our actionable recommendations suggests that engaging sailors on retention can itself serve as a retention tool. One way the Navy can tap the talent within would be through design-thinking, to include future-scenario planning – and we will describe what we mean. We will also point to some strategic challenges. For instance, should the Navy cater to youth or seek to mold youth to the Navy? We will offer some suggestions for how the Navy might better align its needs with the needs of today's and tomorrow's youth.

We will likewise identify some systemic gaps having to do with policies, processes, culture, and technology. However, because we were limited in our ability to conduct prolonged fieldwork, most of our suggestions will fall into the category of what we think the Navy should use as elicitation tools and techniques for addressing this topic community by community.

For instance, among our more obvious conclusions will be that while there may be some Navy-wide commonalities when it comes to what will drive young people out of the force (e.g. toxic leadership), every community may need to treat what will keep its members in the force somewhat differently. This in and of itself could present the Navy with a significant but not insurmountable organizational challenge.

Sexual Assault Prevention and Response Best Practices, Fleet Communication Strategy, and Sexual Assault Prevention and Response Website Analysis

Researchers: Gail Fann Thomas, Jim Suchan, Deborah Gibbons, Sally Baho, and Jessica Neff

Students: LT Tarus Chatman, LT Jessica Denney, and LCDR Anthony Rojas

Background and Problem Statement: Sexual assault within DOD has received national attention from the media, Congress, and the public. To help address this problem, the Navy established the Sexual Assault Prevention and Response (SAPR) Program that has been tasked with supporting DONs goals of combating sexual assault and generating a culture of assault intolerance, compassionate response, and accountability. To achieve its goal, the SAPR Program must communicate effectively with a variety of stakeholders. This study was designed to assist the Navy in developing proactive and adaptive Fleet communication strategies and tailored messages that will help accomplish the US Navy's SAPR vision.

Deliverables:

- *Literature Review:* Investigate best practices of sexual assault prevention communication.
- *Voice of Junior Officers and Sailors:* Work with selected Fleet stakeholders (junior enlisted, enlisted leadership, chief, officers, and CO/XOs) to identify communication strategies (messages and media/channels, and sources) that would address SAPR desired effects.
- *Message Frames:* Provide recommendations for bystander message frames that might improve sexual assault prevention for specific Navy communities.
- *N17 SAPR Website Analysis:* Provide recommendations for improving SAPR's website.

Part I: Best Practices Literature Review – SAPR Communication

Purpose: A comprehensive review was conducted of extant literature on sexual assault prevention and response (SAPR) programs. The goal of the review was to establish the state-of-the-art in SAPR programs and to distill a set of best practices.

Process: The literature review encompassed studies and reports published by universities, government agencies (e.g. Centers for Disease Control and Prevention), think-tanks, advocacy organizations (e.g. National Sexual Violence Resource Center), and academic research. Based on a review of these documents, we generated a list of eight best practices for SAPR programs applicable to the Department of the Navy.

Findings:

- SAPR Programs should be based on an ecological model.
- Programs should be longer and with a higher frequency of sessions.
- Program facilitators should be similar to the target group.
- Single-gender participant programs are often most effective.
- Program format should be interactive. Program should be designed to evoke empathy.
- Program content should be crafted to be socio-culturally relevant to the target group.

- Bystander intervention and social marketing are emerging program strategies that are proving to be effective.

Challenges: While a voluminous body of research exists on the topic, the literature is fragmented and spans many disciplinary divides. Scholars in a wide range of disciplines are conducting research on the topic, including sociology, psychology, communication, gender studies, and public health. “Interdisciplinarity” is a strength, in that the issue is approached from a variety of perspectives, but a shortcoming is the absence of a unified research community engaged in a shared conversation.

Another key challenge is variation in metrics and appropriate program assessment. Intervention success has been measured using a host of different outcome variables, including attitudes, behavioral intentions, self-reported behaviors, and observable behaviors. This limits comparability of study results.

Conclusion: The nature of the DOD lends itself to training that can be customized to reflect the theoretically-backed recommendations and best practices in Sexual Assault Prevention Programming. Furthermore, the DOD has the resources to develop and implement effective training programs, for example, male-led, single and mixed-gender trainings, interactive programming, etc. Based on a review of the literature, it is critical that the leadership support the effort of a culture change in various commands.

Part II: Voice of US Navy Sailors and Officers

Purpose: The purpose of the three-day forum was to engage Fleet members in an informed discussion about communication strategies that support or hinder SAPR. The forum was designed to provide a kick-off for RDML Buck’s 2014 Fleet tour. In addition to the three-day forum, Dr. Thomas’s GB3012 communication class conducted a class project that allowed them to identify strengths and weaknesses of SAPR-related communication. Forty-six NPS MBA students participated in the MBA SAPR mini-project.

Process: The SAPR Forum was presented in partnership with NPS Center for Executive Education, 13-15 January 2014, Naval Base San Diego 32nd Street. Participants included a mix of E2-E9, W2, 01-06; males/females; Surface Warfare Officers, Submariners, Aviators. The 3-day workshop included SAPR-related presentations and several small group discussion sessions. First, similar ranked groups met to discuss identified topics; then heterogeneous ranked groups shared their findings and prepared a debrief for RDML Buck. RDML Buck used the briefing to discuss the issues with the participants on Day 3.

Findings: Using input from the SAPR forum and the MBA SAPR mini-project, the researchers identified the strengths and weaknesses of current SAPR communication. The researchers

also summarized preferred SAPR communication strategies for the Fleet as well as innovative ideas for improving SAPR communication.

Conclusions: The results and recommendations from this part of the study were briefed to RDML Snyder, Mr. Rosen and other SAPR staff, August 2014 in Washington DC. Here are quotes from RDML Buck about the SAPR Forum: "It was an eye-opening week as I realized how few of the Fleet Sailors knew who I was or what I did. Their [forum participants] innovative ideas and the way they presented them amazed me. It made me look at our SAPR messaging in a whole new way, a way that will hopefully reach Sailors on a personal level."

Part III N17 SAPR Website Analysis (thesis project)

Purpose: Research questions for this thesis project included: 1) How does the 21st Century Sailor (N17) SAPR website compare to other DOD, college and university, and non-profit organizations' sexual assault prevention websites? 2) What are SAPR website best practices? 3) Using a website assessment tool, what are the strengths and weaknesses of the N17 SAPR website? 4) How might the N17 website be improved?

Process: The thesis students developed website analysis metric (WAM) and thematic website analysis measure (T-WAM); identified 17 sexual assault prevention websites – (six websites from best practice SAPR universities – Lewis and Clark College, University of California Los Angeles, University of California Santa Cruz, University of New Hampshire, University of Kentucky, Binghamton University; two best practice non-profits – California Coalition Against Sexual Assault, National Sexual Violence Resource Center; 5 military SAPR websites – US Navy, US Air Force, US Army, US Coast Guard, US Marine Corps; two DOD websites – Department of Defense, Department of Navy; and two non-profit, DOD-sponsored websites – Safe Helpline and MyDuty. Using their assessment tool, they conducted a detailed analysis of the 17 websites.

Findings: The thesis students ranked the 17 websites, comparing the best practices to the N17 SAPR website.

Recommendations: The students provided recommendations on each of their 38 WAMs. Screen shots of best practices were provided for each measure. The thesis provides specific recommendations with examples that N17 can use to improve their website.

Part IV – Message Strategy Development (to be completed Nov 30 2014)

Purpose: This part of the study, conducted by NPS Professors Jim Suchan and Deborah Gibbons, focuses on SAPR bystander-intervention messages. The goal is to identify effective themes and frames for presenting a three-part message: (a) sexual harassment and sexual assault are harmful, (b) bystanders can and should intervene to prevent sexual harassment

and assault, and (c) every member of the Navy is personally responsible to intervene when necessary to prevent sexual harassment and assault. We anticipate that members of different demographic groups and Navy communities may be motivated by distinct messaging approaches.

Process: Members of the research team are testing various framing strategies in focus groups comprised of four groups--18-24 year old and 25-32 year old males and females from the Surface Warfare, Aviation, Supply Corps, Special Warfare, and Medical communities. Participants assess a variety of possible framing strategies with regard to how memorable, motivating, likely to influence attitudes, and likely to influence behaviors they are. Participants also explain what makes SAPR training more or less effective with their demographic group, and they provide recommendations for reaching their peers with bystander-intervention messages.

Anticipated Findings: The researchers will identify framing strategies and themes that are most effective overall and those that are uniquely effective for specific Navy communities or demographic groups.

Anticipated Recommendations: Recommendations will include framing approaches and delivery methods that are likely to increase the effectiveness of SAPR bystander-intervention messaging and training.

The Performance of Hispanics in the Military: A Look Across Services and Into the Civilian Labor Market

Researchers: Simona Tick, and Elda Pema

Students: LCDR Case Garrison, LTJG Ryan Bowers, Maj Mateo Salas, and Capt Matthew Curry

Background: As the Hispanic population increases, so does their representation in the U.S. armed forces. These trends have created great interest in the role of Hispanics in meeting the military's future manpower needs. Hispanic males have the highest interest in military service and active duty propensity, compared to other ethnic groups. Yet, Hispanics are currently representing 11.3 percent in the military as compared to 16.3 percent of the total U.S. population. This underrepresentation problem is greater in the officer corps than in the enlisted force as only 5.5 percent of total officers in the Department of Defense (DOD) is of Hispanic ethnicity. The issue of representation of Hispanic officers is especially critical at the highest-ranking levels within the Navy, with Hispanics flag officers accounting for about 240

officers in ranks from O7 to O10, or about 3% of the Navy officer corps in 2012. The representation and performance of Hispanics in the officer corps presents an ongoing challenge to Navy and DOD policymakers in maintaining diversity in the military.

Process: This on-going study has a two-fold objective: (1) using multivariate analysis, conduct a data intensive all-services comparative analysis of the retention and performance of Hispanic and non-Hispanic officers to identify factors (demographic characteristics, commissioning source, citizenship, country of origin, combat deployments, etc) that explain any differences in performance, as measured by retention and promotion; and (2) provide an assessment of factors that are shown to explain any differences in the performance of Hispanics versus non-Hispanics in the civilian labor market. This later objective can contribute to a better understanding of the performance of Hispanics in the military in the context of the overall labor market performance of the Hispanic ethnic group.

To conduct the statistical analysis, data records for officers in all services was requested primarily from the Defense Manpower Data Center (DMDC). In addition, longitudinal data files will be built to allow the analysis of career progress by selected cohorts of commissioned officers. This portion of the data collection will require sufficient data to follow entry cohorts longitudinally for as long as 10 years of service, for officers commissioned in fiscal year 1999 to 2003.

Findings and Conclusions: The findings of this on-going study will provide the Navy and DOD community with decision support for interventions to enhance retention and promotion by a diverse body of officers, and to meet the future manpower needs of the US military.

Recommendations: Recommendations that will be provided when the analysis of the data for this on-going study has been conducted.

N2/N6: Information Dominance

Establishing and Maintaining Semantic Interoperability Under Denied, Disconnected, Intermittent and Limited Telecommunications Conditions

Researchers: Dan C. Boger, Scot Miller, Arkady Godin, Wissem Tebai, and Ray Castillo

Students: Lt Wissem Tebai, and LT Raymond Castillo

Background: The volume of transmitted and processed data in current information technology (IT) systems is growing dramatically, adding challenges in data management and application interactions. Further, the semantic meaning of the exchanged data must be preserved and understandable. Therefore, achieving interoperability between different systems and applications is essential. This integration is usually complex and expensive. Moreover, it does not currently guarantee the exchange of the information's semantics. Military IT and Command and Control systems require sharing information among disparate systems and integration at the semantic level for the systems to communicate meaning effectively. The required integration step is called semantic interoperability (SIOp), and while critical, it is not fully understood, even with advanced capabilities.

Two NPS theses researched two components of this general problem. The first looked at the use of the Data Distribution Service (DDS) in support of achieving semantic interoperability in a Denied, Intermittent, and Low bandwidth (DIL) environment. The second thesis, still in process, is exploring the potential use of the semantic web to achieve semantic interoperability and is focusing on a specific use case.

This research is not directly related to an existing naval research program but touches ongoing research on the Navy Tactical Cloud and Big Data. Elements of both theses have been used in briefs to Navy and DOD organizations.

Process: The first part introduced standards used to implement SIOp. The second described the DDS open standard and compared DDS to web services as middleware technologies used to solve integration problems. The last part contains a suggested DDS design to meet the communication and interoperability requirements in a denied, disconnected, intermittent and limited (D-DIL) environment. The design was implemented in a general scenario to exemplify the tune-up of the system controls offered by the Quality of Service (QoS) provisions.

Findings and Conclusions: The DDS design was customized to the network environment limitations. The different protocols and interfaces used were related to the integration of the different nodes of the network and contributed to solving SIOp issues within the given system. Configuration of the QoS policies was dedicated to make the system work more efficiently and accurately. The overall idea is innovative and the design appears relatively successful in terms of simplicity and feasibility.

Recommendations: This research could be viewed as the first step to develop a middleware for system integration in D-DIL environment. Many commercial solutions can be used; however, to adapt one of them to a specific system can be hard and complex. Hence, we suggest the following:

- Develop and code a basic DDS solution for denied environment. Some of the offered solution can be modified to include a DDS minimum profile.
- Use some tools to help design and code interfaces for different systems. For example, the DDS code generator built by Milsoft.
- Experiment and test for better development using tools such as DDS Spy by Milsoft and Recording and Replay for DDS by Real Time Innovations.
- Further DDS related issues could be investigated such as mobility and security.
- Model the D-DIL DDS environment to determine our weak points and how much it scales given certain operational plans.
- Conduct thesis research on the efficacy of the Efficient XML Interface (EXI) W3C standard as it would apply to this scenario. (this is the subject of another Naval Studies thesis with a different PI).

Data Compression/Transfer Afloat Using Efficient XML Interchange (EXI) Standards

Researcher: Don Brutzman

Students: LCDR Steve Debich, and LT Bruce Hill

Low-bandwidth constraints are typically considered a showstopper for a tactical network with web-based interoperability. This has inhibited the deployment of structured data across Fleet

systems and perpetuated a system of inefficient stovepipes that do not provide the best possible information capacity or throughput. The researchers plan to employ a 4-step approach to address issues: ensure that the Open EXI codebase becomes relevant and effective for use across the Naval enterprise; understand the operational environment and associated requirements with representative use cases' evaluate practical EXI exemplars by comprehensively testing it against the sue cases; and produce recommendations for achieving broad deployment in Navy and joint tactical domains.

Naval Tactical Cloud Data Science and Analytics for Leveraging Meteorological and Oceanographic Tactical Data

Researcher: Arijit Das

Background: Naval Tactical Cloud (NTC) is a new architecture that uses Big Data tools to analyze tactical and non-tactical data in one merged platform. The project comes from the Army and is being adopted by the Navy. NPS researchers wanted to host a version of NTC on their local servers, and study the tools provided to see if Meteorological and Oceanographic (METOC) data can be combined with tactical data, to provide a unified picture.

Process: NPS researchers hosted the NTC development version on their virtual servers to study the various tools. The rack version was planned for a later date. The next stage was to understand how to map community data into NTC. This involved reading the documentation provided by the contractors working on this project. Researchers had to engage via the NTC community wiki and phone conference to pose questions and seek answers, and is an ongoing process.

The other effort was to seek out the METOC data from FNMOC (Fleet Numerical Meteorological and Oceanography Center). This lead to some sample datasets that the NPS researchers are analyzing. There is currently no server script to pull data on an automated basis from the FNMOC servers.

This research has not yet reached a conclusion as work is ongoing.

Findings and Conclusions: NPS has a pool of DOD researchers who, along with students, provide a good intellectual base to test the NTC Big Data tools. NPS participated with students and faculty on the learning of this new upcoming technology, while more needs to be done.

Recommendations: A sustained year-by-year partnership is needed to keep a continued effort. Hiring of tech savvy personnel will increase the value added to this research.

Cyber Threat Detection and Cyber Hunting

Researchers: Shelley Gallup, Thomas S. Anderson, Scott A. McKenzie, and Ryan F. Kelly

Students: LT Kenneth G. Baugess, LT Jason R. Chamberlain, and LT Samuel K. Chung

Background: Computer network defense systems should be sufficiently integrated to pull data from any information source, model an expert cyber analyst's decision process, continuously adapt to an evolving cyber threat environment, and amalgamate with industry standard network hardware. Unfortunately, cyber defense systems are generally stovepipe solutions that do not natively integrate disparate network systems. Correlation engines are generally limited in capability, extensibility, and do not evolve with a dynamic cyber threatscape. Current network defense systems mitigate known vulnerabilities, but effective methods of traffic analysis capable of detecting unknown exploits and identifying advanced persistent threats have yet to be developed. Expert analysts can isolate threats by manually aggregating data sources and distinguishing patterns that indicate a compromise, but there are insufficient skilled analysts available to combat the problem.

Process: This work demonstrates a process control configuration that can emulate the investigative process of a human cyber security expert into a pseudo cognitive apparatus, capable of accessing several network available data sources, determining a network threat, and terminating a connection, in minutes. The investigative process to detect a PHPMyAdmin attack and issue a response was entirely configured in a vector relational data modeling (VRDM) environment. The configuration can detect and respond to multi-part threat specifications from an organization's operating procedures.

Findings and Conclusions: The implementation and testing demonstrated the successful employment of an information apparatus that executed the complex processes necessary to mitigate phpMyAdmin cyber threats while the attacker was in the reconnaissance phase of the attack.

Recommendations: VRDM can be applied on a larger scale to detect insider threats that are not under the purview of traditional Network Intrusion Detection Systems and firewalls. There are many products that can be deployed and combined with VRDM to detect network intrusion and host configuration modification. VRDM can be of greater value if used to aggregate Host-based IDS (HIDS), net flow data, and session data from campus area network

Layer 2 and 3 devices to detect insider threats. Similar suspicion specifications can be configured to characterize the myriad of insider threat behaviors. secure shell commands can be used to impede insider threats using active response by instantly blocking certain transmission control protocol ports and switch ports on a wide range of manageable Layer 2 devices when a breach is detected. Integration of databases for event logs, system logs, web logs, packet captures, antivirus events, and HIDS events can be rapidly correlated within a VRDM configuration. A process specification can be used as a tool to perform relational investigations of suspicious network events. This tool can decrease the time it takes to identify malicious entities operating on a network. Specifications can be developed to modify the configuration of HIDS, host based firewalls, local security policy, and group policy in rapid response to these insider threats. VRDM information configurations can aggregate “hacker” tools into a composite system. The intrusion sequence of scanning, enumeration, gaining access, and escalating privilege can be automated with an executable configuration. Multiple “hacker” tools such as Nessus, Metasploit, Netcat, Brutus, and Network Mapper can form a powerful composite tool for computer network attack (CNA). The implementation of an expert process control specification for network defense is similar to a process control specification for CNA. A process control specification that uses common hacker tools integrated into a VRDM could be an effective tool for cyber intrusion.

VRDM can be taught quickly to an army of cyber warriors, providing them with knowledge of how to configure information from any technology or domain into a mission process. This would enable cyber subject matter experts to transform the data in static log files into actionable information and allow automated process to be rapidly configured according to a mission’s or subject matter expert’s specific Concept of Operation. The technology can be used to rapidly deploy threat analysis and cyber hunting specifications at the enterprise level without costly programmer education and complex correlation engines.

Support to Fleet Experimentation

Researchers: Shelley P. Gallup, and Randy Maule

Background: The Fleet Experimentation (FLEX) program is run by Navy Warfare Development Command (NWDC). NWDC plans and conducts experiments in different venues, including Trident Warrior. NPS (DISE) has been the lead for experiment design and analysis of the Trident Warrior series for the past 13 years. In FY 14, a decision was made to bring all efforts within NWDC, and supplement with analysis organization support where funds are available. The NPS support for FLEX in FY 14 was focused on the Valiant Shield exercise, in two primary areas; the Link Monitoring and Management Tool (LMMT), applied to aggregation of

intelligence, surveillance, and reconnaissance information, and the Multi-level Assessment and Evaluation (MLA&E) methodology. A third experiment initiative, Net-T Enabled Common Data Link Network applied to the Joint Aerial Layered Network, was planned but not executed because of loss of Air Force funding at the last minute.

Process: NPS personnel with extensive experience in experimentation design, planning, execution management and analysis, attended an initial, main, and final planning workshop at the Pacific Warfighting Lab at Ford Island, Hawaii. The NPS role was to assist in the design of experiments, create data collection instruments, design network data collection installations, and assist with the management of the final experiment plan. Execution of the experiments occurred in multiple areas of the Pacific area of responsibility, but principally in Guam and Hawaii. The NPS principle investigator (PI) and Co-PI were actively involved in data collection efforts. Currently, data reduction and analysis are in progress. These activities are in collaboration with other agencies such as Naval Air Systems Command (Patuxent River and Point Mugu) and Naval Sea Systems Command Corona (for MLA&E). NPS will write final reports required for NWDC and United States Pacific Command sponsors.

Findings and Conclusions: The experiment results are classified; however, there are some general conclusions that can be made. The MLA&E effort has produced higher than usual fidelity of results from exercise data. These results will help add increased accuracy to a model of the specific operational threads (Surface Action Group (SAG) v. SAG scenario) and architectures which support the model. The intent is to improve this method of data collection and analysis, and support better decision-making in building requirements. LMMT experiments assessed Tactical Data Link (TDL) network gateways for Integrated Air and Missile Defense. LMMT is scheduled to replace current TDL gateway services in FY 15 and will provide TDL network monitor and management and a means of defend the Common Tactical Picture (CTP) during cyber and electronic attacks. Multicast TDL communications were instrumented and watchstander observation data was collected at the Commander, U.S. Pacific Fleet Data Fusion Center. Analysis of data is currently ongoing.

Recommendations: Experimentation support continues to be important to gaining reality-based data from the field. The FY 14 effort will be continued until March of FY 15 to fully analyze, assess, and report findings. However, there are new requirements for continued field experimentation support which FY 14 funds can still support. We are hopeful that any leftover funds can be used to continue this effort through the rest of FY 15.

Using UAS to Sense the Physical Environment and Predict Electromagnetic System Performance

Researcher: Peter S. Guest

Student: LT Ray Machado

Background: This study provides guidance on the feasibility of Navy use of unmanned aerial systems (UAS) for Meteorology and Operational Oceanography (METOC) measurements. This study is ongoing; more results and considerably more details on the following results will be provided in a final report.

Process: The study consisted of:

- (1) Analysis of data from the Trident Warrior Field Program, which involved collection of data with the Scan Eagle Unmanned Aerial Vehicle (UAV) and various supporting measurements. The Principle Investigator met with scientists from the Naval Research Laboratory, Monterey, who performed the model runs several times and discussed how UAS can be used to improve battlespace awareness of electromagnetic propagation properties and electronic maneuver warfare.
- (2) Survey of Navy UAS platforms.
- (3) Survey of civilian use of UASs for collection of meteorological data and interaction with scientists at scientific conferences
- (4) Report on cost projections for Navy operational use of four small UAS: Sky Ranger, DragonFlyer, InstantEye, Phantom.
- (5) Accuracy analysis of atmospheric measurements using meteorological sensors attached to the InstantEye miniature quad-copter UAV.

Findings and Conclusions

Trident Warrior: Trident Warrior demonstrated that UAS data could be ingested into the Coupled Ocean/Atmosphere Mesoscale Prediction System numerical weather prediction model in near real-time and provide accurate details of atmospheric temperature and humidity structure, which are important to predicting the impact of the atmosphere on electromagnetic systems such as radar, communications, electronic surveillance measures and jamming.

Navy UAS: The Navy uses a plethora of UAS systems for various uses. However, none are currently used for meteorological measurements. Some have temperature sensors, but none have humidity sensors—the latter being critical for electromagnetic propagation predictions.

Civilian UAS for atmospheric measurements: These platforms have proven to be very useful and often can collect data that is not available in any other way. Many innovative sensor suites have been developed.

Cost Projection Study: Estimated costs for Navy deployment on 10 ships for 10 years was as follows: SkyRanger, \$35 million; DragonFlyer, \$ 5 million; InstantEye, \$1.1 million; Phantom, \$410 thousand.

InstantEye Accuracy Analysis: Temperature 0.1 C above 4 m elevation, 0.2 – 0.8 C below 4 m depending on conditions, Relative Humidity accuracies to be determined.

Other Findings and Conclusions: The use of UAS for meteorological measurements on Navy vessels is technologically feasible today and would provide valuable information on the battlespace environment and effectiveness of electronic maneuver methods. The main barriers to use are cultural; Navy leadership and ship captains need to be convinced that these types of measurements provide enough benefit to justify the cost, use of personnel, ship space and air space around the ship.

A serious issue hindering the development of UAS systems for METOC operational use is the costly procedures required to get Naval Air Systems Command's (NAVAIR) approval for flight operations, even for very small UAS that are unlikely to cause serious injury or asset damage. In our case, obtaining the interim flight clearance (IFC) for the use of InstantEye for METOC measurements was \$18K, for a platform that weighs less than 2 pounds and cost \$2K per vehicle. We discovered that many groups within the Navy have ignored the requirements and have flown UAS without IFCs.

Recommendations: We recommend that more experiments be performed on board research and Navy vessels to demonstrate to the leadership the utility and value of the use of UAS for improving weather predictions and characterization of the electromagnetic propagation environment.

We recommend that NAVAIR institute a special category for very small UAS, so that the IFCs for this type of UAV can be obtained with less cost and labor requirements. This would encourage further development of METOC UAS.

Underwater Experimentation Arena for Development Testing and Evaluation of Autonomous Capabilities

Researcher: Douglas Horner

The proposed research addresses the development and use of an Underwater Experimentation Arena (UExA) to support advanced concepts in undersea unmanned-system navigation. The UExA will form a vital bridge between laboratory and open ocean experimentation, providing ground truth measurements to decouple perception and control problems in a realistic ocean environment.

Developing Cyber Skills in Information Dominance Corps Officers

Researcher: Cynthia E. Irvine

Summary: This funding supported travel and supplies for student thesis research on cyber training within the officer Information Dominance Corps (IDC) community [1]. The work initially started with the following questions:

- Why does the Navy require specialized cyber education for officers?
- Who are the best candidates to receive specialized cyber education?
- What are the requirements to train officers in cyber?
- How do you transform officers into cyber warriors?
- Where is/are the ideal location(s) to conduct specialized cyber education?
- When is the ideal time window to educate officers in cyber?

The results of the effort can be summarized as follows.

The Department of Defense (DOD) and its service components are taking an aggressive stance to dominate cyberspace as a warfare domain. The U.S. Navy needs a workforce capable of conducting DOD Information Network operations, Defensive Cyber Operations, and Offensive Cyber Operations. Although a cyber-education program is in place at the Naval

Postgraduate School for select IDC officers, the U.S. Navy also needs a program capable to train a large specialized corps of leaders so that the military value of cyberspace can be optimized in future operations. This thesis surveyed two high-level cyber-education training frameworks, as well as one training and one education program, and merged their perspectives into one training course. This resulted in a set of potential learning objectives that can serve as a starting point from which to further define a cyber-training course for IDC officers. This work is not immediately actionable. Future work will require a number of steps ranging from requirements definition by subject matter experts to the design of the course and its metrics. Ultimately, this will become a training course that can be adapted over time to meet the evolving cyber training requirements of the U.S. Naval IDC officers.

References

[1] Jerry W. Wyrick. Initial recommendations for level 3 cyber skills training for IDC officers. Master's thesis, Naval Postgraduate School, Monterey, California, March 2014.

A Secure Lifecycle Framework for Shipboard Machinery Control System Development

Researcher: Cynthia E. Irvine

Motivation and Background: Attacks on machinery control systems (MCS) transitioned from hypothetical demonstrations to reality with the discovery of the Stuxnet worm in June 2010. A targeted operation, this attack was carefully designed to cause selected critical equipment in specific configurations to run outside of its recommended operating range. Thus, despite the fact that the malware was propagated via a worm that infected other systems, its effects were only felt by the target.

Cleverly constructed to use five zero-day attacks, four against Microsoft systems in the network and one against Siemens software, Stuxnet showed that the target system had only an illusion of isolation. Thus, the axioms for the security of the target system were flawed.

Security for Naval machinery control systems could be similarly problematic.

Deployed across a variety of shipboard assets and heavily networked, MCSs monitor the condition and integrity of the ship's physical plant; their feedback systems and actuators modify infrastructure behavior. Component interdependencies create possibilities for unplanned entry points to data and catastrophic cascading failures. Esoteric hardware, software, and interfaces, combined with physical isolation, offered early MCSs a semblance of

security. Yet, there is no palpable reason to believe they have ever been secure. Adversaries could have subverted them long ago during their development and adversaries known as advanced persistent threats could be lying in wait to trigger their attacks at the appropriate moment.

An example of subversion was the malicious code inserted into control software as part of an intelligence operation several decades ago. Stolen and used by the Soviet Union, the malware caused a 3 kiloton explosion in the then new trans-Siberian gas pipeline. As a result, all of the software stolen by the Soviets from the United States over the years was suspect and the Soviets had an “American software problem.”

Navy ships are built to last for decades; their machine control systems must be designed for long-term use. Furthermore, systems that to civilians might seem to be of marginal importance can be critical within ship-board contexts. Failure of one or more of these systems can affect human health and safety, and, ultimately mission assurance. Unless cybersecurity is considered in MCS construction, these system are vulnerable to advanced persistent threats.

Approach: The objective of this research is to draw upon the rich body of knowledge that has been established for the construction of highly trustworthy information technology systems. Based upon threat analyses, early and subsequent standards were established for trustworthy system construction. The objective of the standards has been to inform developers of highly critical systems of requirements that must be met in order to address the subversion threat during the lifecycle process.

Unfortunately, the standards only state what must be done, but do not provide guidance on how to do it. In fact, since commercial vendors often develop such systems for the government, the lifecycle processes for highly trustworthy systems have been proprietary. This research activity addresses that problem as it applies to machine control sub systems.

This executive summary is provisional and will be updated when the effort is completed.

Study Activities:

Machine Control System Analyses: Student thesis work supervised by members of our larger team has explored threats to and tools for the development of shipboard MCS.

Information Control Systems (ICS) Adversarial and Defensive Tools: The lack of a centralized repository of tools to experiment with ICS, and consequently MCS from a cyber-security perspective was identified. To address this problem, this work examined all publicly available defensive and adversarial ICS-related tools to create a consolidated list based on relevance in the ICS domain. A small number of tools were selected for hands-on evaluation in an experimental supervisory control and data acquisition (SCADA) test environment to verify

each tools availability, to investigate if the tool worked as described, and to confirm the existence of appropriate documentation sufficient to install and use the tool. As a result of this survey and tool evaluations, the Moki Linux distribution was developed and released. The release is an ICS-centric version of Kali Linux tailored with defensive and adversarial tools for security practitioners and researchers in the ICS domain.

MCS Log Data Threats: The second thesis explored the possible disclosure of sensitive information via the logs of shipboard MCS. MCS data can provide insight into operations, maintenance, and the leaderships decision-making process. In addition, most of the data generated by an MCS is unclassified and not properly protected during transit and at-rest. This potentially enables adversaries to mine MCS data to produce intelligence about U.S. military ships and to develop cyber-attack plans.

The work analyzed the MCS data logs to understand what information MCS can unintentionally provide the enemy and how adversaries can potentially utilize this information to attack shipboard systems and impact operations. The study confirmed that a cyber-actor could use MCS log data to construct an accurate operational view of a ship by analyzing the most current event of each MCS component. For example, an adversary can determine whether a ship is underway or in port, or operating at full or degraded capacity by observing the timestamps captured in the log.

In addition to this work, several class projects in the Cyber Systems and Operations program, managed by the NPS Cyber Academic Group, explored threats to MCS and are investigating development MCS processes. Brief project descriptions are provided below.

Message Authentication in Platform Independent Machinery Control Systems PIMCS (Fall 2013): The PIMCS framework was developed as part of a collaborative effort between the United States Coast Guard (USCG) and the Navy, under the auspices of the Coast Guard Machinery Control System (CGMCS) program.

The initial PIMCS/CGMCS implementation provides neither message authentication nor replay protection between the following components:

- Human Machine Interface (HMI) systems;
- HMIs and Programmable Logic Controllers (PLC);
- HMIs and Logger systems; and
- PLCs and Logger systems.

This project investigated the use of IPSec with manual keying to provide message authentication and replay protection for the PIMCS/CGMCS network on a USCG National Security Cutter. The tasks included:

- A survey of best practices for using Internet Protocol Security (IPsec) multicast in real-time embedded systems.
- A survey of IPsec products that support multicast.
- Recommendations for IPsec configurations to implement a bump-in-the-wire.
- An IPsec-based MCS design that can satisfy Sandia's recommendations regarding message authentication and replay protection.
- A key management design that addresses the entire lifecycle of cryptographic keys and other keying material and that is resilient to unauthorized key disclosure.

Continuous Security Monitoring for MCS (Spring 2014): National Institute of Standards and Technology Special Publication 800-137, defines Information Security Continuous Monitoring (ISCM) as "maintaining ongoing awareness of information security, vulnerabilities, and threats to support organizational risk management decisions." The DOD has adopted ISCM for cyberspace defense. DOD components are required to "establish and maintain a continuous monitoring capability that provides cohesive collection, transmission, storage, aggregation, and presentation of data that conveys current operational status to affected DOD stakeholders." Continuous monitoring of adversarial activities (e.g., advanced persistent threats, cyberspace exploitations) and network operations (e.g., traffic load, performance) can help determine the impacts of cyber-attacks on system operations.

Zabbix provides real-time monitoring of computer and network systems. Open Source Security Information Management (OSSIM) is a Security Information & Event Management tool that collects, stores, and interprets system logs.

This project investigated the use of OSSIM and Zabbix in a PCMCS network. During this project, students performed the following tasks:

1. Acquired a full understanding of the tools being investigated. This includes installing the tools and running experiments to gain insight on each tools capabilities, system architecture, software design, and dependencies. This task also included a survey of comparable commercial products.

2. Determined how to use the tools in an ICS. This task included testing the tools with the Tofino SCADA Security Simulator kit, and developing a network architecture for a typical ICS deployment that uses the tools for continuous monitoring.
3. Proposed how the tools can be used in PIMCS. The proposed design was intended to identify the modules (plugins) that must be developed or customized for PIMCS.

Revision Control System for MCS (Fall 2015): This project is ongoing and students are investigating two revision control systems, Apache Subversion (SVN) and Git. The tasks are as follows:

- Survey known threats against revision control systems.
- Survey known attacks against an SVN server and a Git server, including how such attacks could theoretically damage the lifecycle maintenance of MCS software artifacts.
- Recommend how to secure an SVN server and a Git server for use in PIMCS development. This includes eliciting functional and security requirements from PIMCS developers.
- Recommend a revision control system and the method for configuring/hardening it, for use in PIMCS. This must include, but not limited to, discussion of the following:
 1. Existing DOD secure development processes, procedures, recommendations, security technical implementation guides, etc. that include the use of a revision control system.
 2. Challenges for using a revision control system in a disconnected development environment. For example, the revision control system resides in a disconnected laboratory and the corporate local area network is where non-developers (systems engineers, managers, auditors, etc.) view related artifacts.

Recommendations and Processes for Vulnerability Mitigation: As a result of our analysis, we have developed a set of documents that can be used to guide the development of highly trustworthy machine control systems. To date, these documents include:

- Lifecycle Management Plan: The overall purpose and guiding principle for this document is to provide a methodology which will result in the creation of a product that will have a high level of assurance of its security policies being sound and correctly implemented.

- Configuration Management Plan: This document describes the procedures and policy for Configuration Management (CM). The objectives of this CM plan include ensuring the integrity of the configuration items, tracking changes to the configuration items, and ensuring only authorized changes are made to the configurations items.
- CM Procedures: The purpose of this document is to outline the procedures for the CM process. These procedures are meant to provide lower-level details necessary to implement the process laid out in the CM Plan, and to ensure consistency in the exercise of the process.
- Trusted Distribution Plan: This document describes the policy and high-level processes for the distribution of the product to external users. This document is driven by the Lifecycle Management Plan, the CM Plan, and the Quality Assurance Plan. The policy and high-level processes described meet the packaging and delivery requirements described in the Lifecycle Management Process (LCMP). This document also provides the framework for the Integration Procedures and the Delivery Procedures identified in the LCMP.
- Quality Assurance Plan: This document expands and unifies the testing requirements that are stated in the Lifecycle Management Plan, the CM Plan, and the Software Development Standards.
- Low-level Design Document Standards: Low-level design documents provide a detailed description of one or more modules. The level of detail should be sufficient such that two independent implementations will produce functionally equivalent modules. A standard format is essential to ensure that all requirements are met, to ensure a common look-and-feel, and to facilitate collaboration among team members. This document guides the creation of that material.
- Software Development Standards: This document provides policy and process for developing and approving software-related configuration items, giving more detail than was covered in the Lifecycle Management Plan and the Documentation Development Standards.
- Personnel Security Plan: This plan provides the personnel policy necessary to protect the confidentiality and integrity of project data during the development and maintenance phases of its lifecycle.

Each of these documents have been developed based upon the author's experience in the specification and creation of highly trustworthy systems. During the last phase of this effort,

the documents will be reviewed for consistency as an integrated set of lifecycle recommendations for highly trustworthy systems.

Lifecycle Methodology for System of Systems Capability and Integration Analysis

Researcher: Randy William Maule

Background: The project provides model integration with SPAWAR 5.0 Executable Architecture Requirements Model (ExARM) for the Office of the Chief of Naval Operations (OPNAV) Portfolio Health Assessment (PHA).

Fleet experimentation results have not been sufficient to transition capability gap solutions into Programs of Record (POR). Concurrently, OPNAV PHA relies on ExARM models which may not reflect current ship practices due to systems upgrades, integration of cross-service, agency systems, or changes enacted during ship deployments. Each may result in new technical or operational capabilities.

This project integrates tested systems and processes for identified capability gaps through model development and validation. A research workflow is established between the Naval Postgraduate School (NPS) for faculty and student research, Space and Naval Warfare Systems Command (SPAWAR) for model engineering and validation, the numbered Fleet for exercise experiment results, and OPNAV for PHA Program Objective Memorandum (POM)/POR processes.

Process: Valiant Shield 2014 (VS14) was chosen as the experimentation venue for current evaluation of systems and processes for 2014 ExARM/PHA modeling. VS14 was executed in the Guam operating area with two aircraft carriers, 19 ships, submarines, 200 aircraft, and 18,000 Navy, Air Force, Marine, and Army participants. Selected technologies were evaluated across multiple tactical and operational scenarios, each with varying levels of communication jamming, radar spoofing, and red team cyber-attacks.

Network and Tactical Data Link (TDL) packets were captured at Commander, U.S. Pacific Fleet Data Fusion Center to refine and validate models for next-generation TDL networks. Models include TDL relationships with Joint Range Extension, Air Defense Systems Integration, Global Command and Control System–Joint, and Maritime Tactical Command and Control. Also included are test results and models for Navy Integration and Interoperability Mission Level Assessment and Evaluation for Surface Warfare objectives.

A workflow was developed to integrate NPS Fleet experimentation models into SPAWAR ExARM for OPNAV PHA review. Analysis included system interfaces to Navy networks, integration across networks and systems, and component and process measurements.

Findings and Conclusions: Integration between Fleet research faculty and students for modeling, test, and measurement of new systems and processes to address Fleet capability gaps, SPAWAR ExARM modeling, and OPNAV PHA was achieved. Results will inform SPAWAR of ExARM technical baselines and OPNAV for PHA funding decisions. OPNAV achieves system test results to meet identified capability gaps, SPAWAR receives model validation from operational tests and new models for ExARM/PHA analysis, and NPS students and faculty benefit from Fleet operational research. Test data will provide the basis for NPS faculty and student research, and will be integrated into appropriate repositories to support OPNAV portfolio analysis and SPAWAR engineering.

Recommendations: Continue to refine the lifecycle analysis and workflow between NPS, SPAWAR, and OPNAV. Continue the integration advanced in this project to provide needed research for OPNAV, researchers on-deck for SPAWAR, and hands-on learning experiences for NPS student officers. Develop an integrated database of test results and models to enable the acquisition community to quickly ascertain operational system status and results from tested capability gap solutions. Expand the workflow designed in this project across the Fleet field research community to enable Fleet exercise teams to validate current models and input new models and findings.

Sea Cyber Test Range for Assured C2 Networks and Systems

Researcher: Randy William Maule

Student: LCDR John Loomis

Background: A method is advanced to evaluate Navy Enterprise Cyber Systems Readiness (ECSR) with a focus on ship and officer preparation for Command and Control in a Denied or Degraded Environment (C2D2E) under cyber and electronic attack. Research is specific to emergent cyber techniques which cross academic disciplines and for which study is more applied than traditional officer preparation.

Enterprise system cyber approaches are evaluated as a means to evolve Navy architecture and officer preparation to achieve ECSR. Analysis is derived from enterprise cyber

technologies assessed by the author over the past 15 years in Fleet exercises, examination of recent cyber-attacks, and assessment of Fleet-tested systems to mitigate cyber and electronic attacks. Student thesis and project research data was collected during Composite Training Unit Exercise (C2X) 2014 that tested electronic attacks against combat systems, and Valiant Shield 2014 (VS14), which evaluated C2D2E in Anti-Access Area-Denial (A2AD) cyber scenarios. Participants included two aircraft carriers, 19 ships, submarines, 200 aircraft, 18,000 personnel, and offensive/defensive red/blue electronic and cyber operations.

Process: Assessment metrics were developed to address ECSR in A2AD scenarios with cyber and electronic attacks and off-ship communications jamming. In this analysis, ship personnel would be considered ECSR sufficient if able to independently operate mission-critical enterprise infrastructure within the hull of the ship when communications were denied, and also to synchronize enterprise systems, applications, and data with nearby ships and shore sites when communications were restored. Research metrics framed attack trends documented by major cyber security firms and the hacker profession. Metrics based on identified ECSR gaps provide the basis for cyber enhancements to the Naval Postgraduate School (NPS) Service Evaluation Architecture (SEA) test and measurement laboratory to help evaluate ship enterprise systems and prepare officers for ECSR.

Findings and Conclusions: ECSR metrics were advanced to help assess Fleet officer readiness for C2D2E and A2AD. Metrics were referenced against selected DOD university curricula, industry cyber security certification as adopted for Fleet information technology/cyber careers, current attack trends noted by cyber security firms and the hacker community, and proposed solutions as advanced in Fleet experiments over the past 10 years. Results indicate a significant capability gap in ship enterprise cyber systems technology and Fleet officer ECSR preparation.

NPS SEA Cyber Laboratory for officer ECSR research and practice is being developed in consultation with: SPAWAR 52100 Readiness Kill Chain analysis, Space and Naval Warfare Systems Center Pacific 58250 Navy Cyber Situational Awareness, Program Manager Warfare160 Consolidated Afloat Network Enterprise Services, and Navy Air and Missile Defense Command Tactical Data Link (TDL) management for Integrated Air and Missile Defense (IAMD). SEA Cyber tests will support TDL assessment, operations of Collaboration at Sea and Maritime Tactical Command and Control, and Ozone components of Distributed Common Ground System Navy. SEA Cyber supported NPS officer thesis research on Digital Radio Frequency Memory attack mitigation, with data collection during C2X and VS14.

Recommendations: Research indicates officer preparation in enterprise cyber systems is insufficient and there is minimal deployment of enterprise cyber systems on ships, leaving the Navy highly vulnerable in Anti-Access Area Denial scenarios. A recommendation is for

adoption of automated enterprise cyber systems technologies, and an officer ECSR preparation regimen that includes targeted academic studies, cross-discipline education, and continuous in-service training in applied settings. Comprehensive cost-benefit analysis is recommended to confirm that ship enterprise operating costs can be reduced while cyber security is improved through the ECSR method advanced in this project.

3D Simulation Database for NPS C4ISR Research and OPNAV Capability Analysis

Researcher: Randy William Maule

Student: LCDR John Loomis

Background: NPS faculty and students engage in Fleet exercises, providing experiment research to assess new technologies and validate proposed processes. Experiments generate contextual data as scenarios emulate real-world conflicts in live operations. Data can provide useful information for OPNAV capability and cost-benefit analysis, but is not generally available in a user-friendly format.

NPS researchers and students have provided analysis support to the Fleet for the past 15 years. However, after the analysis is complete, the capability to recreate test events in a capacity sufficient for continuing analysis is lost. This results in experiment duplication and cost inefficiencies, often spending millions of dollars to examine issues for which solutions have already been found. The need is for an on-demand, event reconstruction capability, specifically a 3D simulation repository based on assessments of Fleet mission capabilities, with presentation in a format conducive to OPNAV analysis. This project advances such a solution.

Research was collected at Valiant Shield 2014 (VS14) in the Guam operating area. VS14 featured two aircraft carriers, 19 ships, submarines, 200 aircraft, and 18,000 Navy, Air Force, Marine, and Army participants. The NPS research team evaluated systems/processes across seven vignettes that emulated real-world scenarios to assess technical/operational solutions to current capability gaps. Scenarios included communications jamming, radar spoofing, and cyber-attacks.

Process: Recent experiments have integrated Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance and combat systems in tactical field tests. As analyst in these experiments, the NPS team has worked with defense

contractors and DOD sponsors to develop DODAF models for systems to be installed on Navy ships/facilities. Test results are documented, but due to time constraints, models are not updated to reflect actual operational conditions. Comprehensive impact analysis is not conducted, and procedural workflows are not presented in a manner sufficient for command operational decisions, event reconstruction, detailed post-experiment excursion analysis, or OPNAV capability assessment. A mission-based simulation database with live performance data sufficient for 3D virtual event replay would provide a more accurate reference for OPNAV than current reporting techniques, significantly lower Navy integration costs, and provide a more accurate means for effectiveness measures and capability cost-benefit analysis.

Findings and Conclusions: 3D simulation development for tactical scenarios evaluated in VS14 are in process. Selected events and systems will be simulated to supplement test results and provide a visual record of exercise experimental technologies/processes. VS14 and Composite Training Unit Exercise (C2X) 2014 simulations will focus on Tactical Data Link (TDL) analysis, Digital Radio Frequency Memory (DRFM) spoofing, and cyber/electronic attacks. TDL and network data was successfully captured at COMPACFLT Data Fusion Center and in combat systems aboard USS BARRY (DDG-52). TDL relationships will be simulated for Integrated Air and Missile Defense network operations and Navy Integration and Interoperability (I&I) Mission Level Assessment and Evaluation.

Recommendations: Develop systematic program for NPS officer and faculty development of 3D simulations of complex Fleet exercises to enable event replay, excursion analysis, and capability assessment. This effort will reduce costs for large operational experiments through elimination of redundant tests and optimize results for systems evaluations. Continue development of 3D operational simulations that integrate Fleet experimental systems with data collected during Fleet exercises into a repository for NPS student officer reference and OPNAV capability cost-benefit analysis.

Planning for Climate Change

Researchers: Tom Murphree, and Arlene Guest

Student: LCDR Jennifer Cline

Background: Climate change poses significant challenges to the Navy, including the impacts of climate change on infrastructure; energy and water use; sensors, weapons, and personnel performance; and civil and military threats. However, there is a great deal of uncertainty about: (a) the specific impacts for which the Navy must plan; and (b) how to develop policy,

planning, and management (PPM) strategies for dealing with the impacts. This is due in part to PPM processes that are not well-suited for dealing with large, persistent, and unprecedented changes in the physical, economic, political, and security environment.

Process: In our study, we are analyzing: (1) climate and impacts data from the last several decades; (2) projections of future climate conditions and impacts; and (3) existing and proposed PPM strategies. Our focus is on assessing: (a) operational impacts of actual and projected climate changes; and (b) corresponding PPM responses to those impacts. Our main objective is to assess and recommend methods for improving the Navy's planning for climate change (e.g., improving the use of scientific/engineering analyses in developing climate change PPM processes). Our primary focus is on the impacts of sea level rise (SLR) on Navy bases in the mid-Atlantic coastal region, and the responses to those impacts. However, we expect that the results of our study will be applicable to a wide range of climate change impacts. This study will continue into 2015, so our findings, conclusions, and recommendations are still preliminary.

Findings and Conclusions: Our preliminary findings indicate that:

- Scientific/engineering studies of the impacts of SLR are essential, but the utility of these studies is reduced because they are generally developed with only a limited understanding of how they will be used by policy-makers, planners, and managers. These studies would be more effective if they were designed and developed to fit directly into a clear set of climate change PPM processes.
- The existing processes are not well determined, mainly because the instructions that govern them are broadly worded, brief, non-prescriptive, and insufficiently linked to relevant PPM processes being developed and used by other DOD and civilian organizations (e.g., Army Corps of Engineers, neighboring state and local agencies).

Recommendations: Our preliminary recommendations are that greater emphasis should be placed on developing:

- Integrated climate change PPM processes, that: (a) better merge scientific/engineering assessments with the applications of those assessments in PPM; and (b) allow for on-going feedbacks between assessment and applications efforts.
- PPM processes that: (a) apply established strategies for managing uncertainty (e.g., hedging, no regrets, adaptive management); (b) leverage the relevant PPM processes and resources of other DOD and civilian organizations; (c) are well integrated with the processes used by those other organizations; (d) provide the needed when developing

and implementing multi-decadal PPM approaches support (e.g., special resources, top cover); and (e) are specific, detailed, and prescriptive.

Methods of Finding Malicious Files by Cross-Drive Forensic Comparison of Times

Researchers: Neil C. Rowe, Riqui Schwamm, and Chris Herridge

Background: We investigated nontraditional clues to malware on a computer system involving time, with the goal of finding new clues to malware beyond those of traditional signature-based anti-malware software.

Process: We did this by looking at the context and metadata clues of examples of malware found in a corpus of 250 million files with 42 million distinct hashcodes found on 3900 drive images. These files were obtained from 32 countries and were supplemented with data from classroom and laboratory computers at our school. For testing, we used five different methods to identify 395,643 hashcodes (for 612,818 files) in our corpus as malicious (using the Bit9 Cyber Forensics Service, Symantec Antivirus, and ClamAV as antivirus scanners and matches to the Open Malware and VirusShare malware collections), and we used three different methods to identify a total of 2,618,210 hashcodes of safe or “whitelist” files for comparison (explicit identification as safe by the Bit9 Cyber Forensic Service, appearance in the National Software Reference Library, and lack of malware identification for a random subset of our corpus).

Findings and Conclusions: It turned out that time-based clues were not particularly strong, so we broadened our scope to look at a variety of other metadata clues, and did find some good ones. Many clues to malware frequently mentioned in the literature, such as executable files, atypical creation times for a directory, and file-type inconsistency between extension and header data did not show well with our corpus. On the other hand, good clues were a file size logarithm around five or around 15, files at top-level of the directory structure, deleted files, rare hash values, rare extensions, double extensions, long extensions, repeated patterns in the file path, photograph extensions, executable extensions, query extensions, installation extensions, miscellaneous extensions under 100 occurrences, audio directories, security directories, and game directories.

We used the clue strengths observed to build a program that assigns a probability of being malicious to a file. We showed in experiments with random selections from our corpus that our ranking methods could obtain a recall (fraction of malware identified by our methods of

all malware known by any method) of 0.340 and precision (fraction of malware in those identified by our methods as malware) of 0.212, and 0.650 recall with 0.010 precision. This contrasts with the approach of inspecting only executables as potential malware, which gave a recall of 0.190 but a precision of 0.010, and the inspecting only files in the operating system as potential malware, which gave a recall of 0.189 and a precision of 0.001. This provides guidelines for better “quick scans” of malware, with better criteria of what to look for, and not confine to executables or operating system directories.

Recommendations: We provide specific advice on where to look for malware on computers and devices. There was significant disagreement between the malware-identification methods, as to what was malware and what were the good clues for it, since only five percent of the malware identified by any one method in our experiments was also identified by another method. This low degree of overlap suggests that it is a poor idea for the Navy to rely on any single anti-malware product to defend its systems. In particular, comparison of files to those in malware libraries should be a high-priority supplement to standard antivirus software since signature-based methods are not finding much of the contents of such libraries.

Mobile User Objective System Applications In Support of the Tactical Warfighter

Researcher: Alan D. Scott

Students: Capt. Patrick Schrafft, and LT Ryan Seggerty

Background: The Mobile User Objective System (MUOS) adapts Wideband Code Division Multiple Access (WCDMA) cellular technology with geosynchronous satellites to provide internet protocol (IP)-based voice and data communications to mobile users via MUOS Functional Terminals (MFTs). The implementation of WCDMA technology will significantly enhance the narrowband communications capabilities available to the warfighter by enabling the development of associated applications hosted on computer and weapon system platforms. These applications can leverage the tactical networking capabilities offered by MUOS to support communication and information needs for a variety of missions and platforms.

While offering a tremendous increase in capacity and capability, MUOS WCDMA technology is a significant departure from the legacy narrowband voice and data communications currently used by operational forces. To fully exploit the IP-based communication capabilities of MUOS,

a focused effort is required to identify, develop, and test applications to support Navy, Marine Corps, and joint warfighters. This project intended to identify MUOS applications that can support specific missions and platforms and define the requirements, architecture, and associated Concept of Operations (CONOPS) for these applications. In addition, feasibility of modeling the identified applications and associated MUOS network communications using an appropriate network-modeling tool was explored. While considered follow-on activities in the original project plan, modeling of tactical applications over a simulated MUOS network was performed, and successful testing of applications hosted on weapons systems interfaced with MFTs was conducted over live MUOS satellite communications (SATCOM) networks.

This research was sponsored by the Navy Communications and Networks Division (OPNAV N2/N6F1) under the Deputy Chief of Naval Operations for Information Dominance (OPNAV N2/N6). This effort will aid in the mission accomplishment of OPNAV N2/N6F1 by identifying operational applications of the MUOS system and developing the necessary framework to implement these applications, thereby furthering operational integration of MUOS into warfighter operations.

Process: The following process was employed in the execution of this project:

1. Two operationally experienced students were recruited to participate in the study. The students identified specific missions and associated platforms relevant to their warfare communities that could potentially leverage MUOS IP-based communications capabilities and determined specific applications required to support those missions and platforms:
 - a. Capt. Patrick Schrafft, USMC, investigated application of MUOS to Marine Corps fire support communications/coordination using StrikeLink and the Advanced Field Artillery Tactical Data System (AFATDS).
 - b. LCDR Ryan Seggerty, USN, investigated applications of MUOS to Navy helicopter missions, including vertical replenishment, medical evacuation, combat search and rescue, anti-surface warfare, anti-submarine warfare, maritime interdiction, close air support, intelligence, surveillance and reconnaissance, and special warfare support.
2. The students defined the requirements, architecture and CONOPS for the identified applications and other user equipment hardware/software needed to support their selected missions/platforms. Throughout this process, they interfaced, as required, with appropriate user communities, platform program management offices, and MUOS program stakeholders.
3. The students assessed feasibility of modeling the identified applications and associated MUOS network communications using an appropriate network-modeling tool, and

developed a plan for modeling and simulation of the identified applications and associated MUOS network operations, including identification of required hardware/software and network modeling tools. This activity required interfacing with appropriate warfare community and MUOS program representatives along with network modeling experts at NPS as well as within DOD and industry.

4. The students planned the development and integration of the required applications on simulated and actual host platforms and developed a strategy for testing of the applications in a tactical networking experiment. This task included investigation of potential involvement by other NPS academic departments and research centers, such as the Computer Science Department and the Center for Network Innovation and Experimentation, as well as external organizations such as the MUOS lab facilities.

5. Potential follow-on activities for this project include developing and integrating prototype applications and testing those applications in tactical networking experiments or operational exercises. Capt. Schrafft was able to progress further than expected during this period of performance and conducted actual testing with the MUOS SATCOM system in conjunction with the MUOS Reference Implementation Laboratory at Space and Naval Warfare Systems Command Systems Center – Pacific (SSC-PAC). LCDR Seggerty is continuing to develop a plan to conduct similar testing.

6. The students captured lessons learned for the development, integration, and test of future MUOS-based applications and then updated the process established under this proposal, as necessary.

Findings and Conclusions:

1. Capt. Schrafft successfully analyzed the requirements, architecture, and CONOPS for the USMC fire support mission and identified required user equipment hardware and software needed to support the mission.

2. Capt. Schrafft assessed the feasibility of modeling StrikeLink/AFATDS and associated MUOS network communications using QualNet and Satellite Tool Kit and conducted initial modeling using fire support message traffic data from the U.S. Army Fires Test Directorate. While limited in scope, the modeling effort confirmed that MUOS network communications can provide the necessary bandwidth for fire support communications, and that timing restrictions are not an issue.

3. Capt. Schrafft successfully developed a complete fire support scenario (i.e., an arrangement of fire support tools communicating over live MUOS satellite links using AN/PRC-155 radios, emulating a practical observer-to-shooter fire support hierarchy) to

validate the proposed "MUOS for Indirect Fire Support" CONOPS. The 11th Marines Artillery Training School in Camp Pendleton and SSC-PAC supported operational testing of fire control communications using actual StrikeLink/AFATDS systems and MCTs.

4. Capt. Schrafft completed a thesis documenting the project, which was approved by the principle investigator/Advisor, Second Reader (NPS Senior USMC Representative) and Space Systems Academic Group Chair. In addition, Capt. Schrafft authored a journal article which was published in "The Fires Bulletin," a joint publication for the artillery community produced by the Fires Center of Excellence at Ft. Sill, OK.

5. LCDR Seggerty conducted a survey of applicable helicopter missions and discussed requirements for MUOS support of these missions with aviators currently assigned to operational helicopter squadrons at Naval Air Station North Island. In addition, he researched current and past capabilities of datalink communication systems in Naval Helicopters, including Secret Internet Protocol Router Network applications for a transmission control protocol/IP based network in the cockpit.

6. LCDR Seggerty investigated potential for Joint Range Extension Applications Protocol integration through the MUOS platform for aviation units. It was determined that the Naval Special Warfare (NSW) community flying the legacy HH-60H would see the most benefit, as they have no data link capability. LCDR Seggerty continues to investigate potential to conduct field-testing of this capability using HH-60H aircraft from HSC-85.

Recommendations: This study successfully demonstrated the use of emerging space-based capabilities to enhance the responsiveness and lethality of our warfighters at the tactical level. Specifically, employing MUOS to enhance communication architectures between fire support users and providers has the potential to significantly increase the responsiveness of indirect fires and empower key players in the fire support process. Furthermore, it will unleash the full potential of each weapons system, as advertised by the manufacturer, allowing for the conduct of true split-battery and/or independent howitzer/launcher operations. While application of MUOS capabilities to the NSW helicopter community is still under investigation, it is expected that similar benefits will be reflected as a result of that portion of the study.

Based on the success of this study, it is highly recommended that further research be conducted to develop, integrate, and test applications for additional missions and platforms that can leverage MUOS IP-based communications capabilities. Specific additional recommendations include the following:

1. Acquiring QualNet Model Libraries and Product Support: The educational version of QualNet used to enhance communications link analysis of STK objects does not provide the obligatory utilities to accurately model a large number of tactical nodes passing message

traffic via MUOS (WCDMA) links. As such, should interest in MUOS CONOPS validation endure, the purchase of additional capability, in the form of applicable QualNet Model Libraries and associated technical support, is called for. Of note, QualNet has been contracted by DOD to provide MUOS specific network analysis tools. Gaining access to these tools would be most beneficial.

2. High Fidelity Network Emulation and Concept of Operations Validation: Additional emphasis can be placed on validating MUOS CONOPS via network emulation. This will set the stage for field testing and eventual live-fire applications. Of note, the MUOS network simulation and network analysis tool, once authenticated, could also be used to validate a number of other tactical concepts of employment for MUOS.

3. Field Testing and Live-Fire Exercises: The ultimate in CONOPS validation incorporates field-testing and live-fire system employment. CONOPS validation efforts for various missions and platforms should therefore eventually include actual operations conducted by warfighting units. Here, a crawl-walk-run methodology can be used to first introduce specific CONOPS to applicable warfighter communities, verify functionality under realistic combat-like conditions, and finally stress MUOS communications channels with accurate loads.

Mobility and Cloud: Operating in Intermittent, Austere Network Conditions

Researchers: Gurminder Singh, and Man-Tak Shing

Students: FORNATL Toon Joo Wee, and FORNATL Yu Xian Eldine Ling

Background: Cloud computing has rapidly become the mainstream platform for a range of applications and services. For any large-scale, scalable, networked application system, our default starting point for hosting is the cloud, the foundations of which lie in distributed computing, networking, databases, load-balancing, and security. In most cloud-based systems, clients, which generate and/or consume information, are connected to cloud-based servers over wired or wireless network connections. For mobile platforms, this connection, by definition, is a wireless connection. While cloud computing has brought about unprecedented sophistication in the mobile ecosystem, there are a number of issues which need to be attended to in order for the overall environment to be dependable. Operating in intermittent and austere network conditions is one of such challenges, which navy ships face when communicating with land-based cloud computing environments.

Process: Our approach involved research in data structuring, hosting, caching, and scheduling strategies for systems, and techniques for compressing the volume of data that needs to flow. We considered application characterization based on prioritization by data types and the needs of mission. Based on these factors, we proposed strategies for architecting ship-board systems for a smoother user experience.

We involved two master of science students who participated in the research and implemented software to model and simulate network conditions and data requirements.

Findings and Conclusions: Given limited bandwidth and intermittent connectivity of satellite connections, mechanisms are needed to support data requirements of navy ships. Data caching and pre-fetching can be useful in such conditions. Caches act as temporary local storage and can satisfy data requests readily, if requested data is available. They promote faster response time and reduce bandwidth utilization. Cloudlets have the capability to bring the cloud closer to the users when they are deployed, as they extend the reachability of cloud-based servers to the users. In this research, we study the application of these two mitigating strategies in detail and evaluate their performance through modeling and simulation. Results from our simulations have suggested a positive impact. Caches and cloudlets as part of the shipboard architecture produce better performance in data communications. Most importantly, the strategies promote operations continuity for a naval force under disconnected, intermittent, and limited network environments.

Recommendations: We propose implementation of local caches and cloudlets to supplement the cloud architecture for a more efficient utilization of limited bandwidth afforded by the current satellite communications systems and to make the systems more responsive to user needs. Our results have demonstrated that the response time was shortened by at least 20 to 30 percent, which is a significant improvement to the case where all requests had to be made to the cloud server. This finding is based on the lowest cache hit ratio. Input parameters such as the cacheable ratio and the cache-hit ratio were varied accordingly to find their optimal use cases.

Improving Data Fusion Beyond DCGS-N INC 2

Researchers: CAPT Dan Verheul, Dan Boger, Scot Miller, and Arkady Godin

Student: LCDR Henry Lange

Background: Current Distributed Common Ground System-Navy (DCGS-N) Inc 2 Fusion Architecture is based on legacy fusion and correlator algorithms developed prior to the Navy

making a decision to go into the clouds. DCGS-N Inc 2 integrated processing and storage cloud environment is expected to be Naval Tactical Cloud Reference Implementation Platform-as-a-Service. This environment utilizes elastic storage Hadoop Distributed File System (HDFS). JD database is integrated with HDFS to support data unification and distributed data processing using mission models and analytics to help Navy missions.

The following facets of data fusion will be investigated:

- How do we achieve higher Joint Directors of Laboratories (JDL) levels of data fusion?
- Are there any open-source commercial off-the-shelf (COTS) frameworks providing distributed processing to increase the speed of execution of the correlator and fusion algorithms?
- Are there any COTS/government off-the-shelf (GOTS) engines for improving semantic reasoning capabilities for the correlation and fusion algorithms, including machine learning?

The purpose of the research is to provide analysis of alternatives for future experimentations exploring the insertion of promising open-source COTS/GOTS platforms and engines to improve intel battlespace detection of threats and opportunities based on improved quality, speed, and synchronization enabled by fusion architecture.

Process: The process of the research includes discovery of existing DCGS-N Inc 2 data fusion integration framework through interviews with the program executive office C4I (PEO C4I), PMW-120, and PMW-150 in coordination with Robert Poor, DCGS-N Inc2, assistant program manager APM. Alternative approaches are based on literature review, PEO C4I and Air Force Research Laboratory Rome Labs site visits. A stretch goal would be to define two Priority Information Requirements (PIRs) for the ship's Intel Commander. The first PIR will require support of JDL Fusion level 2. The second one will require JDL fusion to be at level 4 or 5.

Findings and Conclusions: Fusion algorithms are not organized into the libraries of functions that could be used by high-velocity, distributed computing frameworks. There is no sufficient level of abstraction over fusion integration frameworks developed by intelligence community agencies (i.e. NSA, NSA) resulting in the point-to-point integration without consideration for a proper decoupling. It is unclear how Intel Commanders are able to express the intents via PIRs without having highly abstracted Application Program Interface (API), which will be there to stay, and which Intel Commanders get trained on how to use it. Another element of concern and active investigation is the presence of several Graph APIs, making it challenging for developers to leverage available information.

Recommendations: Recommendations will be prepared by 30 March, 2015, Master Thesis completion date.

Bridging the Naval Postgraduate School and Naval Oceanography to Accelerate Warfighter Capabilities

Researcher: Warren Yu

Research Question/Problem Statement: How might we best accelerate warfighter capabilities by bridging Naval Postgraduate School (NPS) and Fleet Numerical, Meteorology, and Oceanography Center (FNMOC) for the purpose of improving mission support to the Fleet?

Benefits: Primary benefits of this research include finding ways to strategically leverage the best parts of NPS' higher education and research mission, and the Naval Oceanography's mission (specifically through FNMOC's high performance computing, secure enclaves, and integration of Navy Tactical Cloud-like software and services). This leverage will create actionable recommendations for investment; and identifying mechanisms and process changes to more quickly adopt, broaden, and deepen best practices in order to enable the most compelling, relevant, and sustainable solutions that lead to improved mission effectiveness and more effectively accelerating the integration of the 'next killer app' into the kill chain.

Objectives: Objectives include ways to develop and document an executable concept and process that will develop new techniques for aligning Data Science work across Naval organizations. Particular emphasis will focus on Joint Meteorological and Oceanographic (METOC) (i.e. Battlespace on Demand Tier 3) analytic capabilities supporting Fleet missions innate to FNMOC/Commander, Naval Meteorology and Oceanography (CNMOC) and NPS. The study will outline how NPS can systematically leverage its resources and the intellectual capital of its researchers (faculty and uniformed students) to identify opportunities to improve Data Science capabilities in naval warfare and how ongoing Data Science efforts at FNMOC/CNMOC, NPS, and other Naval organizations may guide effective development. The study will identify new operational (warfighting) use cases, workflows, and METOC products that could be realized through the normalization of atmospheric and oceanic data sets that can be fused with operational and tactical data made available via cloud computing architectures. Where possible, the study will realize synergies with existing efforts at FNMOC/CNMOC and NPS, as well as related studies funded by the Office of the Chief of Naval Operations (OPNAV), to produce new analytics as test cases for implementation of this new capability.

Approach: This study will be accomplished by bringing together expertise from both NPS and FNMOC/CNMOC. The study will identify the data expertise for dealing with the METOC data sets and will identify stakeholders to take the lead associated with defining METOC data/metadata representation and organization within Navy Tactical Cloud (NTC). It will also identify an approach for ingesting METOC data into NTC and the development of new cloud-based entity models. The study will leverage key resources within NPS to identify stakeholders who can develop mission support concepts for METOC that can leverage new cloud-computing technologies. The Cebrowski Institute will oversee this study and capture lessons learned on how to most effectively organize cross-discipline analytic teams using this METOC effort as an initial case. To support this effort, ONR will provide FNMOC/NPS with the latest NTC Reference Implementation (NTC RI). The FNMOC/NPS team will use the NTC RI as the environment for performing this effort.

Findings: Three-year's experience with the forge.mil software development environment crippled FNMOCs agile software development model with horrible performance, customer service, and productivity. In August 2014, we successfully migrated 11,000+ issues & 130+ accounts off forge.mil to NPS' Continuous Integration Environment intending to increase productivity and lower costs. Like the agile software development process we are following, there are no 'end-results' of this study per se, but instead a continually evolving process that spirals out successes, and absorbs setbacks, as it matures. We were fortunate to experience the successes of this study between FNMOC and NPS figuring out ways to best accelerate warfighter capabilities for the purpose of improving mission support to the Fleet. Their successes include:

- Academic software licensing vs. government licensing unexpectedly unveiled 50 percent savings.
- 2,000 –6,000 percent increase in productivity over former forge.mil workflows (reported by Navy integrated tactical environmental subsystem (NITES) Next sys admins Aug 2014).
- Small, agile, collaborative, educational/operations-based partnership beat initial contracted cost by 65 percent and was Initial Operational Capability 30 days early delivering services.
- NPS Chief Information Officer reduced Navy information approval system processing to less than 24 hours from 45-60 days (Echelon 4-cited figure) with web-based, open source software built by collaborating government civilians; approved by N1/N2/N6. (In 2013 NPS purchased approximately 4,400 information technology procurement reviews for less than \$500,000 with about \$12.3M.)

- NPS Information Technology Assistance Center reduced System Authorization Access Request-Navy network access form processing from two weeks to ten minutes, leveraging software ecosystem.
- 20-24 October 2014: Live NITES Next training was conducted using our drop servers to USS John C. Stennis, USS Wasp, and TOP GUN with the NITES Next software package hosted at FNMOC and NPS.
- Procurement: less than eight day turnaround from initial purchase request to sourcing.
- Contracting, warehouse and system administrator teams: Three Dell enterprise servers were ordered, shipped, received, inventoried, delivered, assembled, racked, certified and accredited, and operational in less than five weeks.

Conclusions/Impact on U.S. Navy: There surfaced a realization of greatly improved processes, corporate culture, and productivity when leveraging interdependent and complementary systems, such as higher education naval operations.

Recommendations: Next steps revolve around education and leveraging NPS faculty and students to focus on three areas: 1) Operations, 2) Technology, and 3) Cyber Security. Ideas and ongoing discussions with faculty and students include having METOC students help improve NITES Next workflows, interfaces, and results. The course CS 3695 “Intro to Hacking” class could leverage their off-the-shelf hacking scripts to affirm Naval Network Warfare Command security technical implementation guide requirements NPS follows to secure its servers, and likewise validate cyber policies. They can also open the door for the CS 4678 course class, the more advanced cyber hacking class whereby they create own hacks based on what exists. The Cyber Academic Group’s courses, CY4700 & CY4710, classes are geared to blue team/red team systems, and will have their new Sensitive Compartmented Information Facility battle lab ready to test in the top secret enclave those assets located on the Joint Worldwide Intelligence Communications System and the National Security Agency intranet.

N3/N5: Plans & Strategy

Exploring North Atlantic Treaty Organization—China Military Collaboration

Researcher: Walter Christman

China's rising power in the world has led to increased risk and opportunity for the United States and its allies. During his visit to Moscow in March 2013, China's new President Xi Jinping announced the need to promote a "new type of great power relationship," a theme he returned to during his talks with President Obama at the California Summit in June 2013. It is unclear exactly what Xi means given the vagueness of the language. In general, however, Xi appears to be offering a quid pro quo strategic deal with any great power that advances Chinese national interests in gaining greater prominence through a more even footing relative to the U.S. military, and thereby elevating China's perceived standing in the world. The Obama Administration's "pivot" to Asia has stoked China's fear of encirclement and Europe's sense of abandonment. In crafting responses to Xi's call for a "new type of great power relationship," an unexplored question is how best to engage our North Atlantic Treaty Organization (NATO) allies in developing a balanced and enhanced collaboration with China in a manner that best supports U.S. interests. The research problem is to identify potential modalities of cooperation between NATO and China in terms that both sides can accept within a shareable theoretical frame of reference.

The presentation and analysis of collected data in this research will explore organizations as 'webs of meaning' (Geertz, 1973) in which the researcher is a storyteller. The setting is field research within both Europe and China and the actors observed are the institutions, administrative managers, and thought-leaders engaged in security cooperation among and between the nations.

The argument embraces the notion that organizational life cannot be separated from the discourse of which it is an integral part.

While the research provides a story-telling interpretation of novel approaches to organizational collaboration that are historically and culturally grounded, the investigation was carried out as an organizational ethnographic student in direct response to the call by numerous critical theory scholars for organizational ethnographers to examine issues of power, authority and control associated with the development, maintenance, or transformation of a particular culture.

The approach taken in the research will be extended to encompass potential new examples of what will be developed as a “partnership” framework of addressing shared emerging global security threats and risks.

The research findings will be based on analysis of personal and public documents, informal interviews, and active participation in developing the programs described. The events discussed are effects of decisions taken in the implementation of various collaboration strategies, seeking to uncover descriptive patterns in the process of transformation and adaptation, as participants have experienced it locally.

Chinese Naval Expansion into the Indian Ocean

Researchers: Michael S. Malley, Paul Kapur, Ryan Jacobs, and Christopher Twomey

Background: This project was designed to identify and assess a range of likely Indian responses to increases in Chinese naval activity in the Indian Ocean Region (IOR) over the next two decades. This project stemmed from a concern that growing Chinese influence in the IOR could intensify Sino-Indian rivalry, threaten U.S. interests in fashioning a rules-based regional order, and create incentives for smaller states in the region to reevaluate their relationships with all three countries.

Process: This study proceeded in three phases. First, we developed a balancing-bandwagoning analytical framework to examine the range of Indian options and their consequences for the U.S.. Second, we drew on primary and secondary sources to identify the interests and issues at stake for India, and to gauge Indian perceptions regarding (a) the likely trajectory of Chinese naval activity in the IOR and (b) strategies India is likely to pursue in response to that activity. Third, we conducted roundtable meetings in the IOR with key decision-makers and security elites, who critiqued our hypotheses and preliminary findings, and provided additional information regarding Indian perceptions of China and likely Indian responses. At each step in the process, we briefed the Office of the Chief of Naval Operations N51 and interested offices elsewhere in the U.S. government.

Findings:

- China’s influence in the IOR will grow over the next 20 years. This growth will create opportunities for China to establish a larger, militarily significant maritime presence there, possibly in partnership with smaller IOR countries.

- Indians generally believe China aims to neutralize their position in the IOR and limit their influence in the wider Asia-Pacific region. If successful, China's efforts would undermine U.S. objectives in the IOR and Asia-Pacific.
- India is likely to balance against China through a combination of self-help and alignment with the U.S. and other countries. This alignment will not include the formal commitments typical of U.S. alliance relationships. Instead, India will seek a partnership in which both sides seek to deny China's hegemonic initiatives by coordinating policy and developing interlinked approaches. In the maritime realm, these may include mutual logistical support, combined deployments, and intelligence sharing.
- These strategic dynamics will create significant opportunities for U.S. Navy engagement with India. In particular, the U.S. Navy will be able to pursue joint-technology development, discrete joint operations, and closer coordination at the operational and strategic level with the Indian navy. Specific areas for further engagement are examined in more detail in the non-public report.

Strategic Engagement With Tier One Countries: Track II Strategic Dialogue

Researcher: Michael Malley

The principal purpose of this study is to identify opportunities for closer engagement between the Navy and its counterparts in Brazil, India, and Vietnam. Since 2009, the United States government has reached high-level agreements to deepen defense cooperation with each country. Yet these relationships are nascent ones, and further growth may be hampered by old misunderstandings or antagonisms. Naval engagement is a critical but underdeveloped element in defense cooperation with each of these partners. Effective naval engagement with each of these maritime powers depends on accurately identifying each new partner's strategic interests and priorities in the maritime domain. This study will employ an approach known as a "Track II strategic dialogue" in order to identify these interests and priorities, and to clarify differences in the way each side perceives them. For instance, dialogues may address the type of cooperation that each prefers, political or fiscal constraints on certain forms of cooperation, and ways and means of assuring partners and deterring adversaries. In this phase, dialogues will be conducted with India and Vietnam, and preparations will be made for a similar event with Brazil.

This project is currently in progress, with completion and final project deliverables anticipated in May 2015.

Regional Stability Models and Civil Affairs in the Maritime Domain

Researchers: Anke Richter, and Jonathan Lipow

Background: The Navy disbanded its civil affairs organization—Maritime Civil Affairs and Security Training Command (MCAST)—in May 2014. The objective of this project is to clarify what future role, if any, the USN should be playing in fulfilling the Armed Forces’ civil affairs mission.

Process: The project consists of four components. The first is a thorough review of the relevant literature and the historical performance of the Navy’s civil affairs efforts conducted by MCAST and the organizations that preceded it.

The second is a series of in-depth “stakeholder” interviews of senior officers with experience in civil affairs operations and/or maritime missions that have a civil affairs component—such as counter-insurgency, law enforcement, and riverine operations. In these interviews, we will offer stakeholders an opportunity to offer their own assessments of the Navy’s performance of maritime civil affairs missions and the adequacy of the Armed Forces’ current maritime civil affairs capabilities.

The third component involves a survey of experienced field grade civil affairs officers drawn from all branches of the Armed Forces. In this survey, the officers will be given a hypothetical scenario in which the U.S. liberates an African country from invaders and must establish a transitional government authority. This results in a wide range of requirements for civil affairs capabilities. After familiarizing themselves with the scenario, the officers will be asked to identify which assets would be best suited to accomplish each of the 31 civil affairs missions. Their choice of assets includes civil affairs assets from each of the four branches of the armed services as well as by the USCG, civilian agencies such as USAID, or multi-lateral entities such as the United Nations.

The fourth and final component of the project will be to analyze the findings and synthesize recommendations regarding the Navy’s future role in maritime civil affairs.

Findings, Conclusions, and Recommendations: The proposed senior level interview questions and the on-line field grade civil affairs officer survey are currently under review with NPS’

Institutional Review Board. We expect to be able to start the survey and interview process as of December 1, 2014. While an initial literature review has been conducted to properly situate the researchers and ensure that the questionnaires were well designed, there are no findings or conclusions to report at this time. We expect to be able to complete this project by March 31, 2015.

Strategy and Innovation Cycle

Researchers: James A. Russell, Tom Young, Chris Twomey, Jim Wirtz, Donald Abenheim, Diana Wueger, and Judith Tulcoff

Background: This project investigates the process by which the U.S. Navy formulates and implements strategy. The central objective is to determine whether and/or how that process can be improved by providing Navy leadership with a more robust methodology to link ends and means now and in the future. Strategy is defined here as the process of linking ends and means, framed by conceptual analysis of the future security environment. There is a widespread perception that the Navy's process of developing strategy is primarily driven by money allocated in the Five-Year Defense Plan to the shipbuilding and aviation budgets. Instead of having decision-making on the commitment of money based on thinking about the future security environment, decision-making is instead driven by past practice and institutional interests in preserving its cherished ship and aircraft programs—both of which are deemed essential to institutional identity. In a time of growing budgets, there was little pressure within the Navy to change and/or alter this process. That is now changing, with the prospect of declining budgets for the foreseeable future.

Process: This project involves the analysis of qualitatively-derived data that has been gathered from the many stakeholders involved in the Navy's strategy development process. Information has been gathered from the Office of the Chief of Naval Operations (OPNAV) staff that describes the current Navy strategy development and budgeting process. That information has been correlated with information contained in Navy publications and secondary sources that describe the process by which the Navy develops and implements strategy. The team also gathered data from the other military departments to compare and contrast the strategy development and implementation process. These comparative cases will also be presented in the final report.

The data gathering phase of this project is nearly complete. The team will be assessing the information and presenting preliminary findings to the N51 later this year and in the winter of 2015.

Preliminary Findings and Conclusions:

- Within the OPNAV staff and bureaucracy, programming requirements and budget considerations eclipse policy and strategy. The Navy is institutionally uncommitted to strategic thinking and a process that attempts to link thinking about the future with manning, training, and equipping the force. Bureaucratic interests and politics, established career paths and priorities, and cherished budgets and programs and platforms dominate institutional behavior.
- The OPNAV staff lacks policy and guidance for strategic planning—the process today is ad-hoc and personality-driven.
- The N51 has only marginal influence in the programming and budgeting process and is not staffed and organized to provide systemic input.
- The Navy has the intellectual capital to institutionalize a more rigorous strategy development process but does not attempt to organize and lead a series of fragmented and disconnected organizations to synergistic effect in building a community devoted to developing naval strategy.
- If the Navy does not develop the capacity to think strategically and make corresponding alterations to its mission and force structure, it runs the risk of having this done by outside actors such as Congress.

Preliminary Recommendations:

- The Navy requires a sea-change in its intellectual and educational posture if it seeks to reorient institutional values towards the development of naval strategy that can in turn drive plans, policies and programs.
- The Navy needs a strategic planning process to more systematically link ends, ways, and means.
- The OPNAV staff will have to be reorganized if the Navy is to systematically rebuild and reorient its internal planning and budgeting processes to account for the strategic environment.

N4: Material Readiness & Logistics

Optimal Operating Policies for Hybrid Wind/Fossil Fuel Energy Systems

Researcher: Emily Craparo

Students: Hamadi Bouaicha, LCDR Nicholas Ulmer, and LCDR John Sprague

Renewable energy options are currently being explored as methods of complementing traditional energy sources for military installations. A number of installations currently use wind power to satisfy a portion of their demand. Wind power is clean, cost effective, and does not depend on a steady supply of incoming fuel. However, it is not reliable enough to be the sole power source for military purposes where constant readiness is necessary. Backup generators are required, but these generators are inefficient when utilized intermittently. Thus, direct timing of use with the availability of wind power is not cost effective. In this research, we develop stochastic optimization models for optimally dispatching diesel generators based on ensemble predictions of wind power output. Specifically, we design optimal day-ahead policies for joint operation of wind turbines and backup generators. We also consider storage of energy generated during high-wind periods, and we account for the cost of storage as well as production costs of all forms of power. Building on this model for optimal deployment of existing power generation assets, we will also construct a long-term capital-planning model to determine optimal procurements of energy generation and storage assets.

Reduction of Aviation Fuel Consumption Through Slot Management

Researchers: Michael Dixon, Uday Apte, and Roberto Schetxman

Student: Maj Adam Gable

Background: With over 3,700 aircraft burning over 600 million gallons of gas a year, naval aviation accounts for 54% of all naval fuel consumption. Naval aviation is the second largest consumer of fuel in the Department of Defense; Air Force aviation being number one. Our

goal in this research is to find squadron level efficiencies and bridge the gap between tactical and institutional wide recommendations.

Process: We focus on identifying fuel savings through ground process improvements. In this end, we have created a model that simulates daily flight operations at the Navy's two largest airbases, Naval Air Station (NAS) Oceana and NAS Lemoore. We use data collected by Commander Strike Fighter Wing Pacific and staff, Commanding Officer Strike Fighter Wing Atlantic and staff, training squadrons VFA-106 and VFA-122, and both bases Fuels Division Managers, Air Traffic Control Officer/Chief, and Supply Officers.

Our objective is to identify bottleneck in ground operations that are either shared among bases or base specific, find ways to streamline those processes, and make fleet-wide policy recommendations and base specific recommendations based on our findings. Our simulation is done through a highly parameterized, flexible model using an easily adjustable Microsoft Excel user interface that allows users to experiment with different scenarios. Our recommendations have no adverse effect on readiness, proficiency, or flight operations.

Findings and Conclusions: We model refueling processes along with all other applicable ground processes in our simulation. Through our analyses we determined that approximately two-thirds of all delays occur in processes conducted outside of the squadron-line area, specifically at the hot brake checks and hot skids refueling. At Oceana, 41% of delay time occurs in the hot brake check queue, and 32% occurs at the hot skids queue. At Lemoore, 54% occur in hot skids queue and 28% in hot brake queue. Next, we experiment with potential ground process improvements discovered through our data collection efforts.

Recommendations: We found statistically significant reductions in average idle time by adopting eight policy recommendations.

- Degauss in the squadron line.
- Cover the Captive Air Training Missile-9 seeker head in the squadron line.
- Use a laser gun to check the brake temperature.
- Always refuel the last flight with fuel trucks.
- Be vigilant in making 10 minute out calls.
- Annotate known hot skid turn-around on flight schedules.
- At Lemoore, allow squadron maintainers to operate the 'dead' switch.
- Organize periodic detachments from VFA-106 (Oceana) to VFA-122 (Lemoore)

Combining all of our policy recommendations reduces average idle time by 78, 40 seconds with 95% confidence at Oceana and 72, 24 seconds with 95% confidence at Lemoore. If adopted, we estimate our eight recommendations would reduce fuel consumption by 250,920 gallons of gas, saving the Navy over 8 million in fuel and maintenance costs per year at Oceana and Lemoore alone. If adopted across all fighter bases, savings would be substantially higher.

Finally, we conclude with an investigation into a policy requiring aircraft to shut off an engine after safely exiting the runway post flight. Incorporating a single engine policy into our simulation model results in a substantial reduction in fuel consumption of over 1.5 million gallons, savings of over \$50 million per year.

Accelerating Navy Energy Culture Change

Researchers: Susan Higgins, and Ann Gallenson

This project provides N45E with a method of evaluating the effectiveness of standard and innovative training, and education methods on changing Navy-wide energy procurement and consumption behaviors. New education technologies and methodologies hold promise for rapidly increasing awareness and understanding of energy concerns and solutions. This project explores how these technologies might be rapidly developed and implemented to initiate and accelerate the needed energy-based culture changes across the Navy enterprise.

This project is currently in progress, with completion and final project deliverables anticipated in January 2015.

Alternative Fuel Usage Practices

Researcher: Alan Howard

Student: LT Dustin Crawford

Constrained budgets and fuel costs have long been a concern for the Navy. Several programs have been developed to aid commands in conservation efforts with varying degrees of success. Deeper budget cuts motivate a more aggressive review of alternative energies, technologies, and non-technical processes targeted to gain additional fuel savings. This study will review current afloat business practices, across the full Tactics, Techniques, and

Procedures (TTPs) spectrum; examples of which are budgeting and effectiveness measures. Our objective is to recommend alternative policies, practices, and metrics to leverage and enable additional fuel conservation.

The Principal Investigator will glean best practices through primary interviews and research with the following organizations: U.S. Navy Surface Forces, Atlantic, U.S. Navy Surface Forces, Pacific, Fleet Forces Command, and Pacific Fleet.

The proposed effort will include talking with each of the above organization and gathering their assessments of what they are doing, what is working, and what is not. The team will then:

- Gather available cost and programmatic data on the TTP for each of the concepts being considered. Where use of proprietary data is required, NPS will enter into appropriate non-disclosure agreements, and will handle the data in accordance with U.S. Government policies for storage and use of such data.
- Utilizing Operations Research methodology, create an overview of each projects costs over the planned duration, and modify this projection to illustrate the costs of maintaining one or more solutions through the continuing phases of the program.
- Identify and prioritize potential sources of savings that competition could produce, compared with past experiences of competition for defense programs.

Developing a New Paradigm for High Energy Density Capacitive Energy Storage

Researcher: Jonathan Phillips

Students: LCDR Sam Fromille, and LT Natalie Jenkins

Background: Within this research project, we aim to develop a new type of dielectric material, Super Dielectric Materials (SDM), for potential use as the primary power source for rail guns, directed lasers, and other modern weapon systems. Preliminary work from the first year of this project shows there is a potential—yet to be demonstrated—to increase energy density of capacitors using SDM by several orders of magnitude—relative to current ‘supercapacitors’. This will dramatically reduce the needed size and weight of power sources for these weapons

Process: Using the textbook RC time constant approach and hand building capacitors from SDM 'pastes'—easily created (ca. 1 hour) from refractory oxide powders filled to the point of incipient wetness with water containing dissolved salts (e.g. table salt)—we have:

- i) completed two studies of the use of SDM in capacitors using different salts
- ii) worked with other scientists and engineers to replicate these results,
- iii) filed a provisional patent for the technology,
- iv) initiated work using hollow nanofibers of refractory oxides grown in an array instead of refractory powder and
- v) initiated two new student theses.

Findings and Conclusions: The primary outcomes are clear, repeatable, and replicated demonstrations that we have allowed the discovery of a new family of dielectric materials with dielectric constants (> 1010) with as much as seven orders of magnitude higher than any previously reported. Another outcome, based on preliminary work with the nanofibers of refractory oxides, is that we are clearly on a path to produce a capacitor with a higher energy density than any capacitor ever before produced. Indeed, in preliminary results we have been able, repeatedly, to create capacitors with energy density higher than 200 J/cm^3 ; far higher than the best supercapacitors, $\sim 30 \text{ J/cm}^3$.

Recommendations: In order to test the potential to develop SDM into the highest energy density capacitive energy storage that is appropriate for dramatically smaller power supply footprints for rail guns, lasers, and other directed weapons, we recommend two major thrusts in the coming year. First, further develop powder SDM. Second, developing SDM based capacitors using the aligned hollow ceramic tubes. In the first effort, the MS thesis of Lt. Natalie Jenkins will focus on the impact of different salts (e.g. ammonia chloride and sodium hydroxide), and refractory oxides (e.g. silica gel) on dielectric constant, and other 'equivalent circuit' parameters. In the second effort, the MS thesis of LCDR Jonathan Gandy, will involve building refractory oxide nanotube arrays of different dimensions, with a focus on sub 10 micron structures, and then testing these arrays once loaded with ion containing fluids, as SDM.

THIS PAGE INTENTIONALLY LEFT BLANK

N8: Integration of Capabilities & Resources

Capability Modeling and Assessment for Offensive Swarm Unmanned Aerial Systems

Researcher: Timothy H. Chung, and Chris Wolfgeher

Students: LtCol Robert Davis, Capt Scotty Black

Background: An emerging potential capability is the employment of large numbers of low-cost autonomous systems, such as unmanned aerial systems, to conduct a wide range of offensive missions or other forward operations. Quantifying the effectiveness of such swarms of unmanned systems is necessary to identify existing or potential capabilities and vulnerabilities in both allied and adversarial forces. In particular, openly stated tactics involving saturation attacks using unmanned aerial systems against U.S. and allied surface-combatants highlights the immediate relevance of such threats, as well as the imperative to develop, demonstrate, and deploy such offensive swarm capabilities ourselves for applicable mission sets. These swarm systems can potentially overwhelm enemy defenses and/or force an adversary to expend significant resources to counter this capability.

A capability assessment of near-term operational systems and/or capability engineering of future swarm unmanned systems can drive the concept generation for enhanced capabilities leveraging swarm element autonomy, intra-swarm coordination, implementation of swarm tactics, swarm command and control, etc. It can also expose the limitations and vulnerabilities created by these new warfare systems—either to mitigate in friendly forces or to exploit in adversarial ones.

The proposed effort aligns with active research efforts, including funded research from ONR, DARPA, and the SECNAV initiative, the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER), as well as ongoing interdisciplinary student and faculty involvement, including active student participation in projects-based learning courses and thesis activities. Further, this proposal directly addresses OSD, and OPNAV study needs in offensive swarming system capabilities.

Process: The Principal Investigator (PI) and his research team in the NPS Advanced Robotic Systems Engineering Laboratory investigated the rapidly evolving arena of swarm unmanned systems, specifically highlighting emerging technologies in swarm unmanned aerial systems (UAS). Engagement with researchers and engineers in academia, industry, and across the

naval enterprise supported this study, additionally leveraging the PI's extensive mentorship of NPS students through theses and capstone research.

A capabilities-based planning methodology was used to identify and assess existing and novel capability areas pertaining to employment of offensive swarm UAS capabilities. Agent-based modeling and simulation were constructed, in conjunction with insights from the background research and the performers' experience in field experimentation of new technologies, to construct relevant scenario vignettes and evaluate current, near-term, and future capabilities.

Through Monte Carlo simulation and experimental design, in tandem with the development of concepts of operations for offensive swarm unmanned systems, analysis included trade studies in swarm characteristics, such as swarm size, lethality, and impacts of swarm system deployment concepts.

Findings and Conclusions: The results of this study included an informed overview of technology approaches, current gaps, and future trends that merit and/or support an offensive swarm UAS capability in Naval and Joint operating environments.

Various existing methodologies and technologies presently available in the active robotics community, such as approaches for cooperative localization for teams of assets in Global Positioning System-contested or -denied environments, can be immediately transitioned and incorporated to dramatically improve current operational effectiveness.

Further, this study highlights the emerging trends for incorporating or integrating low-cost open-source and/or commercial-off-the-shelf technologies to accelerate operationally relevant and effective solutions.

Recommendations: Additional study of promising technologies in swarm unmanned systems research can not only highlight the development of an emerging offensive warfighting capability, but can illuminate existing enabling technologies that can be immediately transitioned into current systems for enhanced effectiveness.

Developing Synthetic Theater Operations Research Model Analytic Utility

Researchers: Tom Lucas, Susan Sanchez, Dashi Singham, Paul Sanchez, Mary McDonald, and Steve Upton

Students: LT Christian Seymour, and LT BJ Bickel

Background: Director, Assessment Division (OPNAV N81) provides warfighting analysis to senior Navy and DOD leadership to inform operational planning and acquisition decisions. A modeling environment that underpins many important N81 and joint studies is the Synthetic Theater Operations Research Model (STORM). The Navy and other services use STORM as a tool to evaluate campaign risk and assess the utility of operational and acquisition decisions. Because STORM is stochastic, multiple replications are made for a given set of inputs. A current impediment to fast and efficient use of STORM is the volume of data it generates, as a single simulated battle may create output datasets requiring many gigabytes of storage. In addition, the number of replications may be limited due to processing capacity. The goals of this Phase I effort were to (1) develop prototype tools and processes that reduce the amount of manpower and time required to complete STORM output post-processing, and (2) provide new post-processing data analysis tools to facilitate gleaning insights from a set of replications. Ultimately, the new capabilities will enable OPNAV N81 analysts the ability to make a greater number of dynamically determined scenario replications and boost the speed and accuracy with which they will be able to gather insights.

Process: The NPS Simulation Experiments & Efficient Designs Center teamed with N81 analysts and their representatives in all phases of this project. It was decided that most of the development and testing would be accomplished using an unclassified scenario known as Punic 21. However, many of the new capabilities were also applied to a classified scenario from a previous effort. Iteratively, new STORM-specific post-processing and analysis methods were developed, socialized, tested, and refined. The testing was done both at N81 and by thesis students at NPS. Quarterly results were briefed to an N81 SES, the N81 STORM team, and many members of the broader STORM community in the DOD.

New capabilities: Multiple replications were made on the Punic 21 scenario to quantify the variability of a breadth of output measures—with a focus on “what it takes to win” (WITTW) metrics. The new capabilities developed and tested include:

- Summary output metric tables (e.g., quicklook dashboard, killer and victim scoreboard, and other requested summary tables),
- histograms and summary statistics for WITTW metrics,
- time-varying force-level plots,
- correlations between numerous variables and WITTW metrics,
- conditions, plans, resource, movement, and casualty heat maps,
- partial dependence plots,
- cluster analysis,
- outlier detection, and
- partition trees.

We also applied a recently developed stopping rule to dynamically calculate sample sizes that provides the expected number of replications needed to achieve a desired precision with a specified probability of coverage.

Findings and recommendations: The prototype tools developed in Phase I have already been tested in a larger, classified N81 scenario. The new capabilities have yet to be used to assist in obtaining timely insights in support of an N81 study. The primary objective of the Phase II effort is to assess and transform the prototype tools currently under development for Phase I into products that are valuable contributors to N81 studies. With sponsor approval, the tools will be used to support a to-be-determined N81 study. This research continues with the goals of improving upon and extending the proof-of-concept prototype tools developed in the Phase I effort, testing them, and transferring the new capabilities into a ready-for-use capability at N81. This will include testing, refining, adding new functionality, making user friendly, and documenting the new STORM post-processing tools. If given N81's approval, we will also verify and assess the utility of the tools developed in the Phase I effort on an existing, classified scenario being used by N81 to support senior decision makers. Specifically, can we obtain better insights and/or get them quicker? In addition, pending sponsor approval, we will design, create, and give a short-course to interested Navy analysts on the new capabilities and how to best to apply them to STORM studies.

Unmanned Surface Vessels Anti-Submarine Warfare Employment

Researcher: Luqi

Students: FORNATL Mongi Bellili, LT Andrew Branham, Capt Jonathan Galinski, LT Matthew Gray, LT Seneca Johns, LCDR Jeffrey Korzatkowski, LCDR Sean Nelson, LT Isaac Patterson, LT Jay Taylor, CPT Daniel Alexander, Capt Alexander Beachy, Capt Brian Carthon, Capt Jamie Claflin, LT Joshua Corney, Maj Scott Fortner, Capt Joseph Lukefahr, and Maj Daniel McBride

Background: The objective of this study is to answer the following questions:

1) How might unmanned surface vessels (USVs) be effectively used for anti-submarine warfare (ASW)? What potential attributes of USVs (such as speed, low cost, stealth, endurance, expendability, no requirements for human access or support systems, etc.) contribute to their effectiveness? How can their relative advantage be measured and compared?

2) Are there ASW missions that lone or multiple USVs could accomplish with equal or greater effectiveness than other ASW platforms (manned surface or submarine, manned or unmanned air platforms)? ASW usually requires a coordinated team effort. How would the USVs need to interact with other platforms, and what kind of communications would be necessary?

3) To which aspects of ASW are USVs best positioned to make the greatest contribution? For example, a USV could be used for Information, Intelligence, Reconnaissance, recovery of a UAV, or as a communication hub. What are appropriate measures of cost and value for answering this question? What kind of USV would be best for each aspect?

Past approaches to ASW include frigates and Surveillance Towed Array Sensor System, an aging system due for replacement soon. The purpose of frigates is to protect other ships – mainly via ASW and air defense, while the Littoral Combat Ship (LCS) adds an optional mine-sweeping mission package. The last of the 51 old Oliver Hazard Perry-class frigates is due to be decommissioned by Oct. 2015, and the LCSs that are supposed to replace them are slow in arriving—four have been commissioned as of Sep. 2014, 32 are planned, and plans are under review for possible adjustment. The motivation for the study is to explore whether USVs can effectively augment the capabilities of the relatively small number of surface platforms currently available to focus on ASW and if so in what capacity can they best contribute.

Process: We are reviewing the open literature to identify relevant building blocks and possible concepts of operation. Requirements and environment models will be refined and evaluated with the help of NPS students, in a variety of what-if scenarios that elicit ideas about plausible new configurations, to home in on the most promising ones.

Findings and Conclusions: A preliminary finding of the study is that USVs have advantages over manned platforms in the context of strike group protection. Sanitizing an area prior to transit is a high-risk mission somewhat akin to mine-sweeping. It makes sense to use cheap unmanned systems rather than expensive manned platforms. In addition to these risk considerations, it is difficult to cover a large area with an affordable (small) number of manned platforms—a larger number of unmanned platforms would have better sensor coverage, if the sensors are the same.

USVs providing ASW support for protected transit should have top speed, sufficient to catch up with the strike group during or after a transit. This implies the need for refueling and argues for accepting systems with less endurance than slower USVs that rely primarily on renewable energy sources such as solar, wind, and waves. This limitation is likely acceptable in the context of protected transit because the time span of a typical mission is limited and

because such USVs will be operating near a strike group, so that the larger ships can resupply (mainly fuel) and provide minor repairs/maintenance.

Recommendations: To be provided at the completion of the project.

N9: Warfare Systems

Optimized Naval Aircraft Capital Investment Planning

Researchers: Robert F. Dell, Gerald G. Brown, Javier Salmeron, and Anton Rowe

Student: Capt Holly Zabinski

This research effort continues development of an optimization model called the Capital Investment Planning Aid (CIPA) with a specific tailoring to naval aircraft. CIPA prescribes aircraft procurement and retirement schedules over a 30-year planning horizon while adhering to annual budget constraints, industrial base requirements, business rules, and force structure requirements expressed in terms of supporting mission areas. CIPA considers multiple aircraft types, multiple mission areas, track average aircraft age for each aircraft type, and expected attrition for each aircraft type. As a result of this effort, CIPA will become a fully functional decision support system. This effort is ongoing with completion expected May 2015.

Background: CIPA was initially developed over a decade ago to assist Navy long-range force structure planners at the Chief of Naval Operations, Assessment Division (N81) (see Field 1999, Baran 2000, Garcia 2001, Salmeron, Brown, Dell and Rowe 2002, and Brown, Dell, and Newman 2004). At that time, N81 planners manually considered alternate future ship, submarine, and aircraft procurement and retirement schedules, and evaluated these with a contractor-developed spreadsheet tool. This tool, the Extended Planning Annex/Total Obligated Authority model, estimates the financial impact of any complete future plan over a 30-year horizon. While manually preparing such plans, N81 force structure planners must consider annual budget, industrial base, and force structure requirements expressed in terms of the number of platforms needed to support a mission. CIPA allowed for manual planning to be replaced with optimized planning.

Research/ Study and Analysis Objectives: This research updates CIPA and specifically tailors it for aircraft and use by N98 planners. In the decade since CIPA was originally developed and implemented, there have been substantial improvements in both available desk-top computing power and the underlying algorithms used to solve CIPA. Such improvements enable improved solution time and only add to CIPA's usefulness as a decision support tool. In addition, we are looking to fully implement improvements such as increasing Operation and Maintenance Navy costs as aircraft ages increase, and model an age-dependent aircraft effectiveness of an aircraft type for a mission.

Approach: The summary below (adapted from Garcia 2001) outlines the characteristics of the formulation we will fully implement. See Salmeron, Brown, Dell and Rowe 2002 for a more complete mathematical formulation.

Main Decision Variables:

- Number of aircraft to procure at the start of a fiscal year;
- Number of aircraft to undergo service life extension;
- Number of aircraft to retire at the end of a fiscal year that is a specific age; and
- Magnitude of each constraint violation.

Objective Function: Minimize the penalty for violating constraints for the following areas:

- Annual air mission satisfaction;
- Annual aircraft and air mission average age;
- Annual and cumulative total budget;
- Annual air and cumulative air budget; and
- Annual air mission and cumulative air mission budget.

Subject to the following annual constraints:

- Limit annual minimum aircraft inventory;
- Limit the annual number of aircraft produced;
- Limit annual aircraft retirements;
- Limit annual maximum aircraft average age;
- Limit annual maximum air mission average age;
- Limit minimum and maximum annual and cumulative total budget;
- Limit minimum and maximum annual air and cumulative air budget; and
- Limit minimum and maximum annual air mission and cumulative air mission budget.

Work is ongoing to reformulate the CIPA optimization engine and to make CIPA more user-friendly.

References:

Baran, N. (2000, December). *Optimizing Procurement Planning of Navy Ships and Aircraft* (Master's thesis, Naval Postgraduate School).

Brown, G.G., Dell, R.F., & Newman, A.M. (2004) *Optimizing Military Capital Planning*. *Interfaces*, 34(6), 415-425.

Brown, G.G., Dell, R.F., and Wood, R.K., 1997, "Optimization and Persistence," *Interfaces*, v. 27, No. 5, pp. 15-37.

Field, R.J., (1999, December). *Planning Capital Investments in Navy Forces* (Master's thesis, Naval Postgraduate School).

Garcia, R.M. (2001, December). *Optimized Procurement and Retirement Planning of Navy Ships and Aircraft* (Master's thesis, Naval Postgraduate School).

Salmeron, J., Brown, G.G., Dell, R.F., & Rowe, A. (2002, September). *Capital Investment Planning Aid (CIPA)*. (NPS-OR-02-006). Naval Postgraduate School.

Enhancing Medical Capabilities for Disaggregated Operations

Researcher: Geraldo Ferrer

Students: LT Temitope Ayeni, and CPT Nolan Roggenkamp

This study will require a literature review, including a review of the medical and devices literature (most likely from PubMed), a review of prior studies conducted by the military focusing on the other armed services (especially the Army), a review of research reported by military treatment facilities (such as those reported on in the Navy Medicine Training Symposium), interviews with several Veteran Affairs medical personnel, as well as interviews with novel technology development companies. The latter is feasible since many of these companies are located in Silicon Valley, just a short drive from the Naval Postgraduate School.

We will focus especially on the technologies involving telemedicine and virtual medicine, and the ability to have individual mobile units that can support self-diagnosis and even self-

treatment (if urgently needed), as well as individual mobile units that can serve as stabilization centers. The idea is to extend the reach of the physicians to disaggregated locations when they cannot be physically present and yet there is an urgent need for non-combat health care.

Once the list of potential technologies has been identified, we will examine any existing evidence available in terms of the feasibility of transferring this technology to the military setting. Building on the transfer studies that have already been done by the navy medical community, a heuristic will be developed to help estimate the likelihood that a novel technology can be successfully transferred to the military domain. The list of potential technologies will be evaluated against this algorithm.

After this research is completed, we will make a recommendation for each of the potential new technologies for their adoption into a military sickbay. This will require making trade-offs between the likelihood of effective transfer and the potential benefits of the new technologies. A priority system will be developed to conduct this ranking.

This report is currently in progress, with the final report and deliverable completion estimated in December 2014.

Radar Technology Study

Researchers: David Jenn, Phillip Pace, and Ric Romero

Students: LCDR Cornelius Mason, LT Owen Brooks, ENS Connor Westrick, and ENS Kathleen Heinback

Background: The objective of this research is to examine current radar architectures and technologies applicable to low probability of intercept radar (LPIR) for Navy platforms. In FY14, the study resulted in a new LPI radar concept that provides the same performance as conventional pulsed radar, but is more covert. The radar incorporates digital technology in all functions—in the antenna beamforming, waveform generation and transmission, and receiver processing.

Process: Simulation software was developed, and the radar system performance and the detection of radar emissions by a non-cooperative intercept receiver (NCIR) have been simulated. For our design, when the radar is in the presence of an intercept receiver with a specific sensitivity, the radar is able to detect targets at a much further range than the intercept receiver can detect the radar emission. The details of this research are classified.

Findings and Conclusions: A baseline LPIR was designed and simulated. The radar's target detection capability and covertness were verified.

Recommendations: Future work is proposed to optimize the design parameters and examine the specific technologies that can be employed. A detailed design of the subsystems and their performance will be evaluated using "end-to-end" simulation that includes all subsystems, hardware, target, environmental conditions, and NCIR characteristics. Specifications for components will be determined and their reliability, maintainability, and risk will be assessed.

FA-XX Long-Term Cost and Technology Risk

Researchers: Robert Koyak, and Gerald Brown

Background: Current methods to estimate long-term cost and technology risk in a major defense acquisition project, such as the Thirty Year Aviation Plan, do not provide sufficient rigor to inform long-term decisions on scheduling and cost. These acquisitions are comprised of a large number of components (tasks) that are logically interrelated, with some tasks requiring the successful completion of antecedent tasks before they can be initiated (serial relationship), while other tasks can be initiated independently of the outcome of other tasks (parallel relationship). Taken together, task interrelationships and constraints posed by fiscal-year budgets and maturation of technology affect the propagation of uncertainties related to timeliness and cost of the acquisition in ways that are difficult to describe. We propose an approach similar to one that the investigators developed for the U.S. Army's analysis of alternatives (AoA) for its Future Combat Systems (FCS). Our effort is directed to the Navy's Thirty Year Aviation Plan, or to major programs within it such as FA-XX which covers recapitalization of the F/A-18 series of aircraft.

Process: Our effort focuses on six scenarios for development of aircraft engines to support N98's Analysis of Alternatives (AoA) event in mid-2015. This requires obtaining information on the subtasks that comprise each scenario, defining their parallel-serial relationships, quantifying uncertainties with respect to cost and schedule, and developing an optimization model to find the best schedule given these inputs. Simulation then is used to account for uncertainties of a random nature, which is the approach taken by the authors to support the AoA conducted by the Army for FCS.

Progress to date: Due to the extension of the project to June 15, 2015 we have no findings, conclusions, or recommendations to report at this time. In September 2015, Prof. Koyak visited N98 to obtain information needed to start the development of an optimization model.

During this visit, the investigators obtained detailed information about the six engine development scenarios currently under evaluation by the U.S. Naval Air Systems Command. We continue to evaluate this information for guiding the development of an optimization-based tool that N98 can use as it refines its scenarios over the long range of the Thirty Year Aviation Plan.

ASN (RDA): Research, Development, & Acquisition

Modernizing Test and Evaluation Procedures to Support Navy Open Architecture

Researchers: Valdis Berzins

Student: LT Kevin Killeen

Background: Objectives of open architectures include reducing total system ownership costs and improving agility of force and system capabilities. These depend on sharing components across platforms and enabling system flexibility by component swapping. Reusable components require more stringent test and evaluation than single-use components because of greater exposure to operational risk. Components proven reliable in one context can often fail in a different context, because new failure modes become reachable. Other prominent failure patterns include system integration problems.

Current procedures require retesting a component each time it is reused in a new platform or technology upgrade, even if the component has not been changed. This accounts for a large portion of total ownership cost. Savings depend on determining how and under what circumstances retesting can be safely reduced, and which parts of test and evaluation can replace human effort by automated processes with lower marginal costs. We are studying methods for this and reducing incidence of system integration problems.

Process: Our approach combines software dependency analysis, automated testing, Technical Reference Frameworks (TRF), and quality assurance methods for software architectures.

We use software slicing and other forms of dependency analysis, such as fault trees, to support cost-effective allocation of testing effort to mitigate system risks. This combines a system-level risk analysis with dependency analysis and risk-level acceptance decisions by designated authorities. Methods determine maximum tolerable error rates for each software service and embedded software components, and together with required confidence levels that actual failure rates are below derived tolerances. The number of test cases required are derived from the confidence levels and tolerances. This drives the allocation of testing effort for each component to achieve required risk mitigation with minimum effort necessary. We are continuing work on quality assurance procedures for architectures and transitioning results into the TRF working group.

Findings and Conclusions: We have developed risk-based processes that provide systematic answers to “how much testing is enough,” based on risk tolerances and analysis that identifies the worst-case impact of a failure of each software component. This quantitative process tests the mission, and safety-critical modules more thoroughly than those whose failure has less impact.

We are also seeking ways to reduce system integration problems for systems with open architectures. A preliminary result of our study is that many system integration problems are symptoms of faults in the architecture, or weaknesses in associated quality assurance processes.

Expected long-term impact of our results on the DOD includes reductions in total ownership costs for software-intensive systems, reduction in project development costs, and reduced risk exposure after system deployment.

Recommendations: Our preliminary findings are that:

- Architecture descriptions and associated standards should be a required deliverable in all contracts for systems with open architectures, and these should have to pass quality assurance reviews specifically targeted at preventing system integration problems.
- System implementations should be required to pass quality assurance reviews specifically aimed at checking conformance to the corresponding architecture descriptions and relevant TRFs.
- Automated black-box testing should be combined with clear box testing to assure that every line of code has been tested at least once in order to detect potentially severe software faults such as deliberately injected “back doors”. This process should be supported by automated tools such as constraint solvers for constructing test inputs that exercise rare execution paths, and by human reviews targeted at sections of the code that could not be covered by constructed test cases.

3D Modeling and Visualization of Allied Special Weapons Handling Site

Researchers: Dan Burns, Don Brutzman, Terry Norbraten, and Joe Sweeney

Background: Project goals include site visits to determine measures of effectiveness (MOEs) for improved situational awareness, scenario training, and after-action evaluation that can be derived from 3D visualization. Tactics, techniques, and procedures (TTPs) may vary depending on the site, branch of service, and government involved. The tasks will be performed using U.S. or Allied facilities as appropriate, working in close partnership with host security forces. Our research goal is a study that articulates unique protection requirements and initial proof-of-capability demonstration showing the potential value of modeling, simulation, and visualization technologies to improve both assessment and performance within this sensitive arena. Secondary goals allow for multiple scenario development studies depicting Strategic Systems Programs and Allied Anti-Terrorism/Protection Forces reactions and possible improvement areas.

Process: The research team approach utilized a data-collection model/approach for this project. It will be driven by in-person site visits and in-depth technical reviews at the sponsor facilities. In-person inspections during the recent past revealed the need for deeper exploration and understanding of tactics, techniques, procedures, and response techniques, in the hopes of using the latest capabilities appearing in emerging technologies. No human-subjects research activities subject to Institutional Review Board oversight are anticipated as necessary for successful completion of this project. Raw data will be obtained and reviewed in the context of understanding existing, already-approved security procedures. Modeling of core assets and animation of mobile entities is expected to illustrate these well-understood TTP's in a meaningful virtual context.

Technical details regarding 3D modeling, simulation, and visualization approach follow. As illustrated in the referenced theses, NPS has a long track record of 3D modeling and tactically oriented simulation as a means to visualize and study difficult problems, both qualitatively and quantitatively.

- Use of repeatable standards. Extensible 3D (X3D) is royalty-free open-standard file format and run-time architecture to represent and communicate 3D scenes and objects using XML. X3D is an International Organization for Standardization ratified standard that provides a system for the storage, retrieval, and playback of real-time graphics content embedded in applications, all within an open architecture to support a wide array of domains and user scenarios. X3D has a rich set of componentized features that can be tailored for use in engineering and scientific visualization, computer-aided design and architecture, medical visualization, training and simulation, multimedia, education, and more.
- Practitioners developing open-source technology. No software licenses are required since our team produces open-source modeling software code and will

use the X3D Graphics open standard. Multiple key assets are produced and maintained in version control by NPS MOVES, including authoring tools and open/FOUO X3D model libraries.

A sample modeling Run from the research is depicted below:

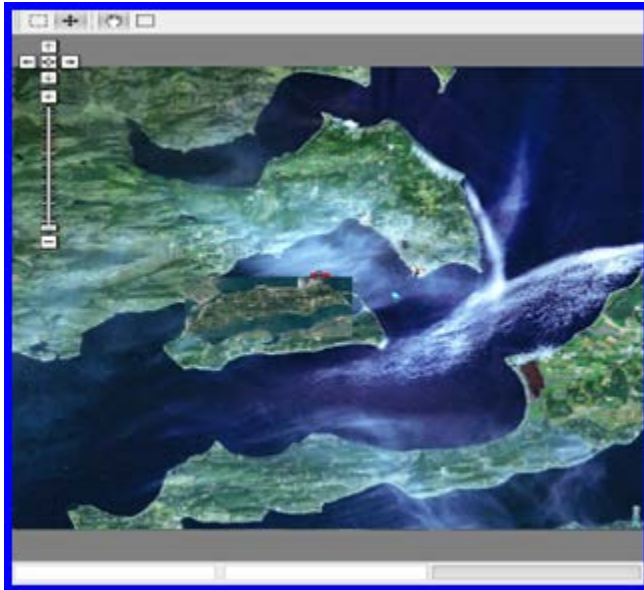


Figure 1: 2D Overview of Simulation Study Area

- Classification. As appropriate, modeling can be performed at an unclassified or higher level. It is important to project classification requirements early in order to facilitate proper preparation and exchange of information.

Findings and Conclusions: The Research Team (RT) traveled to Sponsor Field Site at Bangor & Kitsap Washington. Multiple improvements have been made to the Modeling Software & Visualization Software & tools. RT uncovered a parallel technology effort at the Naval Facilities Engineering Command (NAVFAC) that uses the same standards approach and has been briefed to OSD Office of Transformation, Navy Modeling & Simulation Office, and Deputy Assistant Secretary of the Navy–Research Development Testing & Evaluation. Briefs were presented to Sponsor Representatives at Headquarters element in the Navy Yard Washington DC.

A U.S. Coast Guard Lieutenant student officer assigned to the Research Team specifically accomplished:

1. Thesis proposal has blocked out the background, problem statement, purpose and initial literature review. Quarterly review shows all concepts remain sound with incremental progress occurring as planned.
2. Comprehensive Examination of Literature:
 - Studied three theses and ten related references in detail. Soon to study four additional related theses that illustrate analyst simulation methodologies.
 - Reviewed the NAVFAC visualization program, SPIDERS3D, which provides sharable X3D visualization of all U.S. Navy ports and piers worldwide.
3. Construct Research Design:
 - Conducted two site visits. One more site visit will be needed to ride USCG escort vessels and gain access to USCG/USN team trainers. During the next site visit, we also expect to visit Indian Island to confirm all relevant simulation parameters.
 - Reviewed and commented on the construction of Savage Studio video documenting end-to-end conduct of the analytic process.
<https://savage.nps.edu/videos/SavageStudio-Scenario-Demo.2014OCT01.mp4>

The Project has encountered scheduling delays in FY 14 due to late receipt of funds and hiring freeze and associated end-strength restrictions that necessitated the research going into FY 15. There are enough remaining funds to conclude all project goals by September 2015. No future plus up funds will be requested to achieve the new completion date. Conflicting schedules prohibited completion originally targeted for November of 2014. Data acquisition and analysis is scheduled for second quarter 2015. Project will be completed by September of 2015. The new completion date coincides with the student graduation date. Revised spending plan will be submitted to the NPS Dean of Research Office.

Recommendations: Continue on course and speed with the research. The research sponsor will be onboard the NPS campus the week of 27 October 2014. He will be briefed by the RT members and specifically the USCG student officer.

High Energy Laser Weapon Physics-Based Analysis for Naval Platforms

Researchers: William B. Colson, Joseph Blau, and Keith Cohn

Student: ENS Chris Fussman

Background: The Navy has an intense, sustained interest in high-energy laser (HEL) weapons, as demonstrated by the current effort to deploy an HEL aboard the USS Ponce. HELs are all-electric weapons with deep magazines, and their precise, rapid delivery of energy onto targets makes them advantageous over kinetic weapons in many instances. However, the operational parameters where HELs hold the advantage over their kinetic counterparts are not well defined when considering the physics of delivering lethal energy (both hard and soft kills) to the target. For example, atmospheric considerations (wind, turbulence, scattering, absorption, thermal blooming, etc.) affect how much light from an HEL can be focused onto the target. This research evaluates the performance (including effective ranges and necessary dwell times) of HELs in a wide variety of configurations and weather conditions. It provides important trends to warfighters regarding the effectiveness of HELs in many different engagement scenarios.

Process: We use a systems physics approach, incorporating multiple effects such as diffraction, absorption, scattering, turbulence, and thermal blooming. We consider energy/target interactions (kill mechanisms) for various laser powers, targets, ranges, and atmospheric conditions. For this research, we have developed a new atmospheric propagation code called ANCHOR. Coupled with industry standard radiative transfer codes that estimate the optical properties of the atmosphere, ANCHOR rapidly models laser performance in millions of configurations and weather conditions. ANCHOR is up to a factor of 105 faster than existing codes, and has been validated against industry codes, such as WaveTrain.

Findings and Conclusions: For potential engagements at a 5 km target range, a 100 kW-class HEL is most likely to successfully engage slow-moving targets (such as light aircraft, UAVs, etc.) only in mild atmospheric conditions. Specifically, this requirement is met if atmospheric turbulence is weak to moderate and the visibility is greater than 10 km with no appreciable precipitation. Furthermore, large beam director sizes increase the on-target laser irradiance in only weak turbulence conditions. For target ranges closer than 5 km, the 100 kW-class HEL can be effectively utilized in an offensive and defensive capability against slow-moving targets in visibilities of only 5 km, in very turbulent atmospheres, and even in rainy weather. Since the various contributions to on-target laser irradiance are strongly dependent on target

range, these contributions conspire to greatly increase laser irradiance at shorter distances to compensate for the losses in less than ideal weather conditions.

Recommendations: This study provides this information to the Navy and Marine Corps regarding the strengths and limitations of HEL weapons. The results from this study should be used to develop tactics regarding how HELs can be utilized in conjunction with conventional weapons for different laser configurations and weather conditions.

Department of the Navy Online Fraud Protection Riding on an Integrated Business Intelligence Foundation

Researchers: Robert J Eger III, Juanita Rendon, and Rene. G. Rendon

Students: LCDR Thurman Phillips, and LT Raymond Lanclos

Background: In this study we report on an exploration into the viability of detecting anomalies using data analytics software as a tool in government fraud prevention from a stakeholder perspective. Our focus is on an analysis of the implications of business intelligence and analytics (BIA) fraud tools on federal procurement stakeholders.

Process: We began our exploration by looking at BIA and analytics. We looked at the role of integrated analytics programs, stakeholder implications, and alternative ways to implement BIA programs as identified in the literature. We analyzed, through an interview methodology, the potential impacts of BIA fraud programs on government stakeholders in the procurement process.

Findings and Conclusions: We find that the implementation and integration of a BIA fraud program, from our stakeholders' perspective, is that a BIA program has more procedural implications than policy implications. The four elements of the conceptual framework developed provide a guideline into the successful deployment of a Department of Defense data analytic procurement fraud-prevention program.

The BIA program is seen to streamline processes by consolidating information and presenting data within a singular program. The knowledge gain is that the functioning data analytics prevention program increases the confidence level of our stakeholders without alleviating their responsibility to perform their due diligence in their management functions.

Recommendations: Through the use of established data analytics techniques currently employed in the commercial sector, the issue of fraud could be addressed with the

implementation of data analytics software in the Department of the Navy that aids in detecting anomalies associated with fraud schemes. The detection of these anomalies raises “red flags” within the processes of multiple stakeholders, sparking further proactive investigation into the cause underlying the “red flag”. Data analytics software allows for the near instantaneous analysis of vast amounts of data that would have previously sat dormant, thereby allowing fraud schemes to go undetected within government process. The BIA tool is found to provide the flexibility to detect previously unknown fraud schemes.

Our stakeholder interviews show that by using a data analytics software program in the prevention of fraud, the critical resources of money, manpower, and time would be protected from fraudulent activities in a proactive manner. This proactive approach identifies fraudulent activities before they are implemented and reduces costs to the taxpayer associated with lost resources due to fraud. These critical resources are then freed, to be utilized in a more efficient way.

High Energy Laser Employment in Self Defense Tactics on Naval Platforms

Researchers: Jeffrey E. Kline, Tom Lucas, Paul Sanchez, Mary McDonald, and Steve Upton

Students: LT Brett Roblee, LT Dustin Schultz, and LT Steve Rockwell

Background: With potentially a nearly unlimited magazine, shipboard directed energy weapons tactically employed against enemy air and surface threats provide the possibility of an effective defense against swarm or numerous attacks when combined with other hard and soft kill systems. Technical constraints, however, will require intelligently employing a directed energy system in coordination with other shipboard defense systems against a heterogeneous set of threats from a coordinated attack. Technical constraints include line-of-sight engagements, dwell time for target damage, re-fire rate, re-targeting rate, and beam control due to ship vibration and atmospheric turbulence. As these constraints are relaxed by advances in technology provided by NPS research on directed energy in these areas, an assessment on the value of those advancements may be made by evaluating how many more targets directed energy weapons can engage in a coordinated defense. This project’s goal is to model the high energy laser in various tactical situations to evaluate the impact on ship self-defense in high threat environments and to develop recommendations for best tactical employment in coordination with a full combat system suite.

Process: In coordination with Naval Surface Warfare Center (NSWC) Dahlgren, a team of NPS operations research faculty, students, and research associates developed an agent-based model in Map Aware Non-uniform Automata (MANA) to represent a guided missile destroyer (DDGs) combat suite defending against a variety of threats with and without the Solid State Laser (SSL). Data was provided by NSWC and the Office of Naval Research (ONR), and the results compared to NSWC's laser modeling workbench. A design of experiments was conducted to identify important weapon capability and employment variables and various tactical situations were simulated hundreds of thousands of times to explore those parameters. Advanced statistical tools were used to identify critical operating parameters in SSL employment and to quantify its contribution to ship self-defense.

Findings and Conclusions: Although specific results are classified, the modeling results clearly demonstrate value in adding a SSL to a DDG's self-defense capabilities against swarming UAVs. The "SSL in MANA" outputs compared favorably with NSWC's laser workbench program, providing evidence that an agent-based model may be used to assess laser technical improvements on ship's self-defense and in tactical development. Specific tactical employment recommendations were developed related to open fire range. MANA, however, proved a challenging environment to model naval tactical weapon employment and major effort was required to adequately represent the command and control of various weapon suites. During the period of this investigation, NSWC began development of an agent-based modeling environment specifically designed to represent naval warfare. NPS was provided a beta version of this program and began modeling tactical engagements in it for follow-on work.

Recommendations: With sponsor approval, this work continues by extending tactical situations to include more airborne threats and surface swarms. "SSL in MANA" will be replaced by NSWC's agent-based modeling suite to analyze these situations. The results from this research have provided a quantitative military assessment of employing SSL on a DDG in a high threat environment. Those results have been shared with OPNAV N-81, ONR, and ASN (RDA). Tactical employment recommendations will be provided to Navy Surface Warfare Development Command's tactics group.

THIS PAGE INTENTIONALLY LEFT BLANK

United States Marine Corps

United States-Mexico Security Development Partnership Project

Researcher: Mark Berger

Topic Sponsor Organization: Marine Corps Security Cooperation Group

The purpose of this research is to gain a deeper understanding of the changing character of U.S.–México relations and how these changes affect our shared North American security context. The research will focus on the transformative processes at work in México and the direct and indirect implications that these have on, and for the United States, which is also undergoing major changes. The research will build on the growing number of books, articles, reports, and publications that examine the significance of U.S.-México relations. The research will also contextualize the role of the Marine Corps' and its priorities and objectives by working in harmony with the U.S. Marine Forces North Command, along with the security cooperation teams from the operating forces.

Enabling Marine Aviation Digital Interoperability

Researchers: Dan Boger, and Arkady Godin

Student: Maj Nathaniel Stusse

Topic Sponsor Organization: USMC Deputy Commandant, Aviation

Background: The current Marine Corps Digital Architecture has evolved based only on Tactical Data Links (TDLs). USMC Deputy Commandant, Aviation, has posed a series of questions, spanning physical to logical data layers:

- How efficient are these various data links? Could legacy datalinks be used in conjunction with gateways to effectively move large data requirements, like full-motion video?
- Are tactical data links capable of fusing air and ground data into a knowledge environment where leaders from the platoon to division level can make decisions?

- Describe an ideal gateway for the Marine Corps. Is it located in the air, in space, on the ground, at sea, or is it a modular system that can be moved from one domain to another?

The purpose of this research, at the initial stages, requires an understanding that sponsor requirements represent a mix of requirements at two horizontal layers: (1) physical network layers and (2) logical data layers. Without integrating requirement questions for the former, which have been expressed in bullets 1 and 3, into the physical network layers requirements, the study might completely ignore the logical data layers requirements. Those requirements, expressed via the single question in Bullet 2, are fundamental as physical network layers represent the necessary piping to help the leaders make decisions at the tactical edge (from platoon to division) knowledge environment (KE).

Process: The process of the research is in the preliminary stages as Maj. Nat Stusse and his thesis co-advisor, Arkady Godin, are working on finding an acceptable method for separating the two different groups of requirements. Maj. Nathan Marvel is expected to address the proper methodology by proceeding on two different vectors. The current approach for bullets 1 and 3 is to develop an overview of the best practices based on open standards, Government-Industry consortia, and mature commercial technology solutions to move data over TDLs to highlight ways to address the formulated questions.

Findings and Conclusions: Bullet 2 requires choosing a specific path of research to follow since during the last several years of the Big Data revolution, the Data-to-Decisions (D2D) space has grown dramatically but is not at a Technology Readiness Level required by the Department of Defense. Considering the Joint/Coalition aspects of D2D and KE requirements, the study requires examining methodologies that enable the decision maker to turn information management environment into a KE. The Air Force Research Laboratory, Rome, has been investing in this field of research during the last 4-5 years, so we will be collaborating with them on this issue.

Recommendations: Recommendations will be prepared by 30 June 2015, Master Thesis completion date.

United States Marine Corps Distribution in the Battlespace

Researcher: Anthony Kendall

Students: Maj Paul Hudson, and Capt Jeffrey Rzasa

Topic Sponsor Organization: Logistics Policy and Capabilities

We have been invited to participate in EXLOG Wargame VIII; this will enable us to correctly identify potential Command, Control, Information, Surveillance, and Reconnaissance and Global Combat Support Systems-Marine Corps data streams. Finding valuable information will translate into a common operational picture permitting Marine Air-Ground Task Force commander and his staff (including Small and Medium Enterprise Logistics) to make effective on-time decisions. Continuing focus on the forces and systems forming cloud ecosystem sets a foundation for the Framework for Decision Support Tools to enhance strategic to tactical level decision-making. This is a tightly coordinated effort between NPS Researcher Arkady Godin and sponsor points of contact, Cesar Valdesuso and Dr. Joe Mickiewicz.

This project is currently in progress with the final project and deliverables projected to be complete by September 2015.

Mobile Ad-hoc Network Node Monitor

Researchers: Alex Bordetsky, Eugene Bourakov, and Steve Mullins

Students: Capt Buddy Ellis, Capt Michael Harris, Capt Millard Woodward

Topic Sponsor Organization: Marine Corps DC Aviation

The main objective for this project is to develop a novel predictive aerial Mobile Ad-hoc Network (MANET) node management model. The model would allow monitoring and organizing of MANET aerial nodes on-the-move, to provide required connectivity and performance. The expected model would work with USMC aircraft simulators to train pilots how to 1) operate as MANET nodes in the air, 2) support each other as relays or data processing nodes, 3) augment ground unity connectivity and reach-back, and 4) reposition themselves in their airspace to respond to disruptions caused by an attack or mobility issue.

The main project deliverable will be a new disruption-based network operation decision-support module. The decision-support architecture would include a Common Operational Picture Heat Map Interface, combined with a manned-unmanned teaming knowledge base to predict how and where to move existing or additional aerial nodes, in order to either retain/improve physical layer connectivity, or to become critical passive relay nodes.

This project is currently in progress with the final project and deliverables projected to be complete by December 2014.

Leveraging Mobile Ad-hoc Network and Mobile Devices in Ship-to-Objective Maneuver and Expeditionary Marine Air-Ground Task Force Operations

Researcher: Alex Bordetsky

Student: Capt Joshua Waddell

Topic Sponsor Organization: Marine Corps Warfighting Laboratory

Background: This research is in response to the changing nature of Marine Corps expeditionary operations. Specifically, it seeks to address areas for improvement in command and control (C2) and intelligence collection during initial phases of expeditionary operations in austere environments with limited logistical footprint. This study seeks to leverage current information technology solutions with modern communications architecture to provide a demonstrated proof-of-concept for intelligence collection in tandem with C2 functions in distributed operations.

Problem: The functional requirements of C2 and intelligence collection in modern warfighting have outstripped the linear very high frequency-based tactical communications architecture currently in use by the Marine Air-Ground Task Force (MAGTF), particularly given the stresses of over-the-horizon expeditionary operations. There is currently a lag between the deployment of frontline conventional troops and the establishment of a consolidated C2/Intelligence node on the battlefield in expeditionary operations. This study seeks a solution to eliminate that lag time and further enhance the commander's situational awareness and decision-making process during this critical and chaotic initial phase of operations.

Purpose: The purpose of this study is to assess the feasibility of a system-of-systems approach to C2 and intelligence collection during the initial, austere, and expeditionary phases of operations undertaken by the MAGTF in combat and non-combat scenarios.

This study outlines the advantages to the commander's decision-making process by allowing for a more distributed deployment of his forces through advanced radio technology, more accurate and robust initial intelligence reporting during the initial phases of operations, and an internet protocol-based solution to allow reachback to higher headquarters, subject-matter experts, and trans-national organizations to deal with contingency situations outside the normal scope of operations of the traditional MAGTF. This study will provide a detailed performance analysis of current commercial off-the-shelf and government off-the-shelf

systems through field experimentation with specific focus on the tactical deployment formations of the MAGTF as identified through traditional doctrine and emerging techniques.

Research Methods: This research was primarily conducted in a field setting. It included participation in multiple field experiments with the Marine Corps Infantry Officer Course as well as Marine Corps Warfighting Laboratory (MCWL). In these exercises, the potential strengths and weaknesses of emerging C2 architectures were considered, then used as specific case studies for the C2 equipment itself during the evaluation process. The observations made were then referenced back to the core planning documents of Expeditionary Force 21 (EF21) and the Marine Corps Vision and Strategy 2025. The research included field-testing of emerging radio technology that could allow for high-data throughput in ground combat use cases. Finally, a conceptual architecture for Marine Corps C2, which incorporates the lessons learned from field experimentation and study, was developed.

Over the course of the research, Capt Waddell was able to work with both the Infantry Officer's course and MCWL as they explored ways of tackling these challenges. He was able to physically participate in multiple iterations of these experiments and was able to make some observations worth comparing and contrasting.

Findings and Conclusions: The principal hypothesis underlying this research was determined to be correct. At the current level of technological maturity, it is absolutely possible to support a data-rich environment on the tactical edge of Marine Corps units while operating under the austere conditions outlined in EF21 and the Vision & Strategy 2025 document. By using Persistent Systems MPU-4 radios, we were able to achieve data throughput rates of up to 20 Mbps across an infantry formation while conducting an attack. While in the Philippines, Capt Waddell observed the utility of portable, small aperture satellite communications (SatCom) data terminals. Combined with intelligent, forward-deployed network control nodes and redundant push-to-talk SatCom systems like Distributed Tactical Communications System and Mobile User Objective System, it is possible to create a highly survivable system-of-systems while also maintaining an expeditionary logistical footprint. This network is the enabler for putting smart devices in the hands of talented combat leaders on the tactical edge, to enable a much more robust and responsive information environment than is currently available to today's warfighter.

It is worth noting that equipment like this has already been deployed in real-world situations. In response to the 2010 Haiti earthquake, the team from the NPS Hastily Formed Networks Lab was able to use broadband global area networks and wireless mesh networks to enable communication where no infrastructure currently existed. In the wake of Hurricane Sandy impact on New York City, the U.S. Coast Guard was able to rapidly deploy Wave Relay radios

to enable communications throughput at around 65% of what they had available with fixed infrastructure that had had been damaged in the disaster. This should be encouraging to military acquisition professionals in that many of the risks associated with technology development have been mitigated through years of successful deployments of these technologies within the civilian sector.

Recommendations: This research supports the original hypothesis that these capabilities are possible at the currently available levels of technological maturity. The point we wish to convey is not the feasibility but the urgency of C2 modernization. At the time of this document's writing, permanently stationed Special Purpose MAGTFs are being positioned in Europe, the Persian Gulf, and Southeast Asia. These units have been designated as primarily responsible for crisis response forces, largely growing out of the vulnerabilities demonstrated in the 2012 attack on the American Consulate in Benghazi, Libya. These units, along with the existing expeditionary presence of multiple forward-deployed Marine Expeditionary Units around the world, are requiring Marines to return to their expeditionary roots rather than conducting steady-state operations within established infrastructure, as was done in the wars in Iraq and later-stage Afghanistan.

It is imperative that the Marine Corps, with its unique deployment challenges and mission sets, adopt an aggressive acquisitions strategy to modernize its expeditionary C2 capabilities. The functional requirements for data availability at the tactical edge will likely continue to grow, and the Marines must take steps to adopt a system-of-systems, which provides the services necessary for tactical and operational success while allowing for an upgradable and expandable architecture as technology continues to rapidly improve. Failing this, we may soon see our Marines, with the world's largest defense budget behind them, outpaced and outmaneuvered in the information environment of modern combat by small teams with smartphones, as (Initial Operational Capability)discovered in 2013.

Expeditionary Unified Marine Corps Enterprise Network Information Technology Service Architecture

Researchers: Alex Bordetsky, and Steve Mullins

Student: LT Dusty Bartlett

Topic Sponsor Organization: Headquarters, USMC; Command, Control, Communications, and Computers

As part of joint Maritime Information Operations and Weapons of Mass Destruction Intelligence, Surveillance and Reconnaissance experimentation with 10th Special Forces Group the North Atlantic Treaty Organization Special Operations Forces, and Marine Corps Warfighting Laboratory Home, the Center for Network Innovation and Experimentation team has recently developed an expertise in integrating satellite mesh networking solutions across the autonomous clusters of fast-moving small units. The main objective for this project is to explore cost-effective solutions for the satellite mesh networking services within the expeditionary unified Marine Corps Enterprise Network (MCEN) Information Technology service architecture. This project is intended to explore the following tasks:

- Understand feasibility of using satellite mesh services for supporting the expeditionary units
- Determine scalability of satellite mesh service by conducting the field trials between two major locations, and
- Integrate satellite mesh service with other reach-back solutions.

These observations and findings will be summarized and describe cost-effective for satellite mesh services integration in MCEN architecture.

This project is in progress, and the final report and deliverables are expected to be available December 2015.

Big Data: A Low Cost Alternative to Data Warehousing

Researcher: Arijit Das

Topic Sponsor Organization: Office of the Chief of Naval Operations

Background: The Marine Corps uses a Data Warehouse known as Global Combat Support Systems Marine Corps (GCSS-MC) which is hosted on an Oracle Data warehouse. The data is mostly structured and growing. NPS researchers with their expertise in Oracle Database products and Big Data tools proposed to look at using the Hadoop Distributed File system (HDFS) as commodity hardware-based data store (alternative to the Data Warehouse), and run analytic in HDFS, comparing it to Structured Query Language (SQL) run in the warehouse. Another consideration was moving data between the warehouse and HDFS.

The hope is that providing an HDFS in conjunction with the data warehouse will open up the analysis of all kinds of data, structured and unstructured. The proposed tools involved writing

Java Map Reduce code to do large table scans. Also, a HDFS is built using commodity as opposed to proprietary hardware, which will result in reduced costs. NPS researchers also hope that evaluating these cutting technologies at a DOD lab will reduce reliance on contracting entities.

Process: NPS researchers first worked with the sponsor to get the GCSS-MC data. After the data was obtained, it was hosted on a Oracle 11G DB (database). SQL analytic queries were chosen and the data was exported into JavaScript Object Notation (JSON) format files, and loaded into HDFS. The analytic was generated using Java Map Reduce and the final results were loaded back into Oracle Database tables. Tools to move data fast, like the SQL Loader and SQL Connector, were looked into.

Findings and Conclusions: NPS has a pool of DOD researchers who, along with students, provide a good intellectual base to test HDFS tools for structured and unstructured data processing. A few analytic SQL queries were tested, and that lead to a Master of Science, Computer Science thesis, while more needs to be done.

Recommendations: A sustained year-by-year partnership is needed to keep a continued effort. Hiring of tech savvy personnel will increase the value added to this research.

Analysis of Marine Corps Renewable Energy Planning to Meet Installation Energy Security Requirements

Researcher: Nicholas Dew

Students: Christopher M. Chisom, and Jack C. Templeton II

Topic Sponsor Organization: USMC Logistics Command

Background: Over the past few years, the Marine Corps has recognized the importance of energy to its posture. At installations, energy security is an important issue. Energy security means installations need to be able to meet their minimum energy requirements to complete their missions when the electricity grid is interrupted by natural disasters or by a potential adversarial attack.

The Marine Corps is currently investing in RE (renewable energy) projects in an effort to meet the Secretary of the Navy's stated goal of 50% RE by FY2020. However, the current investment strategy involves a few major projects that boost the Corps' overall RE generation but fails to address energy security concerns at over half of Marine Corps installations, including Camp

Butler, Marine Corps Base (MCB) Camp Lejeune, MCB Quantico, 1st MCD Garden City, Marine Barracks, MCAS Camp Pendleton, MCAS Beaufort, MCAS Cherry Point, MCAS Iwakuni, Marine Corps Logistics Base (MCLB) Barstow, and MCSF Blount Island. Additionally, initial studies by National Renewable Energy Laboratory (NREL) have highlighted that the Corps' Net Zero goals for energy independence of some installations are not economic under any foreseeable financial/budgetary outlook.

The purpose of this project was to examine the economics of meeting the Marine Corps' installation energy security needs in the face of electricity interruption threats.

Process: This work drew on published research on energy portfolio energy economics and public data sources, as well as prior work by NREL on the Corps' energy initiatives. We also conducted a fact-finding trip to interview Deputy Commandant, Installations and Logistics staff and NREL staff face-to-face. We gathered the data from the Defense Utility Energy Reporting System, NREL studies, the Energy Information Administration, and Eaton Corporation's power quality database. In the study, we examined 20 Marine Corps installations to assess (a) how much RE would be needed for each installation to meet minimum requirements during a grid interruption; (b) what RE generation shortfalls exist given current RE projects; and (c) the net present value (NPV) of investing in RE projects when the costs of electricity interruption are explicitly accounted for in the analysis. The analysis was MS Excel spreadsheet-based using NPV methodologies as outlined in the Office of Management and Budget Circular Number A-94 guidelines.

Findings and Conclusions: To date, the Marine Corps has failed to determine the economic value of energy security at its installations. We find that by explicitly including the cost of interruption at each installation, the NPV of investment in RE to meet these installations' energy security needs is positive at 19 of the 20 installations studied.

Recommendations: The Corps should revisit its plans for investing in RE at installations. Planned investments at installations that already meet or exceed minimum energy security requirements, such as MCLB Albany and MCB Twenty-nine Palms, help meet SECNAV's stated goal of 50% RE at minimal cost, but do nothing to increase energy security at the rest of the Corps' installations. This policy of over-investing in low-cost RE generation projects to meet energy goals comes at the expense of providing energy security to other installations that have important roles in fulfilling Marine Corps' missions. Future RE investments should focus on RE projects that meet both the SECNAV's stated goals and provide practical energy security across the Corps' network of installations.

Efficient Intelligence Processing from Large Networks

Researchers: Ned Dimitrov, and Moshe Kress

Student: Chris Wood

Topic Sponsor Organization: Director of Intelligence, USMC

The central issue addressed by this research is how to efficiently and effectively process the glut of intel information by a human processor. The problem is to identify the greatest amount of relevant data in a limited time. Sub-issues include automated reasoning about intelligence sources, optimization of effort amongst difference input streams, collaborating filtering among fellow processors, and identification of new sources, keywords and relevant metadata.

This project is currently in progress, with final report and deliverables expected by December 2015.

Quantifying the Human Domain and Operationalizing Social Network Analysis Targeting

Researchers: Sean F. Everton, Daniel Cunningham, and Robert Schroeder

Background: This project was designed to explore how social network analysis (SNA) can be operationally deployed within the human domain. The project was initially to be carried out by MAJ Brent Molaski in conjunction with the Common Operational Research Environment (CORE) Lab. However, MAJ Molaski was deployed before he could complete the project, so members of the CORE Lab (Sean Everton, Daniel Cunningham, and Robert Schroeder) took it over and applied it to examining how SNA tools could gain a better understanding of the Islamic State of Iraq and Syria (ISIS).

Process: We explored and compared SNA tools for examining ISIS's Twitter communication networks.

Findings and Conclusions: The approach we took was to identify "influential" actors within ISIS's Twitter network and examine their use of ideological, cultural, and emotional terms and concepts to better understand its narrative. The Defense Analysis (DA) Department is collecting data, utilizing Arizona State University's Tweet Tracker and scripts written by DA staff to gather Twitter data. The data we analyzed was collected from 21-29 August 2014 and

consist of 19,267 user accounts in Arabic and 56,690 directed relationships, where accounts represent nodes within the network, while shared tweets and retweets represent ties between those accounts. The directed nature of the ties allows us to know the source of a tweet or retweet along with the recipient (i.e., the target) of the tweet or retweet. The figure below presents a graph of the ISIS Twitter network:

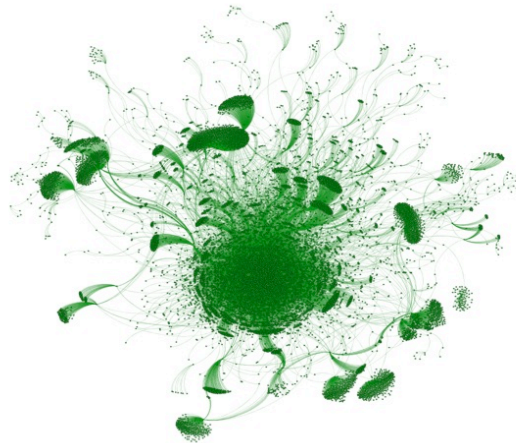


Figure 2: ISIS Twitter Network

This analysis utilizes both social network and semantic network analysis. Social network analysis is a collection of theories and methods used to detect and interpret patterns of social ties among actors. Here, we used an algorithm designed to identify “influential” user accounts within the network. Once we identified the influential user accounts, we extracted and translated the Arabic text of their tweets into English to identify key themes and concepts embedded in the content. Semantic network analysis, which is a set of theories and techniques used to interpret knowledge representation schemes involving nodes (concepts and themes) and links between them, is one approach to examine key themes and concepts and their relationships with one another. The figure below presents a graph of the ISIS semantic network:

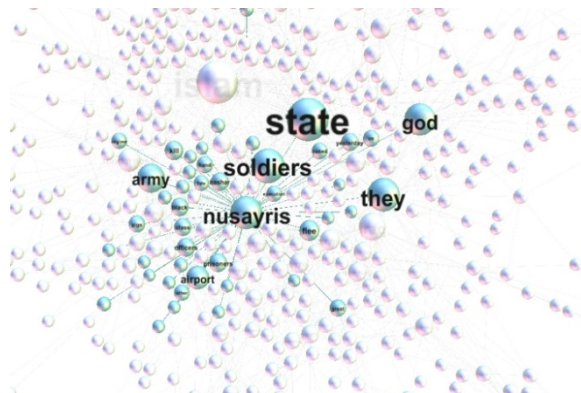


Figure 3: ISIS Semantic Network

Once we built out the network of themes and concepts, we examined which ones were most prevalent and how they were related to one another. The results suggest the discussion is focused on topics concerning Syria and Iraq (i.e., “near enemy”) more than concepts relating to the “West,” (i.e., “far enemy”). The most frequently discussed concepts, besides “Allah” and “Islam,” are largely anti-Syrian or anti-Iraqi government/military in nature (Iraq or Syrian “Army” and “Soldiers”), and they are often associated with negative terms such as “evil.” There is also a heavy focus on sectarian concepts, particularly directed toward Alawites and the Assad Regime in Syria.

Finally, we examined from where the tweets originated. Because where the user accounts indicate as their location does not change as users move from one location to another, we used the time zones from where the tweets originated in order to get a sense of the demographic makeup of the ISIS “community.” The figure below captures the results:

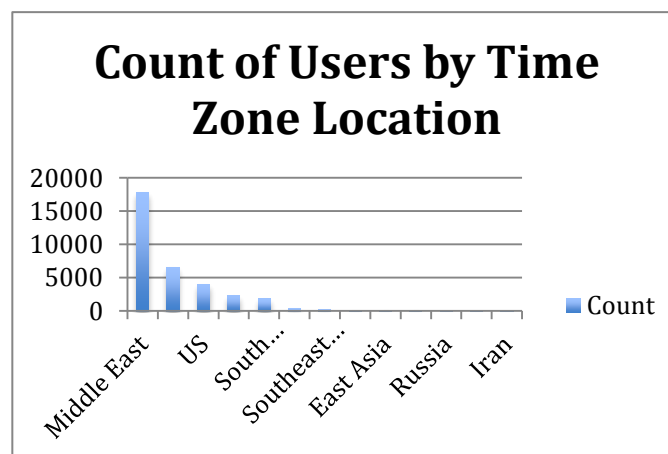


Figure 4: Location of Account

What they suggest is that although ISIS has attracted followers from Europe and the United States, most are located in the Middle East.

Recommendations: Analyzing Twitter communication networks offer a promising venue into better understanding the human domain. Our results are consistent with the analysis of others who have examined ISIS speeches and other forms of communication.

Of course, we need to be careful using social media outlets such as Twitter because their content may not be representative of a particular group; put simply, we should never rely on a single source when trying to understand the human domain. Nonetheless, Twitter is being used to disseminate key concepts and themes that may resonate with large numbers of Twitter users, regardless of their actual affiliation with ISIS; and these concepts provide insight into their overall narrative and appeal.

A Cost Analysis for Life Cycle Preventative Maintenance, Administrative Storage and Conditions-Based Maintenance for the U.S. Marine Corps Medium Tactical Vehicle Replacement

Researcher: Geraldo Ferrer

Students: Maj Paul Goguen, and LCDR Scott Purcell

Topic Sponsor Organization: Deputy Commandant, Installations and Logistics

This research will attempt to analyze the costs of maintenance in the U.S. Marine Corps' tactical transportation assets over a vehicle's lifespan. The goal is to determine the most cost efficient method of maintaining a fleet-ready in an uncertain fiscal and tactical environment. To do this, we will compare the net present values of the costs associated with preventative maintenance and administrative storage programs currently used by the Marine Corps. These values will then be compared to that of the startup, implementation, and execution of a conditions-based maintenance system for the Marine Corps vehicle fleet. The goal of this project is a recommendation of a maintenance program policy specific to tactical transportation assets. This research would pave the way for further manpower studies to determine the appropriate manning requirements for our recommended maintenance policy.

This project is currently in progress, with the final deliverables planned for completion by December 2014.

High Power Microwave Weapon Identification System

Researcher: Dragoslav Grbovic

Student: Lt Col Michael McMahan

Topic Sponsor Organization: Deputy Commandant, Aviation

Background: This project aims to produce a conceptual prototype of a metamaterial sensor that would serve as main element for a system to identify and store the spectral signature of a High Power Microwave Weapons (HPMW), even when the target system is damaged or destroyed. The metamaterial consists of two metal layers, separated by a dielectric. One of the

layers is a solid ground plane while the other is a two-dimensional array of squares. A simple proof-of- concept sensor was fabricated and feasible for use, as a detector demonstrated.

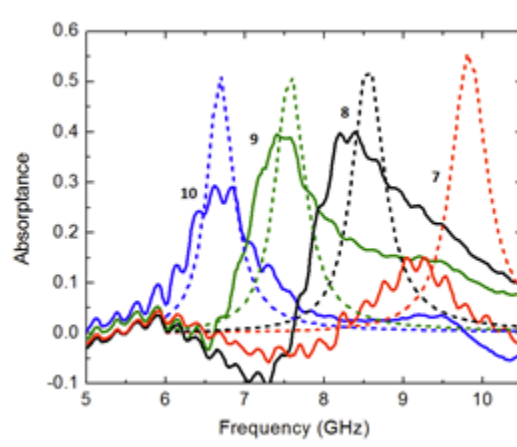


Figure 5

Process: The finite element model at frequencies between 7 to 13 GHz (frequencies often used in HPMW) has been completed. Several variations of metamaterials have been produced according to the specifications obtained from the model. Experimental setup has been assembled and four metamaterials, designed for different frequencies, were tested in the anechoic chamber and showed good agreement with the model (as seen in the figure). Finally, we have started measurements of scalability by analyzing the dependence on absorption magnitude on the detector size. We have chosen 8GHz resonator. Reduction of detector size by 75% did not show appreciable decrease in sensitivity, which is very encouraging!



Figure 6

Findings and Conclusions: The metamaterials studied have definitely shown resonant behavior consistent with similar metamaterials in other frequency bands (such as THz). We have observed some oscillatory behavior in the frequency spectra and have attributed it to the thickness of the metal layers being smaller than the optimal. Subsequent generation of these devices should be made with metal layers thicker than the skin-depth at GHz frequencies. We have also started a detailed investigation of the optical properties of the

dielectric material, necessary for the accurate finite element model. These metamaterials would also provide a good shielding against frequencies of known HPMW

Recommendations: Research should continue toward building sensors to be incorporated in the detector of HPMW spectral signatures. Further work can include the production of a second-generation of optimized detectors using model-refinement during the current study, and then identify minimum size in order to achieve as high resolution as possible for the detector. The last recommendation is to build a simplified detection system.

Mid-Wave Infrared Signaling Tool for Enhanced Targeting Safety and Situational Awareness

Researcher: Richard Harkins, and Nancy Heagel

Student: Maj Scott Jones

Topic Sponsor Organization: Department of the Navy, Program Area Manager

Background: Friendly fire continues to be a major source of casualties on the modern battlefield. Prior work by the Haegel NPS Research Group, successfully demonstrated that the Vehicle Mounted Identification Friend or Foe (VMIFF) device provided real-time operational Indication Friend or Foe feedback to the shooter when interrogated by a friendly target laser designator or laser range finder. A new generation of compact Mid-Wave Infrared (MWIR) sources is emerging to meet demands for a dismounted version that addresses a range of spectroscopy and communications applications. This research includes:

- The effectiveness of compact version of VMIFF as a MWIR signaling tool to enhance combat situational awareness,
- The value and optimum range/footprint of a dismounted version of VMIFF,
- Demonstrate and evaluate field programmable nature of VMIFF for operational security.

Process: The objective is to increase visibility and feedback in a dismounted version of the VMIFF system. We also benchmark the performance of the NPS designed prototype against a commercial version for comparison purposes.

- Design the dismounted VMIFF device,

- The mechanical and electronic design of the Prototype are shown below:



Findings and Conclusions: The conceptual design of the NPS VMIFF prototype and the Syvax electronic design is successfully completed. Delivery of the device is projected for 30 October 2014.

Signal procession algorithms were developed for post-image processing for a 5 Hz modulated signal from the NOVA Beacon.

The Nova MWIR commercial emitter was tested in a lab and field environment to check source and detection parameters.



Figure 9: NOVA MWIR Emitter

The NOVA is a 250 mW device that emits in the 3-5 micron band. Lab results indicate that signal processing techniques can be used to indicate real-time detection in the MWIR range from a 5 Hz modulated Nova Beacon. Please refer to the figure below:

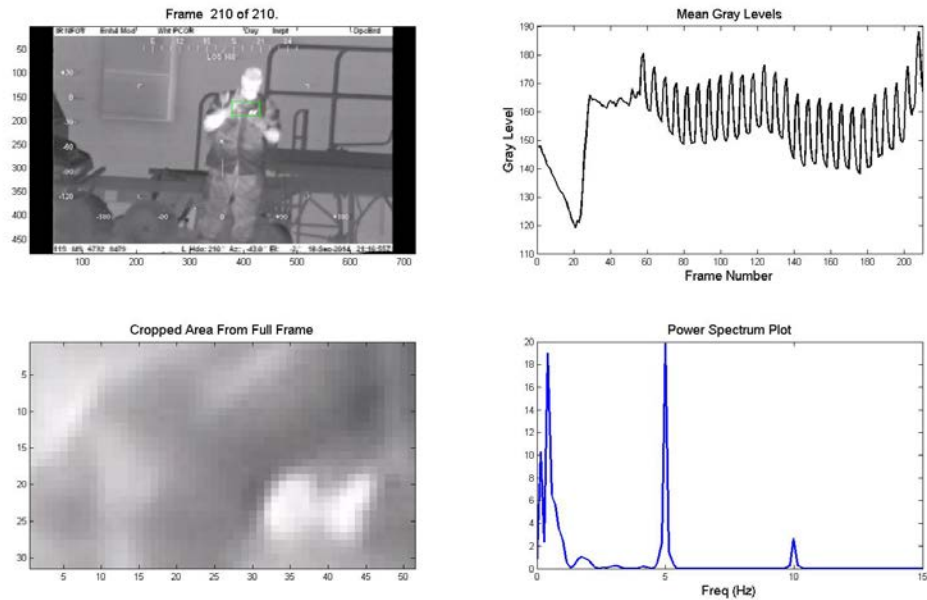


Figure 10: NOVA Beacon lab signal experimental results. The emitter is held in the upper left hand frame, mean gray levels (pixel average) are determined and threshold gain levels are selected, upper right hand frame. The emitter is seen in the cropped image, lower left hand frame. Finally, the image is observed in the frequency domain and the 5Hz signal is displayed, lower right hand frame, indicating detection of the MWIR beacon.

To date, in-field experiments at Camp Pendleton and China Lake have been inconclusive for the Nova beacon. This is attributed to the low transmit power (200-250 mW) of the Nova.

Recommendations: The MWIR VMIFF beacon shows promise as an addition to the operational theatre in the mitigation of IFF problems specifically with regard to ground based autonomous or semiautonomous vehicles. As these devices become ubiquitous, IFF will become equally important.

From a process perspective, it is important to start any NPS contracting processes early in the period of performance. As it stands, the contracting process took over 5 months to complete.

Multidisciplinary Studies Support for the U.S. Marine Forces Reserve

Researchers: Alejandro S. Hernandez, Mark Nissen, Javier Salmeron, Rob Dell, Bill Hatch, Major Chad Seagren, Eva Regnier, and Cameron Mackenzie

Students: Capt Ryan Capdepon, Capt Paul Brisker, and Capt Sean Norton

Topic Sponsor Organization: USMC Marine Forces Reserve

Background: The Marine Corps recognizes that its reserve forces are critical to its success. The ability of the Marine Forces Reserve (MARFORRES) to augment and reinforce active Marine forces with trained and ready personnel comes at a time of austere budgets and an increasingly challenging environment. MARFORRES is essential to relieving Marines in a constantly high operational tempo that includes peacetime activities for a gamut of national and community services. For the first time in recent history, MARFORRES is leveraging NPS capabilities to address a range of issues that the reserve analytical infrastructure has been unable to pursue.

This is an umbrella project that identifies and addresses priority MARFORRES issues for FY14. MARFORRES is primarily concerned with training, decision-making, and technology integration. The diversity of these topics points to a multidisciplinary effort. Four different projects from four scientific fields emerged. The value that MARFORRES is gaining from this research is evident in their application of initial products to their decision-making processes, as well as their willingness to invest their own funds to further investigate the topics in FY15.

Process: Problem definition was the first step in the project. A site visit with MARFORRES leadership and staff early in the timeline clarified the problem areas that the command thought to be critical:

- Lack of a decision support tool to quantify impact of reorganization.
- Unclear understanding of factors or variables that influence individual preferences after organizational restructuring and realignment.
- Inefficient or ineffective methods for training extensively dispersed units.
- Limited use of new technologies, such as modeling and simulation, for decision-making.

The project team tapped into NPS' diverse faculty and staff, students, and familiar relationships to recruit personnel who would provide new insights to these reserve issues. Recruiting resulted in two student theses and two faculty research projects. Each researcher or student developed detailed plans to meet their specific objectives. In total, the four projects involved eight faculty and two students. Planned deliverables include theses, technical reports, and software.

Findings and Conclusions: This section provides a brief summary of each project outcome or its current status. Detailed reports are available upon request.

Optimal Location of Marine Forces Reserve Units by Demographics (Salmeron and Dell): This thesis by Captain Paul Brisker (USMC) developed the Marine Corps Reserve Optimizer (MCRO), an optimization tool to aid MARFORRES in the task of geographically situating their subordinate units with respect to demographics. It implements an integer linear program that selects optimal locations for all candidate-moving units based on the projected availability of qualified recruits in candidate areas. MCRO optimizes to (a) minimize a penalty function that measures stress with respect to demographics, and (b) minimize unit movement. Two base cases are demonstrated, one illustrating the total demographic stress with 2011 population data without allowing unit movements, and another with the projected 2036 population under the same conditions. As an excursion, the MCRO was allowed to recommend movements. The outcomes suggest two significant findings: (1) The relocation of 10 units reduces the number of areas experiencing the highest penalty from nine to three, and (2) All stress can be relieved in 56 movements. Finally, the MCRO is used to evaluate and quantify the demographic impact of four possible unit movements that MARFORRES is currently considering. The results prompted MARFORRES leadership to request additional funds to further develop the model.

Predicting Significant Factors of Selective Marine Corps Reserve Marine's Career Decisions in Response to the Force Structure Review Group (Hatch and Seagren): Significant variables contribute to a Reserve Marine's career decision when faced with changes initiated by the Force Structure Review Group (FSRG). This thesis by Captain Ryan Capdepon (USMC) identifies those variables using research conducted in response to recent Secretary of Navy and Marine Corps research initiatives. A narrative captures the development and roles of the personnel transition team concept created by Marine Forces Reserves in response to changes resulting from the FSRG. Additionally, a decision probability model was developed to estimate Marines' decisions during changes similar to those outlined in the FSRG. This case study constructed and proved that nine different logistic regression models could estimate the effects of independent variables on a Marine's decision to transfer to a different unit, transfer within the same unit, or stay and adjust to new specialty requirements. The findings conclude that military occupational specialty, location, performance, rank, age, deployments, and race all significantly affect a Marine's decision. This set of decision probability model provides a critical tool that will help planning and execution for future changes.

Accelerating Knowledge Flow through Asynchronous Learning Technologies (Nissen): A key component to MARFORRES success is the knowledge of Active Duty Marine Inspector Instructors (I-Is), but a great number of them are required to take charge in such roles quickly. Most lack prior training and experience working with the unique and dynamic challenges of the Reserves—and their extant knowledge flows are relegated principally to error-prone on the job training and questionably effective presentations and slideshows. This project

leveraged the power of information technology—in conjunction with knowledge management principles, methods and techniques—to employ a class of systems used principally for distributed and remote learning. The team engaged key subject matter experts at MARFORRES Headquarters to accelerate the knowledge flows required for effective I-I performance. FY14 work resulted in a prototype distance or distributed learning (DL) site established on NPS Sakai for I-I training modules. This site was used as preliminary training for a sample of attendees to the I-I Training Conference in September 2014. Results of survey data collected during the conference suggests huge return on investment in terms of cost. There are early indications that training efficacy can be just as effective as—if not better than—accomplished through previous methods. MARFORRES has decided to invest its own FY15 funds to expand the capability, including a workshop at NPS to develop a draft DL vision and program plan for the headquarters.

Hurricane Decision Simulator (Regnier and Mackenzie): This research effort will build a computer-based tool to help train MARFORRES decision-makers to prepare for a hurricane affecting New Orleans. In the completed product, the simulator will show the trainee simulated hurricane forecasts, including track and wind-speed probability forecasts, stepping through the evolution of a storm. At different points in time, the trainee will be asked to make decisions regarding preparation and evacuation based on the forecasted hurricane. For example, in one simulated hurricane, the forecast might say that there is a 20% chance that a hurricane will hit New Orleans in 60 hours, and the trainee would be asked to decide whether he or she would begin evacuation procedures for the MARFORRES. The hurricane forecast would be updated at different points in time (e.g., 96 hours, 72, hours, 48 hours, 24 hours), and the trainee would be asked to make new decisions based on the updated forecasts. In this first phase (CY14) of development of the tool, we plan to 1) construct a simulator that provides images of track and wind-speed probabilities at each step in the storm and 2) build a decision-tree model based on MARFORRES preparation timelines.

Recommendations: NPS application of its multidisciplinary approach to problem solving has developed a long-term relationship with MARFORRES. It has provided NPS greater insight to naval reserve issues. In fact, many of the researchers and students involved knew very little about the reserves before becoming involved with the project. The utility that MARFORRES has gained from the past year's efforts are concrete products that it is employing now in its decision-making processes. It has also helped MARFORRES identify important NPS points of contact for other research. Future research efforts should not require an umbrella program. MARFORRES will be able to connect directly with NPS faculty to develop new research agreements.

The way ahead for this project is to continue to cultivate the relationship between NPS and MARFORRES. The reserves have many issues that must be addressed in the very near future.

This project has taught MARFORRES that NPS has a significant capability to help them. They are investing in this relationship in FY15 from their own operational budget. In addition, MARFORRES was approved to continue development of MCRO with FY15 Naval Research Program funds. Recommendations from the individual projects are available upon request in the final reports.

Readiness and System Cost Trade-Off and Management Tool

Researchers: Keebom Kang, and Susan Sanchez

Students: Major Chris Nelson, LCDR Scott Futrelle, Capt Emmaline Hill, and Capt Nicole Simoncini

Topic Sponsor Organization: HQMC, Installations & Logistics

Background: The two most important criteria for weapons system performance, readiness (or Operational Availability ()), and cost are often in conflict. One may increase OA by increasing costs, or reduce costs by decreasing . Many papers have been written using either or cost criteria for making decisions, where cost is typically expressed in terms of the net present value of the lifecycle cost (LCC). However, the modeling of a tradeoff of between and LCC is somewhat more recent. The “Operational Availability Handbook” that the U.S. Navy first released in 1987 recognized the tradeoff, but did not attempt to quantify it. The handbook was revised in 2003 to provide “additional clarity to the interaction between and total cost of ownership” (Office of the Chief of Naval Operations, 2003, p. 9). But even there, the relationship between Ao and LCC is described with graphics and not formally modeled, because there is no simple closed-form relationship between Ao and LCC.

Process: We have developed a spreadsheet-based integrative system management decision-support tool that can be used to examine the impact of acquisition and logistics decisions on trade-off of readiness and cost. This builds on earlier work, where Dr. Kang developed a generic case study tool for exploring readiness and cost trade-offs.

Student-officers (Major C. Nelson, USMC & LCDR S. Futrelle, USN) customized Dr. Kang’s earlier model to obtain a prototype decision-support tool for the joint light tactical vehicle (JLTV), using notional performance data. We briefed the interim results to representatives from Marine Corps Logistics Operations Analysis Division and other interested parties at the 2014 Naval Studies Requirements Fair, and followed up with conference calls involving larger

groups. Subsequently, the PI, Co-PI, and research associates extended this model for enhanced functionality and usability. We also added scenario generator capability to the prototype model to facilitate automated experimentation.

Findings and Conclusions: Our approach is intended to serve as a basis for discussion between program offices concerned with cost and operational commands, or warfighters concerned with readiness. Both warfighters and program managers should understand the importance of logistics and its impact on Ao and LCC. Yet program managers often do not have readily available tools for their analyses. We have developed a prototype decision-support model to conduct readiness and system LCC tradeoff analysis for the JLTV program office.

We are currently conducting some experiments to provide key decision-makers with insight on their investment decisions regarding system design, acquisition, operations, training, and maintenance, as well as evaluate the impact of non-controllable factors (such as fuel costs or operational tempo) on readiness and cost. As an example of our findings, we show that different decisions can lead to very different LCCs while achieving the same expected level of readiness—or very different levels of readiness for the same expected LCC. This underscores the benefits of considering both cost and readiness within a single tool. An updated instantiation incorporating data for the JLTV, along with explicit links between Ao and LCC, will demonstrate the tool's utility. We will deliver this prototype at the end of the project.

Recommendations: The follow-on research for this project will continue in the next fiscal year. We will work on risk assessment of LCC and readiness analysis, in which we will examine the readiness risk (the probability that readiness falls below a certain threshold) and the budget/cost risk (probability that cost will exceed a certain threshold dollar amount). Program managers may be critically concerned with the probability that readiness falls below a planning threshold, or that cost exceeds a given budget—they typically have less concern about the average values. This follow-on research will be sponsored by the USMC PMM-112 (Marine Intelligence).

Evaluating the Oracle Platform as a Decision Support Platform

Researcher: Anthony Kendall

Students: Maj Paul Hudson, and Capt Jeffrey Rzasa

Topic Sponsor Organization: Logistics Policy and Capabilities

The first part of this study is to do requirements/gap analysis of the current Marine Corps logistics system as it applies to decision support tools. This initial study will help focus on what decision support tools are needed/improved and how well they map to Oracle WebCenter/Oracle Business Intelligence existing capabilities or if these capabilities are missing how well can Application Development Framework create a customized decision support tool. Included with this initial study is a feasibility section on what capabilities can be included in the WC/BI prototype. The prototype will be demonstrated and feedback provided by the sponsor as well as final recommendation for the development of a production system.

This project is currently in progress with the final project and deliverables projected to be complete by September 2015.

What Are The Optimal Maintenance Intervals for Preventative Maintenance Checks on Marine Corps Equipment?

Researchers: Robert Koyak, and Michael Atkinson

Topic Sponsor Organization: Marine Corps Logistics Command

Background: We investigate the suitability of available data for development of preventative maintenance checks and service (PMCS) schedules for U.S. Marine Corps (USMC) land vehicles. Current schedules rely on chronological time, which is an inadequate substitute for condition and usage measures with which the need for maintenance is more appropriately expressed. Ideally, these measures would include mileage, cumulative engine cycles, time in use, and past repair history; however, USMC maintenance data generally provides inadequate capture of these quantities. Our effort focuses on three classes of vehicles (medium tactical vehicle replacement (MTVR), Mine Resistant Ambush Protected All-Terrain Vehicle (M-ATV), and Cougar trucks) that are equipped with Caterpillar engines which automatically capture and store usage data for diagnostic applications. We examine the possible use of these data for development of maintenance schedules that are responsive to usage and condition of vehicles.

Process: The Applied Research Laboratory at Penn State University provided us with Caterpillar engine data from 720 MTVRs, 121 M-ATVs, and 135 Cougar trucks that were obtained over a period spanning 2012 to 2014. The Caterpillar data contained information on

mileage (odometer), total engine cycles, time in use, and intensity of usage regimes defined by miles per hour (mph) and revolutions per minute (rpm). The data also provide information on engine diagnostic and critical events that, unfortunately, cannot be associated with dates. Additionally, the USMC Logistics Command provided us with approximately two years of maintenance records from the Global Combat Support System (GCSS) and the Marine Corps Integrated Maintenance Management System (MIMMS) for many of the same vehicles. By merging the two data sources we have been able to examine the occurrence of unscheduled maintenance events in GCSS and MIMMS in relation to usage data obtained from the Caterpillar engine data.

Findings and Conclusions: USMC maintenance data as currently captured cannot by themselves support the development of PMCS schedules guided by usage and condition of vehicles. Automated data captures by original equipment manufacturers (OEMs), such as Caterpillar, are much more promising for such use where they are available. Although the scope of the Caterpillar data that we examined is somewhat limited due to their short time frame, we find indications that usage data are related to the occurrence of unscheduled maintenance actions for at least some vehicle types.

Recommendations: USMC should investigate the feasibility of obtaining OEM automated data captures to support development of its PMCS schedules. Further study is needed to determine how vehicle usage data can be used to formulate these schedules.

U.S. Marine Corps Logistics Force Structure and the Pacific Pivot

Researchers: Moshe Kress, and Javier Salmeron

Student: LCDR Tom Walker

Topic Sponsor Organization: HQMC, Installations & Logistics

The USMC is pivoting to the Pacific region. Current and possibly new forces stationed in the area will continue to execute force-positioning moves over the next years. In doing so, the USMC faces strategic challenges, such as establishing optimal levels of infrastructure capacity at USMC bases, and operational ones, such as determining efficient deployments of logistical assets and optimal assignment of personnel to those bases and to the missions they must conduct. Addressing these challenges must take into account operationally relevant logistics requirements projecting into possible future scenarios in the Pacific.

The objective of this research project is to develop an easily implementable decision-aid tool, based on optimization techniques, that will help Logistics Plans, Policy, and Strategic Mobility (and perhaps other LP* branches in the HQMC, Installations & Logistics) to better plan logistics allocations and deployments in a given area of interest (AOI). The model is first to be tuned to and implemented for the Pacific AOI.

The project comprises five tasks: (1) study of the logistics structure in the Pacific AOI, (2) developing a descriptive model, (3) developing prescriptive models, (4) implementation and fine-tuning, and (5) delivery and final report (see revised proposal TRWG 13-01-001 from 20 June 2014). We are about to complete the third task. A prototype of the optimization model, initially applied to a single logistics resource in a steady-state scenario, has been implemented in Excel (see Appendix 1) and produced satisfactory results. The full optimization model, for multiple resources, has been developed (see Appendix 2) but not yet tested. We will also develop a variant model, which accounts for transient (i.e., non-steady-state) scenarios.

While real consumption, capacities, and transportation data are not necessary at this stage of developing the prototype models, in order to present the in-context utility of the models (for the Pacific AOI) we will need this data. We have not received the data yet from the POCs, and we are planning to approach each one of them and seek these data when Task 4, implementation and fine-tuning, starts.

The model: The model optimizes deployment of multiple supply items in a two-level supply chain in the presence of random demands. The supply items compete for deployment and transportation capacities and the objective is to find a minimum-cost deployment that satisfies capacity constraints and assures a certain level of logistics responsiveness.

Assumptions:

- Two-level hierarchy
 - Operational level: one supply management unit (SMU) at the theater (e.g., Okinawa in the Pacific AOI)
 - Tactical level: Multiple combat units (CU)–consumers of supplies distributed throughout the AOI (e.g., MC combat units in Hawaii, Guam, Japan, Okinawa, etc.).
- Demands at the CUs is random but with some estimates regarding their probability distributions.
- Demand at a CU is satisfied by inventory deployed at that unit and by supplies shipped from the SMU.

- Demands are to multiple types (classes) of logistics items.
- Costs:
 - Inventory deployed in the various units
 - Transporting supplies from the SMU to the CU
 - Transportation cost
 - Delay cost
 - Shortage: penalty for unsatisfied demand

The model is a simulation-optimization model where demands are simulated based on past consumption rates and the optimization part produces the optimal logistics deployment levels that minimize the long-run costs of the deployment in terms of the cost factors mentioned above. The formal description of the model is given in Appendix 2.

The first implementation has been carried out to a special case where only one logistics item is considered. This application is given in Appendix 1.

Way ahead: Complete the (Excel) implementation of the complete steady-state model (in Appendix 2), develop a transient version of the model (non-steady-state), obtain real consumption and cost data from the various POCs, fine-tune the models with the obtained parameters, and finally give a presentation and submit a report.

Appendix 1 – Implementation of the Model for One Item

Below is a screen shot of the single-item model. In this example, there are only three CUs at the tactical level–A, G, and O.

In the yellow region, underdemand at CU there are 10 simulated demand values. The cost parameters are displayed in the blue region. From these 10 simulation runs we obtain that the optimal (minimum cost) deployment is: 600 units in the SMU, 200 units in CU A, 450 units in CU G and no inventory in CU O (see pink region). The optimal transportation schedule and the resulting shortages are displayed in the green and purple regions, respectively. The total cost is 96,175 (see red cell). Obviously, a different cost pattern, e.g., imposing a much larger penalty on shortages, will result in an optimal solution where the numbers in the pink and green regions will increase, while the purple region will become much sparser.

- S_{ik}^j - shortage in supply of item $k, k=1, \dots, K$ in CU $i, i=1, \dots, m$, for demand scenario $j, j=1, \dots, n$.

Model

$$\text{Min } \sum_{k=1}^K \sum_{i=0}^m c_{ik} X_{ik} + \frac{1}{n} \left[\sum_{k=1}^K \sum_{i=1}^m \left(f_{ik} \sum_{j=1}^n Y_{ik}^j + g_{ik} \sum_{j=1}^n S_{ik}^j \right) \right] * \quad (1)$$

st

$$X_{ik} + Y_{ik}^j + S_{ik}^j \geq D_{ik}^j, \quad i=1, \dots, m, \quad j=1, \dots, n, \quad k=1, \dots, K \quad (2)$$

$$\sum_{i=1}^m Y_{ik}^j - X_{0k} \leq 0, \quad j=1, \dots, n, \quad k=1, \dots, K \quad (3)$$

$$\sum_{k=1}^K a_k X_{ik} \leq STR_i, \quad i=0, \dots, m, \quad (4)$$

$$\sum_{k=1}^K a_k Y_{ik}^j \leq CAP_i, \quad i=1, \dots, m, \quad j=1, \dots, n \quad (5)$$

$$X_{ik}, Y_{ik}^j, S_{ik}^j \geq 0$$

*Comment: We could adhere to the capacity constraints regarding X_{ik} and Y_{ik}^j , and ignore the

associated costs, in which case the objective function is simply $\text{Min } \left[\sum_{k=1}^K \sum_{i=1}^m g_{ik} \sum_{j=1}^n S_{ik}^j \right]$, that is,

minimizing the cost of unsatisfied demand. Another possibility is that STR_i and CAP_i become decision variables too, with associated costs.

Plant Utilization at Marine Corps Logistics Command

Researchers: Javier Salmeron, Moshe Kress, and Arnold Buss

Student: Capt. Timothy Curling

Topic Sponsor Organization: Installations and Logistics, Logistic Command

The Marine Corps Logistics Command (MCLC) operates the production plants in Barstow, CA (PPB) and Albany, GA (PPA). These plants provide depot-level maintenance, rebuild, repairs, and manufacturing of platforms. PPB and PPA recently consolidated their headquarters and a series of related activities into a unique maintenance depot. MCLC approached the Naval Postgraduate School in March 2013 soliciting proposals for research on plant capacity and

their effect on various logistical capabilities. The principal investigators' (PIs) proposal was accepted for funding in November 2013 as part of the Naval Research Program.

The initial thrust of the research was to develop scientific methods to examine utilization levels of the different plant resources. The PIs' proposal included the development of mathematical models to guide plant design and utilization at MCLC, including optimal levels of physical capacity, equipment, manning, and operations. However, during the PIs' travel to PPB in April 2014, and after meeting with multiple branch and division heads, PPB identified and expressed interest in "material availability" as a critical component of PPB's production capacity. As a consequence, the focus of the study is the inventory management for critical parts.

During the production process, platform parts (identified by their national identification number (NIN)) are inspected and, if deemed unserviceable (a.k.a. "code-H"), replaced by new ones. This creates a demand for NINs, which is subject to great variability and, among other factors, causes the number of stock-outs and safety stock levels to be random variables. Our goal in this research is to analyze this problem in order to find trade-offs where acceptable fill rates are simultaneously achieved for critical NINs without incurring high safety stock costs. We have devised mathematical optimization and simulation models to help MCLC planners make these complex decisions.

First, we have developed the Critical Part Inventory Optimization Model (CPIOM), which seeks to prescribe optimal order quantities for each "critical" NIN (as identified by MCLC) during a given planning horizon (e.g., a quarter). CPIOM inputs the platforms (e.g., vehicle types) and NINs, along with associated data: NIN cost, initial inventory, stock-out cost, historical information of NIN requisitions by vehicle, and maximum safety stock budget.

The historical information is used to generate a probabilistic distribution of demand for each NIN, which is embedded in CPIOM as a key element of the decision process. Other CPIOM inputs establish constraints in order to ensure that (i) the cost of the expected on-hand inventory at the end of the horizon (i.e., the safety-stock cost) does not exceed the given budget; (ii) order quantities are within any pre-specified limits; and (iii) optionally, NIN stock-outs are probabilistically limited—for example, these "chance constraints" take the form of "the probability that NIN #1 has three or more stock-outs cannot exceed 10%."

The stock-out cost need not be monetary, but can rather be viewed as a penalty for not having a specific NIN part available. These costs are used to calculate the expected cost of stock-outs for all the NINs (based on the order quantities recommended by CPIOM), where such cost is to be minimized.

A second part of the modeling effort is the development of an Inventory Simulation Model (ISM) that complements the optimization. The first step taken by the researchers is to design an ISM component that uses CPIOM outputs to simulate thousands of possible outcomes based on random NIN demands. This allows us to generate detailed probabilistic distributions of the actual stock-out cost and safety stock level (among other features modeled by CPIOM), which can be used to assess how representative the CPIOM solution is given the uncertainty in demand.

A second functionality of ISM is using CPIOM as a sub-model, which is run on a rolling horizon fashion. For example, (i) CPIOM is run to calculate order quantities to supply the demand for month #1; (ii) ISM generates random demands for month #1 and simulates the production process; (note that this step may require additional fidelity and information from MCLC, such as lead times for NINs, repair times, and sequence of steps by platform); (iii) ISM calculates the end-state of month #1 (safety stock, backorders, etc.); and (iv) steps i-iii are repeated for month #2, and any subsequent months, until completing the initial planning horizon.

PPB has provided us with two years of historical data to test CPIOM on a small case consisting of one vehicle type (amphibious assault vehicle, AAV), and six critical NINs (four types of torsion bars, shock absorbers and vision blocks). Historical data here comprises fiscal years 2012 and 2013. Our baseline test problem has a planning horizon of three months, where 12 AAVs are expected to be in production. CPIOM produces optimal quantities and consistently varies those outputs based on “what-if” scenarios, such as a decrease in safety stock budget, or an additional requirement for a chance constraint. ISM shows histograms of frequencies for different stock-out levels based on up to a million replications. Both CPIOM and ISM run in a few seconds for this small scenario. The results have been briefed to PPB and PPA. At the time of writing this report, PPA is in process of collecting information to create a realistic scenario of 118 critical parts.

Over the Air Light Communication

Researchers: Gurminder Singh, Charles Prince, and John Gibson

Student: Capt. Charles Casey

Topic Sponsor Organization: Marine Corp DC Aviation

Background: Problems with battlefield communications stem from live video streaming and other data communications that greatly enhance effectiveness of tactics. More and more data is being sent in digital format and the quantities are ever increasing. Most wireless

communication occurs over WiFi or other waveform communications, but transmissions remain slow and increasing the number of nodes and amount of data transmitted, and slowly increasing the data rates. This study will look at the effectiveness of other modes of communication, specifically Over-The-Air light communication (OTALC), both light-emitting diode and light amplification by stimulated emission of radiation (LASER), and which modes and types work best under which conditions. We are primarily concerned about the back haul of transmissions between groups, not within groups. In addition, waveform communication may be disrupted and identified easier than OTALCs. Different types of communications may optimize different areas of the battlefield. The intent is to come up with a matrix of types, distances, and throughputs as well as best use scenarios, and design use models.

Objectives:

- 1) To survey over-the-counter (OTC) and experimental devices likely to be converted into products in the near term. The survey will contain communication distances, laser wavelength, power, weight, etc.
- 2) What ways OTALC/Free Space Optics (FSO) can optimize battlefield communication.
- 3) Can OTALC/FSO be valuable for ship-to-shore communication?

Approach: Student Capt. Charles Casey, USMC (M.S. Computer Science, NPS Sep 2014) collected information regarding products, devices, and experiments. Once the LASER systems were investigated, a determination was made on what minimally would work with on-the-move Marine elements with respect to communication.

Results: There are no OTC existing products that can perform as optimal communication for on-the-move marines, but several systems had promise to support large amounts of data communication, at the Gbps up to 30km range or more. The Space Photonics Laser Fire system was experimented with at Camp Roberts on the range, by our team, with mixed results. The demonstration devices brought out by the company turned out to have some design/manufacturing problems that the company hopes to fix and will provide another demonstration at a later time. The maximum distance experienced by the devices brought were 1km distances, but the modem used was not optimized, and two devices could work together back-to-back, providing a relay at 1Gbps. The commercial market for FSO is primarily in cell tower back haul and is operable up to 5km at up to 2Gbps, but they are not appropriate for on-the-move, in terms of weight or self-alignment.

Findings: Experimental products like the Talon are available for ship-to-shore, but the range is not great enough for normal usage, however, may work well for littoral vessels. Experimental product from ViaLight, Laser Fire, can track moving objects traveling at 800km/h, at a distance

of up to 60km. The ViaLight system is expected to be available commercially in 2015. The National Reconnaissance Office (NRO) is developing a device that may be useful for local ISR Platforms and relays, provided at low power and able to transmit to many devices at one time. This NRO device may be tested by this group in the next couple of months. Space Photonics has a system that is lightweight and able to self-align within 15min of set up, power is 80Watts, and weight is within 100lbs, but the system is not in production quality yet and the maximum distance is not more than 2km, however, improvements are being made to support up to 5km.

Conclusions: Although there are no devices that are available currently for on-the-move marines, devices are coming out in 2015 and these products have the promise of providing large throughput communication to both on-the-move Marines and for ship-to-shore communication for littoral vessels. Once the devices are available for experimentation objective #2, optimization of communication on the battlefield with LASERs, may be explored.

Trusted Hand-Held

Researchers: Gurminder Singh, Charles Prince, John Gibson, and Jesse Adkison

Students: Capt. Jesse Adkison, and LT Michael Hammond

Topic Sponsor Organization: Marine Corp DC Aviation

Background: The Trusted Hand-Held (TH2) platform holds the promise of becoming a secure yet flexible enough platform to allow multiple concurrent virtual operating systems to run on a single handheld. While this platform is being developed, an investigation is being made of how to effectively use this phone on the battlefield. We would like to investigate what kind of applications can optimize the framework of the TH2 platform.

Objectives: The study questions include:

- 1) What primary use scenarios should drive the internal make-up of the phone?
- 2) Given that this phone may hold secret information, what issues need to be solved?
- 3) Can we control the internal network of the phone to add security?

Approach: Student Capt. Jesse Adkison, USMC (M.S. Information Systems, expected graduation September 2015) signed up to help with the task. It was found that the detailed

Marine Air-Ground Task Force Information Exchange Requirements (IERs) existed from Anti-Terrorism Force Protection Division Capabilities Development Directorate. The USMC use-cases had already been detailed in the document and Capt Adkison's thesis has to do with identifying applications and functionality blocks, and then ranking them according to importance in order to help with prioritization of development for future implementation.

Student LT Mike Hammond, M.S. Combat Systems Officer, is just starting to formulate a thesis on The Management Framework of Mobile Devices Boot Images and Keys. He is reviewing the available material and looking at the direction of how this thesis will be planned.

Results: Capt. Adkison is just now completing his background literature review of chapter 2 of his thesis and started on the methodology of analysis of IERs. His expected finish date of his thesis, according to his present track is between January to May 2015 time-frame.

Findings/Conclusions: The results of this investigation show that this area of research has many interesting topics to investigate and we are hoping to involve further students to investigate topics in this area.

Leveraging Commercial Off-the-Shelf/Government Off-the-Shelf to Extend Wireless Voice and Data Throughout Amphibious Ready Group Vessels, Particularly Within Well-Decks

Researchers: Gurminder Singh, John Gibson, Stephen Iatrou, and Duane Davis

Students: Anibal Intini, and David Scott

Topic Sponsor Organization: USMC, Deputy Commandant Installations and Logistics

Background: This study considers the utility of emerging wireless communications as a means of leveraging broadband communications aboard ships to support data and voice communications to amphibious assault assets prior to debarkation from the well-deck. The goal is to identify and assess Commercial off-the-shelf utility for inter-ship and intra-ship high-speed communications for USMC elements hosted within the well-deck in preparation for USMC amphibious operations. The project identifies an application that demonstrates the potential value of implementing the proposed architecture.

Process: The project developed a radio frequency propagation model to the performance of IEEE 802.11ac performance in highly reflective environments. The model was extended to reflect the interior of a well-deck. As access to an actual well-deck was unavailable, the project then set-up an 802.11ac access point and clients within an International Organization for Standardization cargo container measured the performance of the wireless network in that environment. Finally, the project established a Voice over Internet Protocol (VoIP) capability over an 802.11ac network and assessed its performance. VoIP was chosen as the model application, as voice is a critical fallback capability for many USMC operations, while VoIP also leverages the packet-based networking operation of 802.11 wireless local area networks.

Findings and Conclusions: The advanced capabilities incorporated by the 802.11ac wireless local area networks, such as Multiple Input Multiple Output processing to handle multipath signals and the use of the Orthogonal Frequency Division Multiplexing to improve signal to noise merits of the environment, allow wireless local area networks to be implemented in a highly reflective operational environment such as that typical of a amphibious ship's well-deck. Such networks can be successfully used for military operations in this environment to allow access to Command and Control (C2) or logistics applications during operations, adding flexibility and mobility to the Marine operator. Further, providing this access to personnel within amphibious vehicles in the well deck could provide communications between well decks of several ships by leveraging the host vessels' network infrastructure and inter-ship links, thereby facilitating pre-debarkation collaboration between landing forces.

Recommendations: Additional exploration of the performance of the 802.11ac protocol should be accomplished, especially as the researchers did not have access to a well-deck. To further the results of this project, such access should be acquired and performance metrics for the 802.11ac protocol in an actual well-deck collected and analyzed. Additionally, the VoIP architecture implemented in this study should be leveraged as part of the data collection in the well-deck.

The availability of wireless access to the host ship networks opens many possibilities for extending C2 to the embarked force elements. One area of potential value is logistics analysis; thus it is recommended that further research explore load-tagging and data management applications essential to reducing manpower-intensive equipment tracking during the load-out and embarkation operations.

Handheld Devices for Rapid Request Generation

Researchers: Gurminder Singh, and Arijit Das

Naval Research Program
Naval Postgraduate School

Students: Maj Ryan Barnes, and Capt Buck Bradley

Topic Sponsor Organization: HQMC, Installations & Logistics

Background: Many untrained forward observers (UFOs) have urgent needs to call for resources (such as call for indirect fires, medical services or evacuation, resupply or airlift, etc.), but are not proficient in the procedures used to request needed resources. In stressful conditions, this task becomes even more difficult. The goal of this project is to design and develop a handheld device-based software system architecture that can assist UFOs to perform calls for resources in stressful conditions by asking a series of simple questions and use answers to those questions to generate structured calls for resources. The system is intended to be simple enough for use by any military member without training on the system itself or prior knowledge of procedures to call for resources.

Process: We began our research by reviewing the current digital communications capability available at a line infantry company. We then built a test and evaluation network that was configured as a company combat operations center using the available equipment set. Upon completion of the test network, we designed and created a native application on an Android device. We then tested the connectivity and validated the desired capability. After proper implementation of the application, we researched the training required to familiarize users with the application. As a final proof of concept, we arranged to test the application suite with students awaiting training at the USMC Marine Detachment at the Defense Language Institute.

We involved two M.Sc. students who participated in the research and implemented software to implement the system.

Findings and Conclusions: We were able to validate our research hypothesis. The entry level Marines, with little to no prior training, performed in a superior manner when using HELP software. Those using the application took, on average, approximately half of the time to finalize the request and made approximately half of the errors versus those who used traditional pen-and-paper means.

Recommendations: We strongly recommend a follow-on effort to focus on the security of the application.

In our prototype development, our primary focus was the ease of use and the functionality of the application. Given our limited time, manpower and budget, we could not focus on securing the application. This would be a critical issue for any deployment, especially when it comes to military scenarios.

Digitalizing Consumption Across the Operational Spectrum

Researchers: Gurminder Singh, John Gibson, and Thomas Otani

Student: Andrew Branham

Topic Sponsor Organization: Deputy Commandant, Installations and Logistics

Background: Sustainment planning is currently a manually intensive process requiring significant effort to consult tables of usage, etc., in developing deployment and sustainment plans. This project sought to leverage automation technologies to support the planning and decision-making process associated with operations sustainment. Emerging small-form-factor devices communications and computation, such as tablets and smart-phones, offer significant processing capabilities to support decision-making and logistics planning; however, much of the critical planning and support documentation is unavailable to such devices.

Process: Explore the current state of capabilities for optical character recognition to determine suitable candidates for extracting pertinent logistics planning information from both hardcopy and electronic formatted documents, such as “.pdf” files. Identify candidate applications for further evaluation and experimentation. Based on the experimentation results, select an application for more extended analysis. Based on the performance of the candidate application, propose a general process for digitizing reference documents for electronic access by planners.

Findings and Conclusions: Three prominent applications were considered by this study: one open-source application and two commercial applications. Of these, the professional-grade optical character recognition product, OmniPage®, from Nuance, performed more effectively. However, the performance was constrained by the quality of the document being processed. Once the documents were converted to electronic text format, the data had to be validated for correctness. The feasibility of extracting the data for insertion in a repository, such as a database management system, was demonstrated by use of a simple, custom, python-based program. This program, though, lacks flexibility to address non-specified table formats, such as might be expected in a broad collection of logistics documentation.

Recommendations: Apply the digitization methodology recommended by this study to a broader set of logistics and sustainment planning guidance documents in order to assess the applicability of the process to more general document and table-formatted data sets. Extend the assessment to include analysis of optical character recognition of documents generated

by image capture of hardcopy (paper) documents using smartphone-hosted cameras rather than desktop scanners; this capability would extend the utility of the system to planners operating in remote locations.

U.S. Marine Corps Sexual Assault Data Analytics

Researcher: Lyn R. Whitaker

Student: Capt Bethany Kauffman

Topic Sponsor Organization: HQMC, Sexual Assault Prevention and Response Office

Background: The Marine Corps Sexual Assault Prevention and Response (SAPR) office (SAPRO) has implemented many new training and briefing tools in support of stopping crimes of sexual assault. Baselines need to be established from which progress can be measured. Our focus is how to and to what extent existing data sources can be used to establish baselines for sexual assault and sexual reporting trends in the USMC guided by the following study questions posed by SAPRO:

- What are the best measures of effectiveness (MOE) for the SAPR program?
- What factors are related to an increased probability of reporting and/or being a victim of sexual assault?
- How does the command climate influence reporting propensities and/or disposition of follow on criminal conduct cases?
- What information needs to be collected in order to improve analysis of extant data?

The major focus of the work is to document limitations and strengths of the data used to answer these and other questions regarding sexual assault to illustrate how disparate data sources might be combined, make recommendations for future data collection, and to explore MOEs that SAPRO can use to track their progress.

Process: The four data sources used in this work are the Defense Sexual Assault Incident Database (DSAID) database (the newly mandated source of SAPR data); Marine Corp personnel records from the Total Force Data Warehouse; the Defense Manpower Data Center Workplace and Gender Relations Survey (WGRS); and the Commandant's Command Climate Survey. We had hoped to use questions 14 – 17 from the Defense Equal Opportunities

Management Institute (DEOMI) Command Climate Survey, but were unable to obtain the data from DEOMI.

We used combinations of these data sources: to fill missing values in DSAID fields (e.g. gender, pay grade at time of report); construct new fields (e.g. duty station of the sexual assault); obtain approximate upper and lower bounds for the number of sexual assaults by pay grade and gender; estimate the probability of a sexual assault report based on individual characteristics (gender, pay grade, etc.), characteristic of the command at time of report (size, proportion of women, etc.) and command climate.

Findings and Conclusions: The Masters of Operations Research thesis of Capt. Bethany Kauffman, USMC, is the deliverable for this project. The thesis contains all findings and conclusions with enough of the grungy details of data cleaning, combining, reshaping, and data decisions that all analyses can be reproduced. Data quality in DSAID is poor. To be fair, the first priority is to attend to the victim, not collect data. And, FY2013 is the first full year of mandated DSAID use. Second, most data extractable from DSAID concerns the report not the incident. Thus, graphs and tables based on DSAID record the number of sexual assault reports not incidents. Further, pay grade and time are the pay grade of the victim at the time of the report and not the incident. Instituting effective databases is an iterative process. DSAID will need to mature, with specific input from each of the services, to be truly useful.

Recommendations: Detailed recommendations are given in Capt. Kauffman's thesis. The key recommendations are: DSAID data quality must be improved; with a few relatively simple changes to DSAID, vital questions could be answered (e.g. record if the assault took place prior to entering service/ at a prior duty station/ at the duty station of the report and in addition to UIC's, report Marine Corp unit locations a RUCs); the process for combining personnel data with DSAID is difficult and time consuming, but could and should be automated; the WGRS survey questions should be modified (slightly) so that results can be more easily combined with DSAID; DEOMI Command Climate responses should be made available for analyses.