NAVAL RESEARCH PROGRAM
SHARPENING THE SPEAR
NAVAL POSTGRADUATE SCHOOL

2015 ANNUAL REPORT

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

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MESSAGE FROM THE DEAN OF RESEARCH

The Research and Sponsored Programs Office is pleased to support the Naval Research Program (NRP) in the second complete fiscal year of the program. The Naval Research Program is now an official Navy and Marine Corps chartered program, having had the charter officially signed jointly by the Chief of Naval Research and Commander, Marine Corps Battle Lab in August of 2015. The results of the research sponsored within FY15 have 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. The NRPs -funding and program goals are also directly in line with SECNAV's goal to provide research to "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 NRP research activities conducted on behalf of both Navy and Marine Corps topic sponsors during the 2015 fiscal year. Each of the 43 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 FY16, the program management will continue to be under the direction of Mr. Rodman Abbott. His leadership builds upon the already well established program foundations that have been laid down in FY14 and FY15. 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

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LIST OF ABBREVIATIONS AND ACRONYMS

3D, three-dimensional
I Marine Expeditionary Force (I MEF)
Acoustic communications (acomms)
Additive Manufacturing (AM)
Aerial Layer Network (ALN)
Aircraft Carrier Group (CVN)
Alternating Current (AC)
Amphibious Ready Group (ARG)
Analog-to-Digital (A/D)
Angle of Peak Pressure (AOP)
Air and Missile Defense Commander (AMDC)
Air-Sea Battle (ASB)
Air Warfare (AW) Officer
Anti-Access/Area Denial (A2/AD)
Anti-Submarine Warfare (ASW)
Applications (apps)
Application Development Framework (ADF)
Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA))
Atmospheric NPS Code for High Energy Laser Optical propagation (ANCHOR)
Aviation Energy Conservation (Air ENCON)
Battle Force Tactical Network (BFTN)
Battle Force Tactical Network –enhanced (BFTN-e)
Battlespace Awareness (BA)
Basic Underwater Demolition/SEAL Training (BUD/S)
Beyond line-of-sight (BLOS)
Big Data Architecture and Analytics (BDAA)
Business Intelligence (BI)
Carrier Strike Groups (CSGs)
Chief of Naval Operations (CNO)
Classification and Regression Trees (CART)
Combat Identification (CID)
Command and Control (C2)
Command, Control, Communications, and Computers (C4)
Command Master Chief (CCM)
Commandants of the Marine Corps (CMC)
Commander, MARFORRES (CMFR)
Commander Naval Air Forces Pacific (CNAP)
Commander, U.S. 7th Fleet (C7F)
Commanding Officers (COs)
Commercial Off The Shelf (COTS)
Common Tactical Air Picture (CTAP)

Communications (comms)
Communications Contested Environment (CCE)
Computer-Aided Design (CAD)
Computer Emergency Readiness Team (CERT), Carnegie-Mellon
Computer-Mediated Social Support (CMSS)
Computer Network Defense (CND)
Concepts of Operations (CONOPS)
Consolidated Counterdrug Database (CCDB)
Continental U.S. (CONUS)
Conventional Armed Forces in Europe (CFE)
Cooperative Engagement Capability (CEC)
Cost-Benefit Analysis (CBA)
Dean of Research (DOR)
Defense Security Service (DSS)
Defense Intelligence Agency (DIA)
Department of Defense (DOD)
Department of Homeland Security (DHS)
Department of the Navy (DON)
Deputy Chief of Naval Operations (DCNO)
Design of Experiments (DOE)
Differential Scanning Calorimeter (DSC)
Digital Modular Radio (DMR)
Distributed Tactical Communications System (DTCS)
Drug Trafficking Organizations (DTOs)
Electro-Optical (EO)
Electronic warfare (EW)
Energy Management System (EMS)
Enterprise Social Media (ESM)
Executive Review Board (ERB)
Extended Deterrence Policy Committee (EDPC)
Extended MAGTF Operations (EMO)
Extensible 3D (X3D)
Extract Transformation Loading (ETL)
Facebook (FB)
Fiscal Year (FY)
Fitness Improvement Training (FIT)
For Official Use Only (FOUO)
Forces Innovation & Research Enterprise (FIRE)
Forward Looking Infrared (FLIR)
Fuel Usage Study Extended Demonstration (FUSED)
Gaussian Process (GP)
Global Command and Control System (GCCS)
Global Information Grid (GIG)
Global Navigation Satellite System (GLONASS)

Graphene (G)
Graphitic Oxide (GO)
Ground-Launched Cruise Missiles (GLCMs)
Guided Missile Cruiser (CG)
Guided-Missile Destroyer (DDG)
Heating, Ventilating, and Air Conditioning (HVAC)
High-energy Laser (HEL)
High Frequency (HF)
HQMC Installation and Logistics (I&L)
HQMC Programs and resources (P&R)
Humanitarian Assistance/Disaster Relief (HA/DR)
Hydrogenation-Derived Renewable Diesel (HRD)
Identification Friend or Foe (IFF)
Indian Ocean Region (IOR)
Initial Project Review (IPR)
Initial Operational Test & Evaluation (IOT&E)
Insider Threat (InT)
Insider Threat Program (InTP)
Integrated DEFintion (IDEF) method
Intelligence, Surveillance, and Reconnaissance (ISR)
Intermediate-Range Nuclear Forces (INF)
International Civilian (INTCIV)
International Council on Systems Engineering (INCOSE)
International Standards Organization (ISO)
In-Transit Visibility (ITV)
Java Platform, Enterprise Edition EE (J2EE)
Joint Advanced Manufacturing Region (JAMR)
Joint Operational Access Concept (JOAC)
Low-Probability of Intercept (LPI)
Manpower, Personnel, Training, and Education (MPTE)
Map Aware Non-Uniform Automata (MANA)
Marine Air-Ground Task Force (MAGTF)
Marine Corps Expeditionary Energy Office (E2O)
Marine Corps Forces Cyberspace (MARFORCYBER)
Marine Corps Reserve Realignment Optimization Model (MCROM)
Marine Corps Security Cooperation Group (MCSCG)
Marine Expeditionary Brigade (MEB)
Marine Forces Pacific (MARFORPAC)
Maritime Prepositioning Force (MPF)
Maritime Sealift Command (MSC)
Mass Spectrometer (MS)
Massachusetts Institute of Technology (MIT)
Massive Multiplayer Online Wargame Leveraging the Internet (MMOGLI)
Master of Business Administration (MBA)

Master of Science (MS or M.Sc.)
Maximum Rate of Release (MRR)
Mean Time To Kill (MTTK)
Measures of Effectiveness (MOEs)
Military Construction (MILCON)
Model Based Systems Engineering (MBSE)
Model View Controller (MVC)
Monterey Bay Aquarium Research Institute (MBARI)
National Technical Means (NTM)
Naval Air Warfare Center Aircraft Division (NAWCAD)
Naval Acquisition Executive (NAE)
Naval Air Station (NAS)
Naval Air Weapons Station (NAWS)
Naval Aviation Logistics Command Information System (NALCOMIS)
Naval Facilities Engineering Command (NAVFAC)
Naval Postgraduate School (NPS)
Naval Research Program (NRP)
Naval Research Working Group (NRWG)
Naval Surface Warfare Center Dahlgren Division (NSWCDD)
Naval Tactical Cloud (NTC)
Naval Service Training Command (NSTC)
Navy Atmospheric Vertical Surface Layer Model (NAVSLaM)
Navy Information Dominance Forces (NAVIDFOR)
Navy Insider Threat Board of Governance (NITBOG)
Navy Total Force Strength Model (NTFSM)
Near Vertical Incidence Skywave (NVIS)
Nearly Orthogonal Latin Hypercubes (NOLHs)
North Atlantic Treaty Organization (NATO)
Nuclear Weapons Security (NWS)
Office of the Chief of Naval Operations (OPNAV)
Office of Naval Research (ONR)
Office of Women Policy (OWP)
Officer Strategic Analysis Model (OSAM)
Operations Security (OPSEC)
Orchestrated Simulation through Modeling (OSM)
Over The Horizon (OTH)
Public Affairs Office (PAO)
Peak Pressure (PP)
People's Liberation Army Navy (PLAN) / Chinese Navy
Physical Protection Systems (PPS)
Photovoltaic (PV)
Plan of Intended Movement (PIM)
Planned Resource Optimization (PRO)
Planning, Programming, Budgeting, and Execution (PPBE)

Political-military (pol-mil)
Powder Super Dielectric Materials (P-SDM)
Precision Participation Location Identifier (PPLI)
Presidential Nuclear Initiatives (PNIs)
Principal Investigators (PIs)
Program Area Manager (PAM)
Program Objectives Memorandum (POM)
Rapid Application Development (RAD)
Recruit Division Commanders (RDCs)
Recruit Training Command (RTC)
Reduce Administrative Distraction (RAD)
Republic of Korea (ROK)
Research and Development (R&D)
Research Development Test and Evaluation (RDT&E)
Reserve Training Centers (RTCs)
Resolution V Fractional Factorials (R5FFs)
Revolutions Per Minute (RPM)
Satellite Communications (SATCOM)
Scanning Electron Microscopy (SEM)
Science and Technology (S&T)
Scripps Institution of Oceanography (SIO)
Sea Level Rise (SLR)
Seaport of Embarkation (SPOE)
Secretary of the Navy (SECNAV)
Secretary of the Navy Instructions (SECNAVINST)
Security Force Assistance (SFA)
Seemly Unrelated Security Violations (SUSV)
Self-Propelled Semi-Submersible (SPSS)
Ship to Objective Maneuver (STOM)
Sierra Hotel Aviation Report Program (SHARP)
Simulation Experiments Efficient Designs (SEED) Center for Data Farming
Size, Weight, and Power (SWaP)
Solid-State Laser (SSL)
Space and Naval Warfare Systems Command (SPAWAR)
Start of Injection (SOI)
Strategic Environmental Research and Development Program (SERDP)
Strategic Systems Programs (SSP)
Subject Matter Experts (SME)
Submarine Situ Environmental Sensing System (SubSEnSS)
Super Dielectric Materials (SDM)
Surface Warfare Officers (SWOs)
Sustainable Procurement Program (SPP)
Synthetic Theater Operations Research Model (STORM)
System of Interest (SoI)

System of systems (SoS)
Tactical Action Officer (TAO)
Theater Battle Management Core System (TBCMS)
Thermogravimetric Analysis/Differential Scanning Calorimetry (TGA/DSC)
Top Dead Center (TDC)
Topics Review Board (TRB)
Training & Readiness (T&R)
Transit Fuel Planner (TFP)
Transportation Capacity Planning Tool (TCPT)
Tropical cyclones (TC)
Tube-Super Dielectric Materials (TSDM) or (T-SDM)
Undersea Warfare (USW)
Underwater vehicle (UUV)
Unit Identification Code (UIC)
Unit-Level Training (ULT)
United States Army Corps of Engineers (USACE)
United States Coast Guard (USCG)
United States Marine Corps (USMC)
United States Marine Corps Forces Cyberspace Command (MARFORCYBER)
United States Marine Forces Reserve (USMCR or MARFORRES)
United States Navy (USN)
United States Southern Command (USSOUTHCOM)
Unmanned Surface Vessel (USV)
Unrestricted Line (URL) officers
Virginia Class Submarine (VCS)
Working Effectively in Small Teams (WEST)
World of Warcraft (WOW)
X-ray diffraction (XRD)

Military Structure:
N1: Deputy Chief of Naval Operations (DCNO) for Manpower, Personnel & Training
N2/N6: DCNO for Information Dominance
N3/N5: DCNO Information, Plans & Strategy
N4: Director for Material Readiness & Logistics
N9: DCNO for Warfare Systems
N81: DNCO for Integration & Resources, Director Assessments
N9I: DCNO for Warfare Systems, Integration Division
N97: DCNO for Warfare Systems, Director for Undersea Warfare

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, NPS 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 current and future operational warfighter challenges. The primary mechanism for obtaining NPS NRP support, is through participation at the NPS Naval Research Working Group (NRWG) research meeting that brings together fleet topic sponsors, NPS faculty members, and students, 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 (Research Development Test and Evaluation (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 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 NRWGs 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 the NRWG to maximize the breath 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 are 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

FY15 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 is one 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: To date, the NRP has collected over 1000 potential and current research topics through these events, while funding over 200 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 FY15, NPS received $3.6M, which it translated into over 40 distinct U.S. Navy and Marine Corps projects that cover the entire Office of the Chief of Naval Operations (OPNAV) staff, Fleet Forces (FF), Assistant Secretary of the Navy for Research, Development and Acquisition (ASN (RDA)), Strategic Systems Programs (SSP) and Marine Corps functional organizations.
- One-hundred percent of FY15 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. To date, over 200 faculty and 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 nearly a quarter of the 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 were over 176 United States and Foreign thesis students collaborating with faculty on 35 of the 43 projects.

FY15 Research Highlights

Navy

- NPS researchers John Joseph, Doug Horner, and student LT Bradley Knott, USN completed an initial investigation into the potential application of an integrated system consisting of unmanned surface vessel (USV) and unmanned underwater vehicle (UUV) components in support of wide-area environmental sensing and characterization as part of the Navy's Littoral Battlespace Sensing Program. The study consisted of a theoretical, modeling, and observational approach that provided insight into the strengths and limitations of an integrated UUV/USV system to conduct timely wide-area environmental assessment applicable to Undersea Warfare (USW) and Battlespace Awareness missions.

- NPS researchers Dr. Ying Zhao, Tony Kendall, Bonnie Young, and student LCDR Evan Baumgartner, USN completed a project for N2/N6 dealing with Big Data Architecture and Analytics (BDAA) for improving Combat Identification (CID) and Common Tactical Air Picture (CTAP). The team found that -BDAA shows significant potential for improving the CTAP and CID. The team also found that BDAA could be leveraged to develop advanced data models as part of data integration, data storage, and retrieval; and it could support advanced automated decision aids and resource management capabilities for battle management.

- NPS researcher Jonathan Phillips and students LCDR Jonathan Gandy USN and LT Natalie Jenkins USN developed a possible new paradigm for High Energy Density Capacitive storage on behalf of N4. The study demonstrated the existence of a new class of materials, Tube-Super Dielectric Materials (TSDM), with highest dielectric constants ever measured. The team employed this novel dielectric material to create capacitors with the highest energy densities ever reported, >400 J/cm^3. The potential to enable weapon systems such as the rail gun and advanced lasers was explored. The science of all types of super-dielectric materials for application to these systems has been advanced.

- NPS researchers Dr. Tom Lucas, Dr. Paul Sanchez, Mary McDonald, Steve Upton, and student LT Russell Pav USN conducted research to design and run experiments to better understand the impacts on the hierarchical modeling process associated with error propagation methods and design of experiments techniques for N9. The results indicate that the sampling methodology has a significant impact on the mean probability for Blue forces winning the campaign, as well as the mean number of losses Blue forces takes when it wins. In addition, the sampling methodology has a significant effect on the standard deviation for the probability Blue forces win as well as the amount of losses Blue forces expects to take when it wins.

- NPS researchers Dr. Joe Blau, Dr. Keith Cohn, and student LT Daniel Martell USN researched the characterization of the atmosphere for the Marine base Layer in support of N97's Submarine-based High Energy Laser program. The study found that for unstable turbulent conditions, when the air temperature is less than the sea temperature at the

surface (common in the winter), turbulence tends to be strong right at the surface, but decreases significantly for altitudes just a few meters above the surface. Under these conditions, increasing the mast height correlated with an increase in the effective range of the laser, especially against surface targets. Increasing mast height, however, increased the risk that an adversary may detect the submarine.

- NPS researchers Dr. Don Brutzman, Terry Norbraten, and student LT Marlon Heron, USCG researched tools that can model, simulate, visualize, analyze, and evaluate security measures for ballistic-missile submarine surface transit in support of Navy Strategic Systems Programs (SSP). NPS researchers produced a tool suite and model library capable of supporting a capability and gap analysis for independent system of systems (SoS) that identify dependencies and potential limitations in the topic areas of interest.

- NPS researchers Jeff Kline, Dr. Tom Lucas, Dr. Paul Sanchez and students LT Steven Rockwell, USN and LT Dustin Schultz USN researched the U.S. Surface Navy vulnerability to unmanned aerial vehicle and small boat swarm attack, particularly when coordinated with a multiple anti-ship cruise missile attacks. While the specific findings are classified, the addition of a solid state laser to a Guided-Missile Destroyer (DDG's) combat suite made significant contributions to defending the ship against unmanned aerial vehicles and small boat threats. Recommended surface ship laser tactics have also been provided to the sponsor, ASN(RDA).

Marine Corps

- NPS Researcher Dr. Eugene Paulo and students Paul Bourgeois CIV, Bradley Kelly CIV, John Petrusky CIV, John Williamson CIV and Jonathan Yi CIV conducted a project in support of both Marine Forces Pacific (MARFORPAC) and the Marine Corps Expeditionary Energy Office (E2O). The project examined how to model deployment scenarios and perform trade-off analysis between naval, maritime, and commercial shipping based upon expediency of expeditionary forces arriving at a designated seabase. The project also looked at how to predict energy consumption of the Marine Expeditionary Force in support of reducing dependency on fossil fuels in a deployed environment. Specific questions were established to frame the scope of research focus to assess and select the fuel efficient alternative shipping, sufficient to transport Marines and their equipment from home port to sea base, during a range of military operations.

- NPS Researchers Dr. Javier Salmeron and Dr. Rob Dell developed an optimization tool to guide the, Marine Forces Reserve Commander in conducting realignment studies. The intent was to use formal mathematical analysis to aid the commander's decision. A prototype of the optimization tool has been tested with data from the units and Reserve Training Centers (RTCs) in the San Francisco, CA and Sacramento, CA areas.

- NPS Researchers Dr. Douglas A. Borer and COL Ian C. Rice USA along with students Amrul Adriansyah TNI–AL, Djon Afriandi TNI-AD, Emmanuel G. Cabahug PA, Antione C. Fernandes USA, Don R. Meador USMC, Scott Leuthner USA, Oryan J. Lopes USMC, Benjamin Spera USA, Edy Suntoro TNI–AL, and Travis J. Taylor USA examined prior illustrations of security force assistance in order to help policymakers understand the long-term effects of military assistance activities. By identifying what features impact the tactical operations of prominent states, this research can improve awareness of the impact of specific operational and tactical practices imparted during military assistance activities. Such analysis could then aid the USMC in developing its regional goals to include identifying partner nations to develop into lead actors in all expeditionary type missions.
- NPS Researcher Dr. Anthony Kendall and students Capt Margaret Snyder USMC and Capt Sarah E. Bergstrom USMC were tasked to develop an information architecture that selects relevant information from the C2, C4, ITV databases to create an integrated Information System model that captures the information needed for the effective tactical distribution of supplies for ground and air supporting the Marine Air-Ground Task Force (MAGTF). An Extract Transformation Loading framework strategy for the relational sources will be provided. The research is developing a "proof of concept" prototype that provides example analytics for the end user.
- NPS Researchers Dr. Thomas Albright, Anita Salem and students Capt Lucas F. Hernandez USMC and Capt Derek K. Johnson USMC used Design Thinking to look at how non-monetary incentives can be used to increase retention in the Cyber community. Marine Corps Forces Cyberspace (MARFORCYBER) is a young organization and faces a number of challenges in recruiting, training, equipping, and retaining cyber personnel. There is a pervasive national shortage of qualified cyber personnel, both in the Marine Corps and the Nation at large. To retain quality cyber personnel, the Marine Corps must identify those factors that cause cyber personnel to separate from active service and explore specific incentives to retain them. This research study used Design Thinking to look at how non-monetary incentives can be used to increase retention in the Cyber community.
- NPS Researchers Dr. Gurminder Singh, Dr. Man-Tak Shing, and John Gibson along with students Capt Ben Tuck USMC and Capt Peter Bose USMC analyzed the fully captured cost (USMC and DOD enterprise costs) of current over the horizon communication and its ramifications for equipping the Marine Air-Ground Task Force (MAGTF) during ship to shore operations in support of amphibious and Maritime Prepositioning Force (MPF) operations in conventional and Ship to Objective Maneuver (STOM) scenarios. The study considered both attended and unattended communications systems, terrestrial, aerial, and space-based communications systems.

UNITED STATES NAVY

N1: PERSONNEL

How Japanese Negotiate: Current Practices and Their Challenges for U.S. Negotiators

Researchers: Dr. James Suchan

Student: No students participated in this research project.

Project Summary
This study examines current Japanese negotiation strategies, processes, and communication interaction norms to provide DON negotiators and others who interact regularly with the Japanese a better understanding of how they think about negotiation and the practices that emerge from that thinking.

Background
To counteract China's maritime threat, U.S. defense policy has "pivoted" to the Pacific Rim and will increasingly cooperate with the Japanese Self Defense Force. To contract for the goods and services required to meet these expanded mission requirements, DOD civilians and military will need to negotiate with an even larger number of Japanese vendors. However, negotiating with Japanese companies is challenging because of the unique cultural characteristics—both national and organizational—that affects the negotiation process, strategy, and interaction.

Findings and Conclusions (to include Process)
Data for this study came from the following sources. All interviews were descriptive; respondents were asked to describe various negotiation processes.

- Over 40 academic and practitioner articles, books, and book chapters were reviewed.
- Face-to face interviews lasting from 1 to 3 ½ hours were conducted with 15 Japanese business people (senior executives and middle-level managers) who have negotiated internationally. Academics, who have specialized in intercultural negotiation research and consulted with many Japanese companies on intercultural negotiations, were also included.
- Telephone interviews lasting between 45 minutes and 1 ½ hours were conducted with 6 U.S. DON employees who have negotiation experience with the Japanese. These workers had lived on U.S. bases in Japan.

This research concluded that:

- Neither the Japanese nor U.S. negotiators have had negotiation or intercultural negotiation training.
- Japanese use more robust criteria to choose negotiation team members than the DOD leaders appear to use.

- Japanese lack a history or tradition of persuasion and influence as the U.S. interprets these concepts.
- "Nemawashi," a process of internal consensus building, defined Japanese negotiation processes.
- What the Japanese call their "tatemae" and "honne" selves, significantly influence negotiation interactions and the type of information U.S. negotiators will receive. DOD negotiators interpretation of Federal Acquisition Regulations (FAR) conflict of interest clauses precluded U.S. negotiators from interacting socially with their counterparts. Only during out-of-office, social gatherings will the "honne" self-emerge and a negotiator's unfiltered ideas and beliefs be revealed.
- Japanese have communication habits used during negotiations that often puzzled and frustrated U.S. negotiators. The Japanese use of silence, spiral logic, indirect statements, vague language, and their concern for saving face often create communication breakdowns.

Recommendations for Further Research

- U.S. negotiators should be provided a robust, intercultural management development program--3 days at a minimum--to increase their cultural intelligence and intercultural negotiating skills. If possible, these programs should be conducted in Japan with Japanese participants.
- Shorter (1/2 or 1 day) follow-up programs should be offered to conduct more detailed training on particular negotiation issues such as the Japanese concept of saving face, differences between U.S./Western and Japanese views of persuasion and bargaining, and the Japanese "nemawashi" process.
- U.S. negotiators should be provided training in team formation, stages of team development, team communication, and team leadership to give negotiators the tools to move from a small group to a larger team. Stronger, more coherent team dynamics will increase U.S. negotiators' credibility with Japanese teams.
- U.S. negotiating team members need to be chosen carefully, using more robust criteria such as interpersonal skills, knowledge of Japanese culture, and listening ability for challenging negotiation assignments. To help superiors make smart team membership decisions, diagnostics should be used such as Ang's Cultural Intelligence Instrument, Schwartz's Values Survey, Cheung's Concern for Saving Face, and Neuberg's Need for Closure Instrument.
- U.S. negotiators should be made aware to expect early negotiation stages to proceed slowly, to be prepared for additional requests for information during these stages, to use early stages to develop or strengthen relationships with their counterparts, and delay serious offers to the later stages of negotiations, after the "nemawashi" process has concluded.
- The conflict of interest FAR regulations should be reinterpreted to apply to the unique negotiating context generated by Japanese and Pacific Rim cultural values.
- U.S. negotiators should develop a basic understanding of the differences between high context (Japan) and low context (U.S.) cultures and the affect these differences have on communication thinking and practices. In addition, U.S. negotiators should better

understand the various causes and uses of silence, indirectness, and vague language. Furthermore, they need to develop an understanding of the Japanese concept of "saving face" and communication strategies that preserve face.

Work Life Balance in the Context of the Navy

Researchers: Dr. Kathryn Aten and Dr. Marco DiRenzo

Student: LCDR Kirk D. Emanuelsen, LCDR Jon D. Lee, LCDR Krysten Ellis, and LT Garold Munson

Project Summary

This study sought to develop a better understanding regarding the experience of life-work balance by members of the U.S. Navy. This study was prepared in conjunction with a student thesis, which provides a detailed literature review and examination of gender differences in perception of life-work balance (Emanuelsen & Lee, 2015). A survey was administered to Navy officers conducting graduate studies at the Naval Postgraduate School in Monterey, California and their spouses. The findings indicate a number of interesting trends regarding the desire for balance in the Navy, varying perceptions of the Navy's child- and elder-care resources aimed at enhancing balance, as well as the significance of designators (i.e. career specialties) and commanding officers (COs) to the experience of balance as well. In the sections that follow we highlight these issues, draw causal conclusions, and present sailors' recommendations, drawn from responses to open-ended questions.

Background

After deleting respondents with missing data our final sample consists of 197 officers. Results are based on correlation analysis of the study variables with a .05 level of significance. Participants were also invited to respond to open-ended questions and invite their partners to do the same. Twenty-two partners responded.

Findings and Conclusions (to include Process)

The analysis shows that the extent to which the Navy's programs, policy, and culture enable life-work balance are not only important to attracting competent recruits, but also becomes increasingly influential to retaining a highly skilled workforce. There is a noticeable drop in the salience of the Navy role and a marked increase in the family role when sailors have children. The number of employees who deal with elder care concerns is comparatively small and therefore child care concerns represent a more prominent issue. Nevertheless, when extrapolating to the entire workforce, elder care issues may be confronted by fairly sizeable number of employees. Importantly, even sailors who do not have dependent care responsibilities believe that work demands often conflict with their family and life roles.

The analysis shows that many sailors perceive benefit from Navy programs and policies. However, current programs and practices fall short of expectations by those who may be most in need of and most likely to value balance-related initiatives, and in turn these shortcomings

could ultimately contribute to turnover decisions. Additionally, sailors' comments to open-ended questions called for further culture change and more positive examples from leadership, suggesting that practice may lag behind policies and programs.

Designators are influential to the experience of balance and conflict. Sailors in Human Resources, Information Dominance, and the Supply Corp seemingly consider balance to a greater extent when choosing their careers than do those in other designators, while Sea, Air and Land (SEAL) members, Submariners, and Surface Warfare Officers (SWOs) are less concerned, at least initially, with balance.

Overall, the quantitative analysis and sailors' and partners' comments suggest that life-work balance is and will continue to be an important issue. Providing greater flexibility in work schedules may be a particularly effective way to reduce turnover and retain highly experienced human capital. Further, additional work to ensure that Navy culture and leadership support the programs and policies designed to promote life-work balance may be required, and this effort should include consideration for the life-family needs of sailors without dependents. Future studies should determine in which designators addressing work-life issues are most important. For instance, SEALs and SWOs report fairly similar and high levels of work family conflict, but this appears to have minimal effect on SEALs', but much stronger effect on SWOs' impending career decisions. As such, the Navy should focus its life-work balance initiatives toward the designators most affected by these issues and work with COs to alter current cultures and policies that may be exacerbating these effects.

Finally, an important theme that emerged from partners' comments is the need to involve family in decisions that influence life-work balance, and to involve families in setting expectations.

Recommendations for Further Research

In responses to open-ended questions, sailors called for further culture change and more positive examples from leadership, suggesting that practice may lag behind policies and programs. Further research should identify key cultural barriers and suggest levers for change.

Improving Navy MPTE Studies with Model-Driven Big Data

Researchers: Dr. Thomas Lucas and Dr. Susan Sanchez, Dr. Sam Buttrey, Mr. Steve Upton and Ms. Mary McDonald

Student: LCDR Erin Borozny USN, LT Nick Dehollan USN, and ENS Will DeSousa USN

Project Summary

The objective of this research was to improve upon the ability of OPNAV N1 analysts to quickly and efficiently obtain experimental information from their computational models. This will allow N1 to quickly identify and quantify the potential impacts of numerous resource and policy options. To accomplish this goal, the research assessed the feasibility and potential benefits of data farming with a selected manpower model—that is, embedding the chosen N1 manpower, personnel, training, and education (MPTE) tool in an environment that enables efficiently running and analyzing designed experiments over a breadth of input variables, thereby creating model-driven big data. The chosen model was the Officer Strategic Analysis Model (OSAM), and we also made some initial explorations of the Navy Total Force Strength Model (NTFSM).

To make OSAM data farmable, NPS researchers developed, tested, and began the initial usage of a prototype software tool known as OSAMRunner. OSAMRunner is a command line wrapper, written in C#, around a SEED-modified version of the OSAM model that allows users to run multiple replications of OSAM (without human intervention) from the command line. It also exports the OSAM output database tables to a set of csv-formatted files that users can easily open in any analysis package—such as Excel or JMP. We have also added a much better random number generator to OSAM—the Mersenne Twister. Two student-officers, LCDR Erin Borozny and Lieutenant Nick DeHollan, used the new data farming capabilities in proof of concept analyses with OSAM—their summary findings are in findings and conclusions section below. In addition, Ensign Will DeSousa did some initial manual explorations to help test and assess NTFSM.

Background

Manpower and personnel costs consume a substantial portion of the U.S. Navy budget. The Chief of Naval Personnel (N1) is responsible for analyzing manpower inventory forecasts and estimating the Navy's manpower expenditures to be included in the budget and Program Objectives Memorandum (POM) submitted to the Secretary of the Navy every two years. The Chief of Naval Personnel has a dedicated staff that provides him with the necessary information and associated risks to make decisions on manpower. Of course, forecasting Navy personnel levels is a complex problem compounded by numerous uncertainties. Therefore, the staff relies critically on manpower, personnel, training, and education (MPTE) models that allow them to project future force levels given a set of assumptions and historical experience. Two important models in this process are the Navy Total Force Strength Model (NTFSM) and the Officer Strategic Analysis Model (OSAM). Both of these models have numerous input variables and generate multiple outputs of interest. Both of these models can be made more useful to N1

analysts by embedding them in an environment that allows analysts to quickly and efficiently extract additional experimental information. This research builds on previous efforts at enhancing the analytic utility of the OSAM model and some initial testing of the NTFSM. The goal is to enable N1 to better understand and utilize its complex models to support resource and policy decisions that create and shape the future Navy.

Findings and Conclusions (to include Process)

New software was developed, tested, and applied in proof-of-concept applications to begin the processes of enhancing N1's ability to quickly and efficiently obtain information from some of their computational models. The new software enables OSAM users to run designed experiments over a breadth of input variables. This structured approach is useful for assisting in model verification, validation, and assessment by characterizing the sensitivity of the model to the input variables and establishing cause-and-effect links (in the modeling environment) between various interventions and model performances. In a study by LCDR Borozny (2015), the interactions between natural losses, accession methods, and forced losses were examined using analysis of variance and regression trees. This is the first instance of a multi-factor design being run in OSAM without human intensive manual inputs. Her analysis reveals that the standard deviation from the mean end strength is heavily dependent upon accession method and simulation year.

In another application, LT DeHollan (2015) used sophisticated design of experiments (DOE) techniques to determine the degree of stochastic variation in OSAM and explore the effect of a three-year period of poor retention of Unrestricted Line (URL) officers in paygrades O3 through O6. In all, he varied 27 input variables over 257 input combinations, with 10 replications each—for a total of 2,570 simulated manpower levels. All of this was done automatically, and was heretofore not possible. His analysis indicates that OSAM produces very little stochastic variation, suggesting planners may be able to accurately and precisely predict the effect of this poor retention scenario on specific groups.

ENS Desousa (2015) investigated the behavior of NTFSM's output and the sensitivity of the user entered economic factors. After manually implementing a sophisticated design of experiments (DOE), he simulated and analyzed a variety of scenarios to better understand the behavior of NTFSM and to determine the sensitivity of the user defined economic factors. The results of the analysis unexpectedly show that NTFSM's economic factors have no significant impact on NTFSM's end-strength output, this warrants further investigation. More research is necessary to find out why this happened.

Recommendations for Further Research

Follow-on work has already commenced. NPS student-officers who are participating in this research are coordinating with OPNAV N1 staff—in partnership with Simulation Experiments Efficient Designs (SEED) Center researchers—to identify studies and models (e.g., NTFSM) that will use and test the data farming capabilities being developed. If the new capabilities in OSAM and NTFSM prove valuable, they will be applied to support other N1 studies—such as, the results of various policy options on retention. Since N1 uses many other models, additional

ones will be considered as candidates to make data farmable—such as the Planned Resource Optimization (PRO) model. In addition, focused workshops will be held to facilitate transitioning the new data farming capabilities to N1 analysts.

Social Media Use in the U.S. Navy: Opportunities and Challenges

Researchers: Dr. Gail Fann Thomas, Dr. Kathryn Aten, Dr. Kimberlie Stephens, Dr. Jessica Neff, LT Emily Allert and Ms. Sally Baho

Student: LT Emily Allert USN, LCDR Reza Achwandi Indonesian Navy, Capt Michael Griner USMC, LT Stephanie Montano USN, LCDR Emily Allert USN, LT Jessica Groot Australian Navy, LT David Mundell USN, CAPT David Anderson USMC, MAJ Edward Gutierrez USA, LCDR Kurtis Noack USN. CAPT Rebecca Ban USAF, Capt Danny Hamler USMC, LCDR Carrie Paben USN, CAPT Brett Barnes USAF, Capt Michael Herendeen USMC, LT Matthew Poss USN, MAJ Brian Brauer USMC, LT Daisuke Hidaka Japanese Navy, Capt. Mark William Powell Australian Air Force, LTJG Caroline Brown USN, Capt Todd Hoyt USMC, LT Christopher Santos USN, Capt Zachary Burke USA, Capt Jacob Johnson USMC, LCDR Wendell Stephens USN, MAJ Michael Carroll USA, Maj Anthony Johnston USMC, LTJG Deniz Can Uysal Turkish Navy, Capt Matthew Comer USAF, CPT Melissa Joy Australian Army, LCDR Jesse-Larou Walsh USNR, CPT Gary Croston USA, CDR Stefan Koenigsmark German Navy, LT Andrea Watling USN, Capt Jamie Davis USAF, MAJ Zachary Lewis USA, LT Mark Weiss USN, LT TJ Goss USN, LT William Maugeri USN, Wan Ying Wong Singapore Civilian, Maj Joshua Gregory USMC and CPT Keith Miner USA

Project Summary

This study includes five parts: a literature review about Enterprise Social Media (ESM), identification of social media applications (apps) that could be used to address operational problems in the Navy, focus groups of 142 18-29 year-old sailors and officers about their social media use, identification of social support derived from internal Navy Facebook groups, and analysis of Massive Multiplayer Online Wargame Leveraging the Internet (MMOGLI)crowd sourcing used by Naval Air Warfare Center Aircraft Division (NAWCAD) for strategic planning. Four faculty, one research assistant, one thesis student, and 42 NPS Master of Business Administration (MBA) students participated in the various parts of this research. The findings of this study have wide-reaching implications for promoting “The Digital Navy.”

Background The Pew Research Center shows a dramatic increase in the use of social media across all age categories, but particularly among 18-29 year olds. While the U.S. Navy has been experimenting with various social media tools, crowd sourcing, and mobile apps, we have much to learn about how the nuances of these new media - might help us better communicate with today's junior sailors and officers. While we can learn from the corporate world about the importance of using social media and mobile apps in the workplace, we need to investigate the

idiosyncratic ways that the personnel in the U.S. Navy use and would like to use social media. The purpose of this study was to learn more about the way that junior Navy personnel inhabit social media spaces or how and why mobile apps might best be employed to enable particular organizational objectives. A study to investigate these issues would allow us to better understand the nuances of sailors' social media use. For instance, how, when, and, why do sailors use various social media tools and apps? What apps and social media might be most effective in the work environment? What apps and social media are strictly social? How might we rethink traditional media practices for improved engagement among young sailors?

PART I: Enterprise Social Media Literature Review

Purpose and Process: The goal of the literature review was to examine the state-of-the-art with respect to enterprise social (social media within organizations) and to differentiate it from social media that is used outside organizations. The review was predominately derived from the academic literature and private sector reports.

Findings and Conclusions (to include Process):

1. Enterprise social media is on the rise. Several organizations have developed proprietary social media systems to harness employees' ideas, improve knowledge sharing, increase collaboration, and develop employee ambassadors.
2. Different patterns exist for internal and external networks. External networks often consist of strong ties (people they are interacting with on a regular basis); internal networks, alternatively, employ weak ties more often (people they intend to interact with).
3. ESM is dramatically shifting communication patterns and practices in organizations that use them well.
4. Analytics are useful in monitoring and shaping internal communication.
5. ESM improves innovativeness, connectedness, and buy-in.
6. ESM and productivity
    a. Many studies show an increase in productivity as network ties increase (e.g. source of innovation, improved collaboration).
    b. Social media can boost morale by improving social support and engaging in activities that can increase employees' energy during downtime.
    c. Social media can be an important job preview and socialization tool.
7. Social Media and the individual
    a. Even though the enterprise may "own" the social network, users expect some level of privacy (e.g. email). Laws generally support the corporation; however, some individuals are challenging these rulings in courts of law.
    b. Individual motivations differ for using social media.

c. Adult development theory helps us understand how social media dovetails with identity needs at different ages.

PART II: Enterprise Social Media Solutions to Navy Operational Challenges

Purpose and Process: The goal of this part of the study was to examine opportunities and challenges of social media in the U.S. Navy. Teams of 2-3 MBA (GB3012 Communication for Managers) students identified a persistent Navy problem and came up with a social media solution that would help solve that problem.

Findings and Conclusions (to include Process)
Student teams identified these social media applications:

PROBLEM	*SOCIAL MEDIA SOLUTION*
Lack of information sharing and collaboration across communities	Virtual water cooler and other network ESM (e.g. General Electric's Colab, TIBCO's tibbr, Microsoft's Yammer)
Too many SM tools	*Milboard* (social media aggregator)
Low morale, lack of transparency	Twitter ESM (e.g. real time data distribution)
Lost opportunity of gaining insights from junior sailors and officers	Crowd sourcing (e.g. Whitehouse "We the People," war gaming, humanitarian relief, policy consultation)
Need for improved information dissemination and networking opportunities	U.S. Navy internal Facebook for use within Navy communities (e.g. Facebook at Work)
Improve recruitment of millennials	Mobile apps to better inform millennials who are interested in joining the Navy
Impromptu On-the-job training (OJT) is not documented and becomes lost institutional knowledge	Apps to enhance rate-specific training; incorporate tracker to update
Lack of effectiveness in job assignments	App-based *Resumil* to create a virtual marketplace for officers.
Improve leadership development	3.6.0. app to solicit input from subordinate, peers, and superiors for leader feedback and personal development
Time lost commuting	App that provides real-time input from base services to estimate wait times, scheduling of appointments ("experience Disney")
Health care coverage during Permanent Change of Station (PCS) move	User-friendly app for locating Primary Care Manager (PCM) or scheduling medical appointments; online chat for Tricare customer; crowd sourced public review of patient service
Physical fitness remedy	Fitness tracking devices (e.g. Fitbit); host competitions to improve sailors' overall health

DoD travel complexity	User friendly app to guide travelers through guidelines
Liberty call improvement	Apps for real-time information as sailors disembark (forbidden zones, timely return to ship)

Recommendations for Further Research
Create prototypes of apps, develop analytics to test effectiveness of the apps. U.S. Navy should consider less push of mandatory training and more interactive use of apps that allow sailors to input data and get information to improve operations. Use apps as a network platform; not a communication one-way channel.

PART III: Social Media Use by U.S. Navy Junior Officers and Sailors

Purpose and Process: The purpose of this phase of the study was to identify the ways that junior sailors and officers use social media. In July and August 2015, Dr. Gail Fann Thomas and three of her colleagues visited two carriers and 2 amphibs that had recently returned from deployment in Norfolk and San Diego. They conducted focus groups with 4 different age groups, the youngest 18-20 and oldest 27-29. 142 participated in the focus groups - both enlisted and officers. The research team also conducted 15 one-on-one interviews with the ships' COs, XOs, CMCs and PAOs.

Findings and Conclusions (to include Process):
1. Millennials rely on their smart phones for a multitude of everyday professional and personal tasks. Data from focus groups suggest that U.S. Navy 18-29 year-old social media use reflects similar data from Pew social media use studies. Personal media devices are an integral part of many millennials day-to-day activities (e.g. getting information, keeping in touch with friends and family, reading books and magazines, keeping up with current events, listening to music, playing games, checking weather, doing school work, coordinating work, fitness, messaging, paying bills).
2. Professional social media use and personal social media use are distinctly different; but personal social media use can impact morale and productivity at work.
3. Four key considerations for social media use are Operations Security (OPSEC), safety, morale, and productivity. OPSEC and safety must be first and foremost. Morale appears to be closely related to internet access. Strong differing opinions exist among middle managers about the relationship between the use of social media and productivity. Research primarily shows that there tends to be a positive relationship between social media use and productivity.
4. There are significant generational differences in opinions about social media use that will complicate the management of this issue.

5. Commands are missing opportunities to incorporate social media use as part of their larger command's strategy. The research team saw little use of social media metrics or social media data mining activities.
6. Millennials use social media in this order: Facebook, Instagram, Snapchat, YouTube, and Netflix. Their social media networks and the way sailors present themselves in these networks often vary by social media type. Millennials connect with others on social media in this order: friends, family, colleagues, brands, organizations, politicians.
7. Through social media, sailors touch thousands of U.S. citizens and are serving as the Navy's brand ambassadors.
8. Social media use and individual networks mirror adult development (e.g. 18-20 year-old's networks are very different than 27-29 year-olds' networks.) Most 18-20 year-olds need strong social support when they first enter the Navy. 27-29 year-olds have built professional networks.
9. COs, XOs, CMCs see an increasing demand from young sailors for internet access and social media use and are having to develop policies that are enforceable. Many leaders are experimenting with different approaches that maximize OPSEC, safety, morale and productivity (e.g. MWR networks, policies that address access to social media).
10. Social media use impacts a broad array of functions: CO, XO, CMC, PAO, HR, JAG, IT, Personal security, Chaplain, Intel, Psychologist, Ombudsman, in some cases NCIS, FBI.

Recommendations for Further Research

1. Think strategically about how social media can be used to improve performance and increase morale. Current thinking is too focused on thinking about social media as a one-way communication channel rather than as a multi-directional influence network. One size will not fit all. Tailor social media strategies to meet generational differences and various Navy platforms (e.g. ships, submarines, aviation).
2. Find opportunities to turn communication upside down – social media is an ideal vehicle for "listening to the troops" and learning from their unique perspectives (e.g. Reduce Administrative Distraction (RAD) crowd sourcing experiment).
3. Educate leaders about social media opportunities and challenges. Many leaders are asking for assistance and advice. Sailors' demand for internet is increasing, but leaders have limited knowledge about managing this issue.
4. Engage the chiefs. They will be central to these issues because they have close contact with enlisted and strongly influence them. Chiefs will make or break social media initiatives.
5. PAOs and other Navy personnel need more formal education in social media, effective website development and social media analytics that focus on strategic objectives and stakeholder effects. Create proof-of-concept projects to demonstrate data mining opportunities for internal Navy social media.

PART IV: Analysis of Facebook Posts

Purpose and Process: The purpose of this part of the research was to address five research questions with regards to enlisted women's and women officers' Facebook (FB) group that is administered by the U.S. Navy's Office of Women Policy (OWP): 1) What are the advantages, disadvantages, and limitations of the Facebook groups from an Enterprise Social Media perspective? 2) What are the advantages, disadvantages, and limitations of the FB groups as a platform for Computer-Mediated Social Support (CMSS)? 3) What categories of CMSS are being provided and solicited on the FB groups? 4) What are the most common topics in the FB posts? 5) What are the similarities and differences between the three FB groups? Thesis student, LT Emily Allert, analyzed the FB data and conducted seven interviews with the FB administrators to identify the OWP's objectives and to explore the types of social support provided by these FB groups.

Findings and Conclusions (to include Process)

1. Facebook is a valuable tool for promoting social support for enlisted women and women officers.
2. Members are able to connect anytime, anywhere.
3. Facebook offers OWP a means for having their "ear to the ground" about Navy women's issues.
4. Facebook is meeting many OWP objectives, but could be improved to increase social support for enlisted and officers.

Recommendations for Future Research

1. DOD - Expand FB groups for other minority groups
2. Conduct training for FB administrators
3. Develop a strategy for FB groups
4. Better advertise the FB groups
5. Ask members to act as geographic representatives (recruiting, vetting, mentoring, networking, meet ups)
6. Expand data set – longer period of time, include responses, and likes.
7. Interview sample of FB group members to identify strengths and weaknesses of the FB site.
8. Make improvements to the site.

PART V: MMOWGLI NAWCAD Strategic Planning Crowd sourcing

Purpose and Process: The purpose of this phase of the research was to answer the research questions: How does crowdsourcing influence organizational strategizing? We used a case analysis of two approaches to strategic planning – traditional planning process and crowd sourcing planning process. We conducted interviews with key players and analyzed archival data from traditional strategic planning effort and MMOWGLI crowd sourcing archival data.

Findings and Conclusions (to include Process)

1. Traditional strategic planning processes are often limited to a small group of leadership.
2. Output is often a strategic planning brochure that must be disseminated or cascaded to the rest of the organization.

3. Enterprise personnel often have little buy-in and little understanding of significance of the priorities or the process by which they were determined.
4. Crowd sourcing strategic planning involves a large number of personnel, both inside and outside the organization.
5. The command gets many people engaged and is able to work across silos.
6. Anonymity gives people freedom to share their ideas without fear of retribution.
7. Crowd sourced strategy creates a massive database of ideas, but also a large amount of data that must be managed.
8. The crowd sourcing tool can be designed to identify actionable plans.
9. Crowd sourcing requires significant resources in planning and managing the process.

Recommendations for Future Research

Conduct social and semantic network analysis on crowd sourcing data to better understand the dynamics of open strategy. Conduct further analysis of crowd sourcing Navy sites to identify intellectual resources that personnel bring to the Navy.

Leadership Training in Virtual Worlds

Researchers: Sue Higgins, Peter Denning and Scot Miller

Student: No NPS students participated in this research project.

Project Summary

Our project met its final deliverable with a book chapter, (Innovative Learning: A Key to National Security, 2015), published in The Army Press. This project explored how military officers would respond to a virtual world, in a course designed to improve effective leadership of small teams.

Six U.S. military officers – a Navy and a Coast Guard Lieutenant Commander, a Marine Captain, a retired Navy Captain, a retired Navy Commander, and an Army Reserve Major – voluntarily participated on weekends in a virtual course called Working Effectively in Small Teams (WEST). Using a Skype-like group communication tool, students participated from global locations, spending approximately 3-4 hours each week on coursework.

The officers were initially divided randomly into teams of five. For the first two months each military member was part of a mostly civilian team; for the second two months the military members formed their own team.

In weekly assignments teams read and discussed articles and received initial guidance for planning team operations to be conducted inside the platform of the commercial virtual fantasy game World of Warcraft (WOW). Much like a flight simulator, the WOW virtual world places teams of participants in “quests” that provoke the same moods and reactions as in the real world. WEST uses WOW as a virtual laboratory in which teams experienced challenges with

coordination and communication in fast-paced “battles” needed to complete quests. When the challenge was done, each team debriefed in an after-action session and followed up with short written reflections on what they experienced and learned. A coach accompanied them to observe their in- game actions and conversations and to help them make effective use of the language distinctions in their group debriefings.
The (civilian) success of this commercial course flows from its careful attention to how students use language and how that affects their moods and willingness to trust each other. WEST is designed to help people develop and practice skills needed to work in “pluralistic networks” – in which participants from different backgrounds and cultures must coordinate as members of diverse teams to create meaningful action. This emphasis on pluralistic networks intrigued us because military joint international operations aspire to be effective in exactly that type of environment.

A key part of team coordination consists of making assertions (verifiable facts) and exchanging grounded assessments (opinions backed by relevant assertions) about each teammate’s performance. The coaches repeatedly emphasized that the assessments should be aimed to help the team achieve its goals -- not as personal criticisms or attacks. Many found this honesty tough at first and diluted their assessments with unnecessary verbal filters. Yet it soon became apparent to all teams that their effectiveness depended on each member’s skill in making and receiving these honest assessments. The challenge of doing this well was compounded when team members were from different cultures and backgrounds.

Background
Our Naval education systems, designed in the machine age, do not adequately prepare our military for the emerging new world. Our adversaries, who are not subject to our institutional constraints, are moving into the new age faster than we are. It is time for a new conversation about the design of military education.

Findings and Conclusions
Leadership skills can develop across distance. A common belief is that meeting “in-person” is the only way to develop leadership skills. Developing leadership practices in virtual environments is valuable, especially for organizations where geographically dispersed teams are the norm.

Core skills for teams working in new, uncertain and emerging environments can be developed and practiced in virtual environments.
Participants re-experienced what it is like to be a beginner – an unusual opportunity for developing empathy among seasoned professionals.
Participants practiced building trust in teams. Many realized they often talk about the importance of trust but have little sense of what conversations actually contribute to creating a sense of trust.

Participants built relationships with each other. This helped develop a sense of commitment among team members to provide honest assessments and stick with the course.

Participants created shared understanding by practicing new skills together, further contributing to their mutual trust and team effectiveness.
Participants had fun. Their enjoyment of their teams and projects kept them engaged week by week for the full four months.

Participants saw broader value for the course as they considered opportunities to provide the course within their own Military Services.

Participants learned to operate across organizational and cultural boundaries.
Commercial virtual games can be a very cost effective method for training and are much cheaper than organization-specific games.

The course effectively cultivated several aspects of network age leadership including innovation, navigation, and appropriation.

The challenges and quests within the game of WOW elicit various moods and emotions, which can be discussed in terms of how they promoted or hindered working together.

Recommendations for Further Research
Based on the students' positive recommendations, a Marine Reserve Forces Command team will participate in WEST from January to May 2016.

Design future experiments to insert WEST (or WEST-like) modules or courses into Naval schools such as the Naval Academy.

Design future experiments to insert WEST (or WEST-like) modules or courses into community-specific leadership training, such as Basic Underwater Demolition/SEAL Training (BUD/S).

Analysis of Suicide Behaviors in the Navy Population

Researchers: Dr. Yu-Chu Shen and Dr. Jesse Cunha

Student: LCDR Neeta Serena Blankenship USN and LCDR Kristen Shepherd, USN

Background
U.S. military suicides have increased significantly over the past decade and currently account for almost 20% of all military deaths. Effective suicide prevention efforts require better information to identify high-risk segments of the population. In this research project, we investigated the associations of suicides and suicide attempts among current and former service members with a comprehensive set of time-varying risk factors including: deployment, diagnoses of major mental disorders, history of unlawful activity, stressful life events, and other

demographic and service factors. We observed suicide death rates of veterans after separating from the military, not including attempted suicide. Our analyses were based upon both a joint-service population and a Navy-only population.

Findings and Conclusions (to include Process)
Since the last interim report, we have acquired additional data assets that allow us to have a more comprehensive model, including the Defense Casualty Analysis System (to capture oversea deaths), personnel separation files, and transaction files to capture initial service information. We decided to implement a survival analysis in order to capture the time varying effect of the risk factors, and moved to quarterly data analysis (as opposed to yearly observation). The project is very resource intensive due to the complexity of the data structure and estimation methods.

Our population is all U.S. military personnel who were on active duty between 2001-2011 (N=110,035,573 person-quarters for all-service analysis; N= 24,982,930 for Navy specific analysis). We implemented Cox proportional hazard models to examine associations of deployment, diagnoses of major mental disorders, a history of unlawful activity, stressful life events, and other demographic and service factors with suicide death.

We found that the strongest predictors of suicide deaths were current and past diagnoses of self-inflicted injuries, depression, and substance use disorder (comparing to those with no history of diagnoses, hazard ratio, HR, ranged from 1.47 to 13.75, all $p<0.001$). Compared to those never deployed, hazards were lower among the currently-deployed (HR=0.47; CI,0.38-0.57) but significantly higher in the quarters following first deployment (HR=1.47; CI,1.13-1.90). Hazard of suicide was elevated within the first year of separation from the military (HR=2.73; CI,2.33-3.19), and remained high even for those who separated six or more years ago (HR=1.52; CI,1.36-1.70).

In the final phase of the FY16 project, we are now focusing on models for suicide attempts and replicating all models on the Navy specific population. Due to the sample size, some of the sub-sample analysis is only implemented in the all-service sample.

So far, we found consistent evidence that elevated hazard of suicide death varies by time-since-exposure to deployment, mental health diagnoses, and other stressful life events. To the extent that the elevated suicide hazards of the previously-deployed persist over time, the association between deployment history and suicide will increase in the current cohort due to the growing proportion of previously-deployed among those currently in the military. Continued monitoring is particularly needed for those with mental health history. Additional information should be gathered to address the persistent elevated risks of suicides among service members after separation.

Recommendations for Further Research
Not applicable as this is interim report.

N2/N6: INFORMATION DOMINANCE

Integration and Optimization of UUV/USV Operations in Environmental Characterization

Researchers: John Joseph and Doug Horner

Student: LT Brad Nott USN and LT Chris Bade USN

Project Summary

This research is an initial investigation into the potential application of an integrated system consisting of unmanned surface vessel (USV) and unmanned underwater vehicle (UUV) components in support of wide-area environmental sensing and characterization. The project was suggested as a topic of interest by N2/N6 which has been contemplating the development of a USV program under the Navy's Littoral Battlespace Sensing Program of Record. A comprehensive theoretical, modeling, and observational approach was used to weigh strengths and limitations of an integrated system that leverages use of available unmanned system technology to develop an effective integrated system for characterizing both the oceanographic and acoustic environments supporting undersea warfare (USW) and battlespace awareness (BA) missions. The study was largely conducted as the basis for thesis research (Nott, 2015), conducted by LT Bradley Nott a USW curriculum student who recently graduated with his Master of Science (MS) Physical Oceanography degree in September 2015.

Background

This effort provides information that supports N2/N6 program planning, policy and strategy development, organizational support, and lessons learned. The study examined cooperative use of small, remotely-managed undersea gliders and unmanned surface vehicles providing the warfighter with critical real-time environmental characterization, both oceanographic and acoustic, for multi-month periods of on-scene operations. The long-endurance aspect allows the system to operate extended independent missions, minimizing any support tail it would otherwise impose on in-theater assets required to maintain operations. Our hypothesis is that a system with reliable long-endurance characteristics can leverage the strengths of the individual platforms while mitigating their limitations, resulting in a more effective force-multiplier than if the components were deployed independently.

Findings and Conclusions (to include Process)

The study consisted of a theoretical, modeling, and observational approach that provided insight into the strengths and limitations of an integrated UUV/USV system to conduct timely wide-area environmental assessment applicable to USW and BA missions.

An extensive literature search was conducted on applications of various types of USV and UUV systems in research, industry, and the military to understand the potential capabilities that might be valuable to the system we envision. The literature search provided many examples of

cooperative USV/UUV behavior that have been successfully demonstrated, shaping our understanding of what may work and where the challenges are. We have been fortunate to tap into expertise at Scripps Institution of Oceanography (SIO) and the Monterey Bay Aquarium Research Institute (MBARI) that have guided us towards our current approach.

Physics-based propagation modeling results were compared against field data collected in a representative ocean environment. A deep-diving Spray glider was used to collect both oceanographic profiles and receive signals transmitted from a shallow mid-frequency source. A similar effort to collect high-frequency acoustic communications (acomms) signals was also conducted to compare modeled performance against successful acomms message transfer in the field. Results demonstrate that, with appropriate environmental information, system performance of an integrated USV/UUV system can be well-predicted and optimized, thus supporting our hypothesis that optimized positioning of system components can provide long-term, continuous coverage with real-time reporting of critical information that is not achievable with the components working independently.

We are in the process of modifying NPS UUV/USV platforms that will be used to conduct testing under a variety of real-ocean conditions. This includes an upgrade to the glider control system and installation of a directional acoustic modem on the Spray glider. This will enable the undersea glider to be controlled remotely via acoustic commands passed through a USV, as well as pass navigation information between the glider and USV. With FY16 funding, this effort continues.

Our results and the current state of research in this area provide confidence that our approach will lead to a relevant operational capability, however more development work needs to be done to iron out the details.

Recommendations for Further Research

Continued development of the system we envision is highly recommended. This study has laid essential groundwork for development of a credible, long-endurance, remotely piloted integrated UUV/USV system based on exploiting the local environment. Recommended future work should include addressing technical details that still need to be resolved and additional field testing under real-world environmental conditions to ensure full functionality is attained.

Big Data Architecture and Analytics (BDAA) for Improving Combat Identification (CID) and the Common Tactical Air Picture (CTAP)

Researchers: Dr. Ying Zhao, Anthony Kendall and Bonnie Young

Student: LCDR Wesley (Evan) Baumgartner USN

Project Summary

In the past year, the research team found that the Aegis combat system, Cooperative Engagement Capability (CEC), and Link 16 are critical systems supporting combat identification (CID) for sharing data among distributed platforms, correlating and fusing data, and displaying tracks. The CID process was found to rely on the application of doctrine and the collaboration of multiple decision makers. The process was found to be significantly manual and very reliant on the experience level of analysts and decision makers. The team found that Big Data Architecture and Analytics (BDAA) shows significant potential to improving Common Tactical Air Picture (CTAP) and CID. The team also found that BDAA could be leveraged to develop advanced data models as part of data integration, data storage, and retrieval; and it could support advanced automated decision aids and resource management capabilities for battle management.

Background

Accurate, relevant, and timely CID enables the warfighter to locate and identify critical airborne targets with high precision. An effective CID capability optimizes the use of long-range weapons, aids in fratricide reduction, enhances battlefield situational awareness, and reduces exposure of U.S. forces to enemy fire. CID plays an important role in generating the CTAP which provides situational awareness to the air warfare decision-makers.

The amount of exponentially expanding and diverse data generated by intelligence, surveillance, and reconnaissance (ISR) sensors has created a Big Data environment that poses a CID challenge. Traditional information systems cannot meet the timelines required for air picture CID when presented with extremely large amounts of data. Nor can they process and analyze additional types of data such as information from the Internet, social media, and commercial airline information. New information system technology and methods, such as BDAA, show promise for handling and analyzing the rising tide of sensor and non-sensor data, and fusing it in a timely manner to enhance CID dramatically.

Findings and Conclusions (to include Process)

In the past year, the research team participated in the exercise Northern Edge at Alaska, worked with domain experts on the USS Howard, the Pacific fleet Naval Air Weapons Station (NAWS) at China Lake, the Massachusetts Institute of Technology (MIT) Lincoln Lab, and the Navy Tactical Cloud at Dahlgren. The team has studied current CID methods used in existing

Joint and Naval systems including platforms, sensors, networks, and data/databases. The team's primary questions for Phase I of the project were:

1. What information is used for the current CID process?
2. What data sources, displays, and fusion processes are currently used for CID decision makers and end-users?
3. What are the challenges for the current CID process?
4. How can BDAA assist in CID?

The team found that current CID processes included the use of Naval and Joint combinations of:
- Platforms: destroyers, cruisers, carriers, F/A-18s, E-2Ds
- Sensors & data sources: radar, Forward Looking Infrared (FLIR), Identification Friend or Foe (IFF), Precision Participation Location Identifier (PPLI), and National Technical Means (NTM)
- Networks: Link-16, Cooperative Engagement Capability (CEC), Global Command and Control System (GCCS), and Global Information Grid (GIG)
- Decision makers: Air and Missile Defense Commander (AMDC), Air Warfare (AW) Officer, and Tactical Action Officer (TAO).

The team identified the following CID air picture challenges for the Navy:
1. An extremely short dwell time for fusion, decision making, and targeting.
2. Uncertain and/or missing data outside sensor (e.g., radar, radio) ranges
3. Track picture uncertainty (track conflicts, multiple objects per track or multiple tracks per object).
4. Manual decision-making, group decision-making, and overwhelmed decision-makers (i.e., complex threat environments can create situations in which decision-makers can be overwhelmed by large amounts of data, uncertain track pictures, and complicated if-then doctrine statements)
5. Hard-to-detect anomalies and a lack of predictive analytic capabilities.
6. Manual methods for incorporating electronic warfare (EW) and non-cooperative sensor measurements and signature databases, into the CID process.

The team explored how BDAA could address these challenges. BDAA technologies have been developed in the commercial world to provide: 1) data collection, ingestion, integration, and safe storage, 2) parallel/distributed processing, and 3) deep analytics. The team developed a Big Data Architecture concept for CTAP and CID called the CTAP Cloud Concept. The CTAP Cloud Concept, which could be physically associated with a Big Data cloud implementation such as the Naval Tactical Cloud (NTC), is used to store the additional data sources that are not traditional CTAP and CID data sources. Such a configuration would include elements such as temporal, spatial, and organic sensor data that are collected but not currently used (e.g. Aegis residual data), open sources flight schedules, advanced (EW) signature data sources and Intel. These new data sources could be fused and analyzed in parallel using deep analytics in the CTAP cloud. The resulting knowledge repository, i.e., Smart Data, could be searched, matched, and cross-validated with real-time data streams of traditional sensor and track level data in the current CTAP and CID platforms, used by the warfighters to provide new and enhanced

situational awareness. For example, the cloud could send or push Smart Data (e.g. early warnings or alerts generated based on BDAA) to various platforms within a battlespace. A platform with partial or uncertain sensor/track data could send a real-time query to the cloud to find a higher certainty match with a higher probability or confidence. The Smart Data push and pull would have a relatively small data size and therefore not strain current networks for transmission between platforms.

The team also studied Big Data Analytics to address CTAP and CID challenges that included unsupervised learning, self-taught learning, deep learning, pattern recognition, anomaly detection, and data fusion. The team developed and selected machine vision and deep learning algorithms for improving object recognition, classification accuracy and certainty of air objects by associating, correlating, and fusing heterogeneous data sources that do not share data models. The team developed pattern recognition and anomaly detection that could be used for identifying intent, air picture event anomalies, or launch predictions. The team provided evidence for the selected tools and methods on how to fuse tactical data such as infrared, Electro-optical (EO), and radar with alternative data such as text-based data from open Internet and social media sources to improve object recognition and predict interesting events.

Recommendations for Further Research
In the follow-on research program, the team will provide additional evidence through further collaboration and experimentation. The team plans to further develop the CTAP Cloud Concept and associated analytics, as well as pursue data models and battle management tools.

Crowd Sourcing Human Analyst Playbooks for Insider Threat Mitigation

Researchers: Dr. Shelley Gallup and Dr. Thomas Anderson

Students: CAPT Ryan Kelly USA, LCDR Richard Mascolo USN and LT Jeremy Sellen USN

Project Summary
We conducted an analysis of the insider threat (InT) hub processes derived from multiple organizations and perspectives. InT analysts, case managers, and subject matter experts interacted in a crowd-sourcing game called the Massively Multiplayer Online Wargame Leveraging the Internet (MMOWGLI) using themes derived from interviews to stimulate seeds (inputs). Themes, issues, and recommendations from the wargame were further refined and are included in a version of the framework for a Navy InT hub. Integrated DEFintion (IDEF) method format modeling was used to analyze processes, procedures, and personnel roles from the results of the field research and MMOWGLI, and from documents from Space and Naval Warfare Systems Command (SPAWAR) 5.0 and interviews with the Defense Security Service (DSS) and Defense Intelligence Agency (DIA). Using case examples from the Carnegie-Mellon Computer Emergency Readiness Team (CERT), we propose a set of “playbook” processes. We

elicit the key aspects of Hub Architecture organization and information flow that must be considered when devising an Insider Threat Hub playbook.

Background

The policy and guidance surrounding Insider Threat is relatively new. The DOD Directive 5205.16, of September 2014, establishes policy and assigns responsibilities within DOD to develop and maintain an insider threat program to prevent, deter, detect, and mitigate actions by malicious insiders who represent a threat to national security.

In August 2013, Secretary of the Navy Instructions (SECNAVINST 5510.37) established the Department of the Navy Insider Threat Program (InTP) to promulgate policy, assign responsibilities, and institute a governance framework. On 27 January 2015, the Chief of Naval Operations (CNO) released the Navy Insider Threat Program Instruction (OPNAVINST 5510.165) which levied requirements for the Navy to detect, deter, and then mitigate insider threats. It establishes the Navy Insider Threat Program (Navy ITP) to promulgate policy, assign responsibilities, and institute the Navy Insider Threat Board of Governance (NITBOG). This instruction was superseded by (OPNAVINST 5510.165a) which revised the original instruction and added an ITP implementation plan.

This research seeks to collect, evaluate, and codify in-use and recommended practices for Insider Threat (InT) mitigation. Interviews with subject matter experts (SME) comprising a variety of skillsets and analysis of organizations involved in InT operations over a broad geographical/mission area were conducted. The intended outcome of this work was to align Insider Threat Program (InTP) and Computer Network Defense (CND) processes and procedures through the development of an automated and manual "Playbook" construct. The project will seek to understand the organizational structure that best suits the InT hub mission.

Findings and Conclusions (to include Process)

Our research led to the emergence of three very specific insider threat hub operations problem areas: information sharing, technology integration, and organizational policy. These problems affect the movement or flow of information in and out of the Hub. Information must be pulled together from many areas to create a whole picture of a threat. The results from the MMOWGLI war game show that classified network enclaves can limit both the social-networking and techno-networking between insider threat analysis communities. This limitation can lead to breakdown in information flow that permits a damaging InT event to take place. Thus, we arrive at our preliminary hypothesis: the insider threat problem is perpetuated by cross organizational communication barriers. And if true, the InT Hub playbook must incorporate policy and procedure to specify ways and means of cross organizational information flow and situational awareness.

Recommendations for Further Research

In Fiscal Year (FY) 16 the Insider Threat research team is funded to continue development of the Insider Threat playbook for the Navy's hub operations. Three theses are in progress with this research, and one Ph.D. dissertation. One thesis will refine the collaborative capacity necessary

for hub operations to be successful. Another will look at the needs and opportunities for automation of hub processes, and interoperability between hubs. The third thesis is by a Turkish student, looking at the adaptation of the Navy and DOD hub operations by the Turkish Gendarmarie. A second crowd sourcing (MMOWGLI) game is being planned for April 2016 to refine inputs to hub operations using specific case studies and outputs of thesis work. In addition, analytic tools for use in the Insider Threat analysis hubs (such as sentiment analysis) will be included in FY 16.

N3/N5: PLANS & STRATEGY

Maritime Strategy and Alliance Policy in East Asia

Researchers: Dr. Christopher Twomey

Students: Capt Patrick Acox USMC, Mr. Daniel Alvarez CIV, LT Walter Buitrago USN, LTAnthony Culwell USN, Capt David Garcia USMC, Capt Robert Garcia USMC, LCDR Joseph Greenslade USN, LCDR Shawn Kocis LCDR, LT Andrew Konowicz USN, Lara Magallanes CIV, Lt Col Michael McMahan USMC, Giovanni Minelli CIV, LT Judson Thomas USN, LT Mathew Thomas USN, LT Edward Tremblay USN, MAJ Steven Wojdakowski USA, Richard Zappulla CIV, and LT Zachary Zarow

Project Summary

Three interrelated studies addressed the challenges facing the USN and its allies in Asia. (Two studies were dropped given labor and financial constraints.) The aim of the first study is to evaluate Chinese views of maritime strategy to -determine possible areas for cooperation, deterrence enhancement, and risk mitigation. A second focuses on China's expanding counterspace capabilities that threaten U.S. Naval strategy Asia. Analyzing the emerging threat environment, thinking through specific counter-measures, and developing allied strategies with East Asian military partners could strengthen deterrence, reduce vulnerabilities, and ensure operational effectiveness. A final study looks at the dilemma of strengthening U.S.- Republic of Korea (ROK)- deterrence while minimizing risks of conflict escalation in the maritime realm. The context for this includes recent North Korea provocations, changes in ROK declaratory deterrence policy, and renewed ROK interest in tactical nuclear weapons.

Background

Perceptions of Maritime Strategy

In Asia, Chinese development of a range of capabilities encapsulated in the anti-access/area denial (A2/AD) moniker has raised significant questions about the future of international security in the region. Situated on top of a broader narrative of the "rise of China," (Friedberg, 2012); (Tellis A. J., 2013) specific operational challenges to USN access to the region potentially raise questions about alliance commitment and the broader balance of power in the region. In the context of the "rebalance" or "pivot" to Asia, the U.S. military is developing a range of

responses as laid out in the Joint Operational Access Concept (JOAC) (Dempsey, 2012)and Air-Sea Battle (ASB). (Schwartz & Greenert, 2012) Deepened understanding of the nature of Chinese strategy is critical for the future developments in this regard.

Implications of China's Counterspace Developments

China's expanding counterspace capabilities raise serious concerns for the future of U.S. Naval operations in the Sea of Japan, the South China Sea, and certain areas of the western Pacific (Tellis A. , 2014). Some U.S. military officers, civilian officials, and academic analysts believe that the Navy may "lose space" early in a future conflict with China (Hagt & Durnin, 2011). However, these scenarios assume a static U.S. response to China's emergence in space, which is far from accurate. Moreover, it assumes that the United States will fight alone, failing to consider the possible contribution of U.S. allies. More work, including a mix of technical and policy analysis, on the nature and capabilities of comparative space networks is needed to assess the extent of U.S. vulnerabilities and to develop both tactics and a broader strategy for "fighting through" emerging challenges posed by China in space.

Maritime Deterrence in the U.S.-ROK Alliance

Extended deterrence has girded the U.S.-ROK defense relationship since establishment of the U.S.-ROK Mutual Defense Treaty. Throughout the Cold War, U.S. nuclear weapons provided the "ultimate" deterrence guarantee. With the collapse of the Soviet Union, U.S. policy deemed extended deterrence robust enough that U.S. tactical nuclear weapons could be withdrawn from the ROK. Korean security conditions continued to evolve, however, most notably with the rise of Chinese regional influence and the growth of North Korea's nuclear weapons capabilities. (Jeong, 2012) In 2010, North Korea's sinking of the ROK navy's *Cheonan* and artillery shelling of Yeonpyeong Island spotlighted the existing alliance posture's insufficiency in deterring such "smaller-scale" aggressive actions (Bush III, 2011), (Saunders, 2012), (Lewis, 2012). The alliance partners' responses included formation of an Extended Deterrence Policy Committee (EDPC) to increase information sharing and develop "policy alternatives for deterring North Korean provocations (Hyuk-chul, 2010), (Whun, 2010), (Presence with a Purpose, 2011), (Eun-jung, 2012)." Despite calls in some circles to redeploy U.S. tactical nuclear weapons in the ROK (Kim, 2011), (Huntley, 2013) enhanced nuclear threat-making may lack the credibility to effectively deter smaller-scale aggression. Enhanced conventional capabilities to defend against and/or respond to these contingencies may also provide more robust deterrence. But broad-based conventional force enhancement also risks widening pathways for rapid conflict escalation in the event of deterrence failure. Thus, a fundamental challenge of the U.S.-ROK alliance today is to strengthen *credible* and *robust* deterrence of smaller-scale aggression without eroding regional stability and increasing prospects of conflict escalation. This project will evaluate the potential role of U.S. & ROK maritime forces in resolving this dilemma.

Findings and Conclusions (to include Process)

Fighting through a degraded space environment in Asia

Rather than blithely ignoring the problem or simply assuming the worst, the study examined adversarial counter-space capabilities challenging U.S. space superiority and identified mitigation measures that can be implemented with existing capabilities. These can improve

resiliency of DOD space-enabled operations in contested environments in East Asia scenarios. The study was conducted by a team of students and faculty from the Space Systems and National Security Affairs departments at the Naval Postgraduate School, as part of the Naval Research Program (under OPNAV sponsorship). This study is part of a broader political-military (pol-mil) project on East Asia that we are conducting in response to a request from Commander, U.S. 7th Fleet (C7F). Further details are available subject to classification.

China's Maritime Strategy:

In Chinese military writings, counter-intervention is not described as a general military strategy. To be sure, China is developing new capabilities that could be used against the United States if it intervened in a regional conflict involving China. Chinese sources to describe the need to "deal with" or "resist" intervention as a part of specific campaign, especially a conflict over Taiwan. That is, China views dealing with the United States not as the primary goal of its military strategy, but as one component of a subset of possible scenarios it envisions. Once we recognize this, it becomes clear that China faces a range of security concerns, and that presuming it focuses narrowly or solely on the United States can lead to self-fulfilling prophecies and downward spirals

U.S.-ROK Alliance:

The core deterrence problem on the Korean peninsula today is not that capabilities are insufficient, or that the will to use these capabilities in appropriate circumstances is particularly lacking. Rather, the core problem is that threat of use of overwhelming force in response to lower-level aggression is not credible, because all sides know it would not be strategically appropriate. Deterring a wide range of potential low-level aggressive acts therefore requires a broad array of conventional capabilities tailored for deterrence as well as defense across a range of threat scenarios. Escalation concerns can be minimized by matching the deterrence capability to the aggression threat as closely as possible in both scale and kind. Hence, ROK maritime forces should be a major element of a credible conventional deterrence posture, with focus on deterring maritime threats (as represented by the *Cheonan* sinking). Additionally, broadening interaction between U.S. and ROK maritime forces with respect to such roles can enhance both allies' assurance that deterrence commitments will be upheld, projecting joint will and thereby bolstering the tailored deterrence posture.

Recommendations for Further Research

In the space area, further work is warranted both on the broad polmil options, but also on the narrow operational considerations. Classification limits discussion, although encouraging a broad discussion about the higher level strategies remains important. Regarding China's maritime strategy, charting the continuing evolution is an important goal, as well as further investigation of the interaction of that strategy with U.S. capabilities and the prospects for spirals should be considered. Finally, with respect to the role of ROK maritime forces in a tailored joint U.S.-ROK deterrence posture, current results indicate three areas for deeper examination: specifying threat contingencies for which ROK maritime forces are best suited to enhance deterrence credibility while minimizing escalation risks; determining appropriate degrees of specificity in declared joint deterrence postures; and examining the historical role of maritime collaboration as an assurance instrument in the U.S.-ROK security relationship.

Responding to Russian Noncompliance with Nuclear Arms Control Agreements

Researchers: Dr. Mikhail Tsypkin and Dr. David Yost

Students: No students participated in this research project.

Project Summary
This paper reports on an investigation of Russian noncompliance with nuclear arms control agreements. It discusses three examples: the Presidential Nuclear Initiatives in 1991-1992, particularly with respect to non-strategic nuclear forces; the Budapest Memorandum concluded with Ukraine in 1994; and the 1987 Intermediate-Range Nuclear Forces (INF) Treaty. The paper considers possible explanations for Russian noncompliance with the INF Treaty, including financial and strategic advantages in developing and testing intermediate-range ground-launched cruise missiles (GLCMs). The paper examines the prospects for Russia's acknowledgment of its violation and return to compliance with the INF Treaty.

Background
This study focuses on Russian violations of nuclear arms control agreements. The United States is confronted with two types of violations of such agreements. One type (as with the Budapest Memorandum) is open and clear. Russia's noncompliance has damaged the cause of nuclear non-proliferation around the world. The other type of violation is covert; a violator of an arms control treaty usually engages in subterfuge in order to achieve a unilateral advantage. As Deputy Secretary of Defense Robert Work and Vice Chairman of the Joint Chiefs of Staff Admiral James Winnefeld stated in their Congressional testimony regarding the INF Treaty, the United States "will not allow the Russian Federation to gain a significant military advantage through their violation of an arms control treaty. We are developing and analyzing response options for the President, and will consult with our Allies (United States, 2015)." The goal of this study is to contribute to this process by clarifying the probable motivations of Russia in violating arms control agreements, and, on the basis of this knowledge, assessing possible responses to violations.

Before offering an analysis of Russia's possible motives in violating the INF Treaty, this paper considers Moscow's failure to honor two other nuclear arms control agreements — the Presidential Nuclear Initiatives (PNIs) in 1991-1992, particularly with respect to non-strategic nuclear forces; and the Budapest Memorandum concluded with Ukraine in 1994.

Findings and Conclusions (to include Process)
The paper devotes most attention to the INF Treaty. It considers how the political context in Russia under Putin's rule has become increasingly skeptical about the benefits for Russia of agreements concluded with the United States and other North Atlantic Treaty Organization (NATO) nations by Mikhail Gorbachev, the last Soviet president, and Boris Yeltsin, the first president of the Russian Federation. Russian critics of these agreements, including the 1990

Treaty on Conventional Armed Forces in Europe (CFE Treaty), have described them as the products of "weak" presidents who allowed the United States and other Western countries to take advantage of post-Soviet Russia's weakness and desire for reconciliation with the West.

The paper also considers possible explanations for Russian noncompliance with the INF Treaty, including financial and strategic advantages in developing and testing intermediate-range ground-launched cruise missiles (GLCMs). Above all, the platforms for GLCMs are much cheaper and more survivable than the ships and aircraft that could be used to deliver sea- and air-launched cruise missiles; and the defenses of the United States and the other NATO Allies against cruise missiles are rudimentary at best.

The paper next examines the prospects for Russia's acknowledgment of its violation and return to compliance with the INF Treaty. It concludes that these prospects are poor, in the light of (a) the history of Soviet and Russian behavior concerning cases of noncompliance with arms control agreements and (b) the prevailing political dynamics in Russia.

The paper then reviews possible U.S. responses to Russian violations of the INF Treaty.
The development of active defenses against intermediate-range cruise missiles would be costly and technically challenging but advantageous in light of the proliferation of cruise missiles among potential adversaries in addition to Russia.
The procurement of enhanced counterforce capabilities to neutralize intermediate-range ground-launched cruise missiles would also be expensive and technically demanding, given long-standing target acquisition problems; and such capabilities could present political and practical challenges in escalation control. As with improved active defenses, however, enhanced counterforce capabilities could be relevant and useful in non-Russian contingencies.

The concept of developing new U.S. "countervailing strike capabilities" as a possible response to intermediate-range Russian GLCMs has yet to be defined publicly with precision, but it could take various forms without violating the INF Treaty — for example, increasing the range and number of U.S. sea- and air-launched cruise missiles.
The idea of deploying U.S. non-strategic nuclear weapons to additional NATO nations in Europe has little support among the Allies, partly because it would be inconsistent with the 1997 NATO-Russia Founding Act and partly because of other political and cost considerations. The NATO Allies generally regard the sustainment and modernization of the Alliance's current nuclear posture, based primarily on the triad of U.S. strategic nuclear forces and complemented by U.S. B-61 gravity bombs and U.S. and allied dual capable aircraft in Europe, as the fundamental priority in the nuclear domain. The Allies support the pursuit of the B-61 life extension program and the renewal of the U.S. and Allied dual capable aircraft involved in the Alliance's nuclear-sharing arrangements.

The pursuit of a symmetrical U.S. response-in-kind to the Russian violation — for instance, developing and testing an intermediate-range GLCM or ground-launched ballistic missile — would delight the Russians, who have for years made clear their interest in terminating the INF Treaty. This approach might in public perceptions put most of the political blame and discredit

for ending this arms control regime on the shoulders of the United States, even if Washington protested accurately that Moscow had first broken with the INF Treaty. The idea that a U.S. initiative to develop and deploy ground-based intermediate-range missiles would enable the Alliance to repeat the experience with its double-track decision in the late 1970s and early 1980s — and thereby bring Russia back into compliance with the INF Treaty — overlooks the fundamental differences in the political circumstances in that period and the present.
A more imaginative approach would be to place pressure on the Russians via focused technology-denial programs. These programs could be targeted to limit Russia's capacity to obtain essential electronic components for the Global Navigation Satellite System (GLONASS) guidance system for intermediate-range cruise missiles.

Recommendations for Further Research
The armed conflict between Russia and Ukraine has highlighted the Kremlin's growing reliance on nuclear weapons as a practical instrument of national security. For the last several years, Russia has actively used elements of its strategic nuclear triad to send signals to the United States and other NATO members, as well as to Japan. Russia has also embarked on a massive modernization of its nuclear forces.

This proposed study will address the following questions: how likely will the Russians be to use nuclear weapons in a crisis? What do Russian policies and behavior imply for long-standing U.S. assumptions about the requirements for deterrence and escalation control? What should be the U.S. policy in response to these changes in the Russian force posture and conduct? What role should the U.S. Navy play in such a response? What policy revisions should the United States recommend to its NATO Allies and other security partners? To what extent should Alliance plans concerning air and ballistic missile defenses and other capabilities be revised in light of Russian behavior?

Responses to Chinese Naval Expansion into the Indian Ocean

Researchers: Dr. Michael Malley, Dr. Paul Kapur and Ryan Jacobs

Students: No Students participated in this research.

Project Summary
This project, which continues through 30 June 2016, was designed to study the responses of small and medium powers in the Indian Ocean region to a rise in Sino-Indian rivalry in that region. It builds on a previous project in which we examined India's response to increased Chinese naval activity in the Indian Ocean region. In this phase, we applied the same analytical framework that we used in the initial study, namely one drawn from the field of international relations in which a country's options range from "balancing" to "bandwagoning." Thus far, we have completed studies on Australia and Sri Lanka.

Background
China's ongoing economic expansion has facilitated growth in Chinese military power, including an increase in Chinese Navy (PLAN) capabilities. These capabilities and Chinese soft power will enable China to expand its reach across the Asia-Pacific and into the Indian Ocean region (IOR). This is likely to lead to rivalry with India, which aims to achieve some form of maritime dominance in the IOR. Smaller states in the region will face a complex set of choices about whether to balance with one power against another; whether to seek partners from outside the region to balance against India and China; and whether to bandwagon with one or both of these Asian powers.

Experts are divided over the choices that these countries will make. Some predict that the opportunities for joint economic gains between China and states in the IOR, as well as the high cost of competition and conflict with an increasingly powerful and assertive China, will create strong incentives for smaller states to cooperate with China. In such a cooperative scenario, states may not simply strike economic deals with China—they may bandwagon more broadly with the Chinese, acquiescing in the rules, institutions, and military arrangements favored by Beijing for management of the IOR. Other analysts expect that these states will view an increased Chinese regional presence as more of a threat than an opportunity. In response, they will likely take steps to balance against the potential dangers of Chinese power, including such measures as arms racing and regional and extra-regional alliance seeking with India and others.

The first phase of this study focused on India's expected reaction to PLAN encroachment into the IOR. It used an analytical framework that divided India's options between balancing and bandwagoning—with regard not just to China, but also to the United States, or a U.S.-led coalition, which is likely to be the other major player in the IO region. In this phase of the study, the same framework is being applied to small and medium powers in the Indian Ocean region, mainly Sri Lanka and Australia. Because of their strategic locations, these states are important to any assessment of the regional security environment.

Findings and Conclusions (to include Process)
So far, this project has produced two For Official Use Only (FOUO) reports, one on Australia and the other on Sri Lanka. Since the project remains underway, its findings remain tentative. However these findings can be summarized with respect to both countries.

Like India, Australia views China's rising power in the IOR as a multifaceted challenge, not just to its own security but also to the liberal political and economic order on which regional peace and prosperity has rested. In response to this challenge, Australia is much more inclined to balance with a U.S.-led coalition rather than bandwagon with China. However, there is growing uncertainty in Australia about American willingness and ability to underwrite this sort of coalition over the long run. As a result, Australia will continue to pursue a policy of "strategic diversity," which emphasizes closer cooperation not just with the United States, but with other regional countries – including China, whose economy is crucial to Australia's own economic growth.
In contrast to India and Australia, Sri Lanka lacks a coherent, long-term strategic vision

regarding the Indian Ocean region. Its leaders are less concerned with geopolitical alignments and regional security architectures than with post-conflict redevelopment, economic growth, and domestic political survival. Leaders are willing to accept Indian assistance, but are warier of Indian intentions than Chinese. In the past, they have sought to balance against India, but have never managed to break free from its orbit. They have not sought to balance against China. The United States does not figure prominently in Sri Lankan strategic thought and is not seen as a reliable long-term partner.

Recommendations for Further Research

Follow-on studies would examine additional countries and their responses to the same dynamics of Sino-Indian rivalry. In particular, those that occupy locations between the Indian and Pacific Oceans, such as Malaysia and Indonesia, would be crucial cases since they face China on one side and India on the other and hence are likely to face pressures from both of Asia's rising powers. Myanmar and Thailand present similar challenges. Although Myanmar does not touch the Pacific Ocean, it is located between India and China and is accustomed to dealing with pressures from both of its large neighbors. Thailand does not share any borders with China, but has a sea border with India. Recently, Myanmar and Thailand have experienced significant political changes, which have reshaped their foreign policies and their vulnerability to Sino-Indian rivalry. Apart from additional country-focused studies, it would also be useful to examine the implications of the first two sets of findings for the U.S. policy of rebalancing to the Indo-Asia-Pacific region.

N4: Material Readiness & Logistics

CAD Interoperability for Navy Reuse in X3d Printing, Maintenance and Training

Researchers: Dr. Amela Sadagic and Dr. Don Brutzman

Student: LT Matthew Friedell USMC and Mr. Bernardo Michael Luhrs CIV

Project Summary

Additive Manufacturing (AM), three-dimensional (3D) printing and computer-aided design (CAD) export are critical for Navy maintenance. Rapid change continues to occur across the design, engineering, manufacturing, and production processes - many products can now be fabricated using AM methods. Iterative design processes require close collaboration of all entities involved from design to production; with AM, the lines between these previously stovepipe steps become blurred. A need to design, test and adopt different maintenance workflow becomes a necessity in cases of preventive and corrective maintenance of mechanical components on Navy ships and aircrafts where such operations have major impact on operational readiness. This project proposes to study and test elements that are identified as critical for effective deployment of AM in Navy operations, with specific emphasis on maintenance operations, while remaining sensitive to other Navy domains and activities where the use of AM could bring significant value. Our overarching goal is to provide a comprehensive approach that would lead towards reduction of energy costs, as well as reduction of materials and human resources engaged in that process.

Background

Preventive and corrective maintenance of mechanical components on Navy ships and aircrafts is a complex task that can have major impacts on operational readiness. In situation when a component needs to be delivered to a remote team (an off shore installation or ship), the final cost of transit and delivery can be further exacerbated if newly received component is confirmed not to be adequate, leading to a new iteration of physical delivery. This results in extreme and unplanned costs of the overall mission, and a new mode of operation that leverages additive manufacturing has a promise of much needed change in this domain.

Findings and Conclusions (to include Process)
Our team completed following activities:

1. Initiated research of domain literature, companies with businesses directed towards AM domain, forums, groups and events organized for both academia and practitioners.
2. Acquired more comprehensive understanding about current practices, constraints, and options available to the units in maintenance domain. This included technology market research (special emphasis: 3D printers and 3D scanners), and domain survey.
3. Initiated the effort of cataloging the use of AM within NPS, and identified the colleagues and research efforts that have been using AM capabilities. Begun establishing NPS portal forum for AM.
4. Conducted a series of consultation sessions with the office of Topic Sponsor, Space and Naval Warfare Systems Command (SPAWAR), Naval Facilities Engineering Command (NAVFAC), NPS Center for Asymmetric Warfare.
5. Executed field trips to Port Hueneme, CA (collaboration with NAVFAC); SPAWAR, San Diego, CA; USS BOXER, San Diego, CA; and USCGC HAWKSBILL, Monterey, CA.
6. Established active collaboration with Joint Advanced Manufacturing Region (JAMR) SW.
7. Participated in Web3D 2015 conference: presented conference workshop, two papers and a poster.
8. Conducted market research for both 3D printers and 3D scanners capable of supporting projected laboratory and field testing of maintenance workflow.
9. Acquired project infrastructure: two 3D printers (Replicator and Replicator Z18 by MakerBot), 3D optical scanner (DPI-8 by Dot Product), and software packages (NuGraf base package and Dual-CAD-Granite/Pack by Okino).
10. Built a laboratory setup that used newly acquired project infrastructure. Conducted a small-scale feasibility and usability assessment, and evaluated the fitness of proposed workflow for the real-world conditions and deployment. The quality of current commercial off the shelf (COTS) solutions for 3D scanning is still not sufficient to support scanning of fine object features, but it is sufficient to support scanning of larger objects and rooms. Our research suggests that new (better) 3D solutions are becoming available and more superior product are to be expected to reach a product line.
11. Participated in extensible 3D (X3D) CAD Working Group: Collaborated on technical report for the International Standards Organization (ISO) titled “CAD-toX3D Conversion for Product Structure, Geometry Representation and Metadata.”

Recommendations for Further Research
Future work should include (1) continued review of ever growing literature and AM products, (2) study of potential Navy-wide contract requirements for new deliverables (Intellectual Property rights, 3D watermarking, digital threat), (3) empirical research: survey of user base focused on user attitudes, current practices, value system, including conditions that may positively or adversely influence adoption of AM in Navy domain; (4) continued engagement in X3D-related committees and development of supporting software infrastructure. Select activities are designed to include student thesis research.

Developing a Paradigm for High Energy Density Capacitive Energy Storage

Researcher: Dr. Jonathan Phillips

Students: LCDR Jonathan Gandy USN and LT Natalie Jenkins USN

Project Summary
Demonstrated the existence of a new class of materials, Tube-Super Dielectric Materials (TSDM), with highest dielectric constants ever measured. Employed this novel dielectric material to create capacitors with the highest energy densities ever reported, >400 J/cm^3. The potential to enable weapon systems such as the rail gun and advanced lasers was explored, and the science of all types of superdielectric materials was advanced. Two student MS theses (LCDR Jonathan Gandy and LT Natalie Jenkins), two journal publications, one presentation at an international conference and one patent were generated based on work conducted.

Background
The Fiscal Year (FY) 15 NRP supported research was part of an ongoing program of study focused on novel dielectric materials, so-called super dielectric materials (SDM), invented by the PI while working at NPS. Program Justification: An 'all electric navy', rail guns, high energy lasers, etc. requires higher energy density capacitors than those that presently exist. Work conducted over the past two years suggests SDM based capacitors may be a viable, enabling, technology, justifying additional study.

SDM are a class of simple, inexpensive materials. It is postulated SDM comprise any solid electrically insulating material filled with a liquid containing dissolved ionic species, such as high surface area silica (e.g. beach sand) filled with salt water. The underlying principle: Porous electrically insulating solids in which the pores are filled with liquids containing an ionic species (such as water with dissolved salt) will have very high dielectric values by virtue of the separation of ions in the liquid phase, that upon the application of an electric field form giant dipoles, and concomitantly unprecedented dielectric values.
In the first years of the program (FY 2013/14) it was demonstrated high surface area, high

porosity powders, particularly alumina, filled with aqueous salt solutions (boric acid or NaCl) have dielectric constants of order 10^9, approximately six orders of magnitude higher than any previously studied dielectric. In FY 2015 work continued on the original class of SDM, that is 'powder' SDM (P-SDM), and a second type of SDM based on anodized titanium foils, so-called 'tube' SDM (T-SDM) were introduced. T-SDM are created by filling the tightly packed layer of nano-scale hollow tubes that form when certain metals, particularly titanium, are anodized with a liquid containing dissolved ionic species.

Findings and Conclusions (to include Process)

Studies of both P-SDM and T-SDM were conducted in FY 2015. P-SDM studies demonstrated that silica based P-SDM generally have higher dielectric values than alumina based P-SDM. In particular, fumed silica dielectrics filled with aqueous solutions of either NaCl or NH_4Cl had dielectric constants at low frequency of order 10^{11} vs. 10^9 for alumina.

TSDM created from anodizing titanium metal filled with aqueous solutions of either NaCl or $NaNO_3$ were found to have dielectric values that increased with tube length (3 micron to 27 micron) from 10^8 to 10^{12}. The highest energy densities measured, >400 J/cm^3 are more about an order of magnitude better than the best commercial capacitors, and better than the best reported prototype high energy density 'supercapacitors'. A new mathematical model was introduced that was predictive of TSDM behavior, including energy density independent of tube length.

It was concluded that the dielectric and energy density values discovered with the early generation of SDM demonstrate the validity of the SDM hypothesis, and suggest even better values will emerge in the future.

Recommendations for Further Research

Future work should include determining the dielectric, energy density, and power behavior of capacitors based on all types of SDM. Recently a modern galvanostat, an instrument required for studying the impact of frequency of dielectric behavior was purchased for our use. In addition, the impact of various parameters, such as the use of electrolytes with high breakdown voltage, the addition of metal particles, the use of other anodized metals, thinner layers, should be explored in a search for yet higher energy density capacitors based on SDM. The key equivalent circuit parameters of internal resistance and output resistance should be determined. The durability/corrosion should be studied.

Energy Management Systems to Reduce Electrical Energy Consumption

Researcher: Dr. Alexander L. Julian

Student: LCDR Matthew McCulley, USN

Project Summary

An energy management system comprises an electrical energy storage element such as a battery, renewable electrical energy sources such as solar and wind, a digital signal processing controller and a solid state power converter to interface the elements together. This hardware demonstration in the lab at the Naval Postgraduate School will focus on solid state power conversion methods to improve the reliability and efficiency of electrical energy consumption by Navy facilities. This is accomplished by peak power shaving, power factor compensation and online standby redundancy. Harvesting renewable energy, especially solar power, will also be investigated.

Background

Energy savings and energy efficiency have become top priorities all around the world, stimulated by the Kyoto protocol and other pressing needs to reduce fossil fuel consumption. In particular, in the United States, the Department of the Navy (DON) has listed its shore energy goals to include a 50% 'ashore energy' consumption reduction by 2020 (OPNAVINST 4100.5E). Additionally, energy security is a necessity for all DON installations. Shore energy security for the U.S. Navy is "the mitigation of vulnerabilities related to the electrical grid, including outages from natural disaster, accident and physical and cyber attack" (OPNAVINST 4100.5E). Therefore reducing energy consumption must be accomplished while keeping critical electrical loads serviced at all times.

Findings and Conclusions (to include Process)

The physical layer has been assembled and is being debugged. Several debugging milestones have been achieved. The analog-to-digital (A/D) converters have been calibrated. The digital data acquisition system has been expanded to record four channels of data simultaneously. The overcurrent protection features of the integrated circuits have been tested. Islanding mode to improve electric power reliability has also been demonstrated in the lab.

Recommendations for Further Research

Further research can focus on hybrid energy storage, such as supercapacitors in addition to batteries, so that peak power demands are not serviced by the batteries alone. Alternative control strategies to improve the output power quality, such as a repetitive controller, can also be explored. The detection of power disturbances and the response by islanding the system is another focus for further work.

Energy Management Systems to Reduce Electrical Energy Consumption - Analysis

Researcher: Dr. Giovanna Oriti

Students: No students participated in this research project.

Project Summary

This project investigates the use of a power electronics based energy management system to reduce electrical energy consumption on Navy facilities. This goal is accomplished by peak power shaving, power factor compensation, and an interface with batteries. Harvesting renewable energy, especially solar power, was also investigated. Modeling, simulations, and analysis were used in this investigation. The results of this project will be used in the classroom to support a new energy course in the Naval Postgraduate School (NPS) Electrical Engineering curriculum.

Background

The Navy is looking for means and technologies to reduce electrical energy consumption on its installations and increase energy security (OPNAVINST 4100.5E). A power electronic based energy management system (EMS) provides a reliable and effective interface between an existing electrical power system and renewable energy sources as well as energy storage systems (Oriti, Julian, & Peck, 2016); (Kelly, Oriti, & Julian, 2013). Ongoing research at the NPS has led to the design of a single phase EMS which can greatly improve an electrical power system by:

- Power metering
- Peak power control
- Active and reactive power flow
- Load, sources and storage management
- Power quality, reliability and fault management

EMS technology has two main components, solid state power converters to interface distributed generation and several control algorithms to manage the power flow. A bidirectional H-bridge inverter can operate as a current source to supply additional power to the loads when the microgrid is connected to the main grid. It can also be controlled as a voltage source in islanding mode when the main alternating current (AC) grid is disconnected.

Findings and Conclusions (to include Process)

This project analyzed a scenario in which a Navy electrical power system can be made more efficient by introducing an EMS. An EMS includes bidirectional power converters to interface with the energy storage systems, a bidirectional inverter to interface with the AC loads and unidirectional power converters to interface with photovoltaic panels. It also includes embedded electronics where several control algorithms are implemented. The EMS is connected to photovoltaic (PV) modules and batteries so that critical loads can be powered even in the absence of the AC power grid. In fact the EMS monitors the power flow and matches the load power demand to the available power. Mission critical loads are powered at all times, even when the AC grid is not available, therefore ensuring energy security to the power system.

This project demonstrated in simulations the functionality of an EMS. A physics based model of the power system with an EMS was developed and implemented using the Matlab/Simulink software. The simulated results show that the EMS operates the power system as a microgrid when the AC grid is not available and it helps reduce the electricity charges by implementing peak power savings when the AC grid is available. A cost analysis demonstrates the latter feature of the EMS. A full report was submitted electronically to the sponsor in September 2015.

Recommendations for Further Research

Future work should analyze the impact of the PV panels on the overall cost of electricity. The power system can also include backup generators for either military installations or mobile military camps where the EMS can help reduce fuel consumption.

Graphitic Oxide and Graphene as Enhancers for Energetic Mixtures

Researchers: Dr. Claudia Luhrs, Dr. Sarath Menon and Nicholas Vilardi

Students: LT Benjamin Carroll USN

Project Summary

The aim of this project was to study the effects of using graphene (G) and graphitic oxide (GO) as additives in energetic reactions. The thermite oxidative reaction was selected as the initial reaction to test. The rationale behind the use of GO and G as additives originates from the fact that GO has the ability to release its oxygen groups when heated at low temperatures and graphene burns off generating volatile species at moderate temperatures. GO or G were added to thermite mixtures and heated to promote the aluminum oxidation in the presence and absence of iron oxide, in inert, and oxygen containing atmospheres. The changes in mass were

recorded using thermogravimetric analysis while the heat flows involved were determined by calorimetry. A mass spectrometer analyzed the evolved gases. The solid crystalline precursors and byproducts were identified using x-ray diffraction techniques and their microstructural characteristics and identity studied using microscopy and spectroscopy. Evidenced by the byproducts generated, the thermogravimetric/calorimetric study of the processes and the microstructures observed, the addition of GO or G to aluminum accelerates the oxidation reaction. A mechanism for the different oxidation steps when additives are used was proposed. In addition to the thermite reaction, GO and G were also used as additives in the combustion of propellant mixtures. Testing was conducted to determine changes in visible smoke and flame distance from the propellant during burn.

Background

The United States Navy has ambitious goals for reducing energy consumption in the coming years. To achieve the desired goals will require a multi-faceted approach, which will necessarily include improvements in energy efficiency. This provided the motivation for this research, the purpose of which was to study the effects of adding graphitic oxide (GO) and graphene (G) to materials known to experience exothermic reactions during heating. The question to be answered: Could these materials enhance the exothermic reactions, either by making them more exothermic, or by inducing reactions at lower temperatures? A positive response will justify the future use of the additives in other fuel mixtures.

The primary means of conducting this analysis was through experimental research: mixing of graphitic oxide and graphene with materials known to react exothermically. Thermite mixtures of aluminum and iron oxide were selected as the first type of energetic reaction to test and the study focused on analyzing their energy changes through calorimetry. Complete characterization of the materials microstructure and composition both prior to and after heating (including byproducts) was also conducted to ensure a complete understanding of the observed mechanisms.

A secondary means of conducting this analysis was through the mixing of graphitic oxide with a known propellant. In this case, the purpose was a test of practicality and feasibility. Characterization of the propellant was also conducted, though not to the same level of detail as with the thermite mixtures.

Findings and Conclusions (to include Process)

The following are the conclusions and milestones that resulted from the research conducted during the process of completing this project. There were numerous milestones achieved and lessons taken away from the research conducted to determine the advantages of utilizing GO or graphene as additives in combustible mixtures. The most significant are summarized below.

Graphite oxide (GO) and graphene (G) were successfully prepared. The former was generated from graphite flakes treated in a controlled highly oxidant environment. The latter was produced when GO was treated thermally at 1000°C.

The samples weight changes and heat flows of the process were studied *in situ,* employing a simultaneous Thermogravimetric analysis/differential scanning calorimetry (TGA/DSC)

apparatus while being heated from room temperature to 1050°C (thermite) or 900°C (propellant). The evolved gases from the processes were identified by mass spectrometry. All the solid precursors and byproducts microstructural and crystalline features were identified by the use of electron microscopy and x-ray diffraction techniques.

The hypotheses proposed at the beginning of this research were tested; both graphitic oxide and graphene could be used as additives to enhance the thermite reaction studied. Graphene presents a much higher improvement in terms of the heat flow achieved when compared to graphitic oxide when enough oxygen is contained in the process atmosphere.

The makeup of GO, approximately 50 percent carbon and 50 percent oxygen groups attached to its surface, increases the amount of oxygen in the reaction crucible through the release of the oxygen groups at temperatures close to 200°C. However, since the temperature of oxygen release happens at much lower temperatures than the one at which aluminum melts (660°C), only a slight amount of oxygen coming from GO gets to interact with the aluminum particulates. In contrast, graphene does not have the ability to free oxygen at low temperatures, but instead burns off in oxygen containing atmospheres to produce CO_2 in a rapid process that promotes the swift release of gases. The interaction of the latter with the melting aluminum removes the thin layer of aluminum oxide already present on the aluminum particles surface, exposing unreacted aluminum and increasing its oxidation rate. In contrast, when the process is carried out in inert atmosphere instead of an oxygen containing one, GO tends to lose the oxygen group to form graphene at low temperature and the remnant graphene reacts with aluminum to form the corresponding carbides.
In air environments, or those including at least 20 percent oxygen, graphene, due to its high thermal conductivity in conjunction with its high surface area (close to 600 m^2/g) and geometry, seems to be a great prospect for improving exothermic reactions.

The most significant finding was the mechanism by which, in the thermite mixtures studied in oxygen, the effect of the additive was to release gases that promote the bursting of aluminum shells, exposing more Al surface area and increasing the oxidation rate. The purpose of the thermite reaction is the rapid oxidation of one metal, due to the rapid reduction of another material. This project demonstrated, unequivocally, that the additives employed could enhance the existing mixtures, or even possibly serve as substitutes of the reduction agent. Moreover, the use of GO and G do not have a downside from the environmental point of view since they burn off completely without generating solid byproducts.

Recommendations for Further Research
Further study of systems such as F76 diesel fuel or biofuel is recommended. Based on the thermite reaction outcomes presented herein, the use of graphene instead of GO could prove advantageous.

Study of Graphite Oxide and Graphene as Enhancers for NATO F-76 and Biofuel

Researchers: Claudia Luhrs and Douglas Seivwright
Students: LT Benjamin Carroll USN

Project Summary

The aim of this project was to test the performance of Graphite Oxide (GO) and Graphene (G) as fuel additives. Both compounds are variations of the honeycomb structure found in graphite but possess higher surface areas and different amount of oxygen functional groups. The use of Graphite Oxide was considered due to its ability to release the oxygen species at moderate temperatures, while Graphene could be readily dispersed and completely burned off during the combustion process.

Graphite oxide was fabricated by chemical routes and graphene by thermal exfoliation. X-ray powder diffraction was used to characterize the crystal structure of the initial powders and the particulate sizes were studied by scanning electron microscopy.
The additives were mixed with North Atlantic Treaty Organization (NATO) F-76 diesel fuel in 0.1 to 3 % wt ratios and with 0.01 % wt of biofuel. The mixtures were then analyzed by differential scanning calorimetry and thermogravimetry to determine heat flows and mass changes as the samples were heated, then compared with bare F-76 or bare biofuel. The evolved gases from all the processes were identified by mass spectroscopy.

The fuel-additive mixtures were tested in a diesel engine to determine ignition delays and the cetane numbers for each composition are reported.

Background

During 2009 the Secretary of the Navy (SECNAV), set forth five Department of the Navy (DON) energy goals to be reached by the year 2020; the goals aim to reduce the DON's environmental fingerprint and increase its energy independence (The Department of the Navy's Energy Goals, 2015):

- Energy Efficient Acquisition: Evaluation of energy factors will be mandatory when awarding contracts for systems and buildings.
- Sail the "Great Green Fleet" (2015): DON will demonstrate a Green Strike Group capable of using advanced biofuel blends, nuclear power, and employing energy saving methods in local operations by 2012 and sail it by 2016.
- Reduce Non-Tactical Petroleum Use: By 2015, DON will reduce petroleum use in the commercial fleet by 50%.

Increase Alternative Energy Ashore: By 2020, DON will produce at least 50 % of shore-based energy requirements from alternative sources. These include, but not limited to, sources such as wind, solar, geothermal, wave energy, tidal currents, nuclear energy, and biofuels derived

from algae, camelina, and other feedstocks (Department of the Navy's Energy Program for Security and Independence , 2015).

- Increase Alternative Energy Use DON-Wide: By 2020, 50% of total DON energy consumption will come from alternative sources (see previous bullet).

Regarding the production and use of "alternative sources" stated in the last two energy goal bullets previously mentioned; such alternative sources "must be 'drop in' replacements, able to mix with traditional petroleum products with no adverse effects to the fuel quality." Furthermore, the DON mandates alternatives have lower lifecycle greenhouse gas emissions than conventional petroleum-based fuels. These requirements added to the motivation to study GO and G as drop-in additives to F-76.

While the SECNAV mandates that alternative sources must be drop-in replacements, there are considerations that the DON must overcome in order to transition into a more energy efficient entity amongst petroleum users in the world. Among these considerations include technology maturity, resource availability, and alternative fuel availability. As technology matures, the DON must leverage leading-edge advances in technology and deploy them in the tactical and shore arenas (Department of the Navy's Energy Program for Security and Independence , 2015).

Thus far, research into alternatives has included the Green Hornet flight (Department of the Navy's Energy Program for Security and Independence , 2015); (Navy Tests Biofuel-Powered Green Hornet, 2010) the Great Green Fleet demonstration (Great Green Fleet., 2015) and studies involving additives in thermite mixtures (Vilardi, 2010) among others. Earth Day 2010 marked a significant milestone in fuel alternative studies as the DON successfully launched an F/A-18 Super Hornet using a 50/50 blend of conventional jet fuel and a biofuel derived from camelina (a hardly U.S.-grown plant that can thrive in the harshest of soils). The 50/50 blend made absolutely no difference in performance of the fighter, which displayed its capabilities at speeds including supersonic. During the July 2012 Pacific Rim exercise, the largest international maritime warfare exercise, United States' participants, which included an aircraft carrier and its air wing, a cruiser, two destroyers, and an oiler, (nicknamed the 2012 Great Green Fleet), demonstrated successful performance of drop-in replacement advanced biofuel blend (50/50 blends made from algae mixed with petroleum: HRD-76 and HRJ-5) and other energy efficient technologies in an operational setting. All systems met operational tempo requirements.

Lastly, the Mechanical Engineering Department at the Naval Postgraduate School (NPS) has researched drop-in additives (graphite oxide (GO) and graphene (G)) in solid propellants to study thermite reactions. Conclusions from research showed significant increases in exothermic reactions when compared to the solid propellants without the additives (Vilardi, 2010).

The next step is to consider these two additives in fuels used by the DON.

Findings and Conclusions (to include Process)

Graphite oxide (GO) and graphene (G) were successfully prepared in the laboratory. GO was synthesized by oxidation of graphite, while G was prepared using thermal exfoliation of GO. X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM) techniques were employed to verify their crystalline structures and their particle size and distribution, respectively. Calorimetric characteristics were studied using a Differential Scanning Calorimeter (DSC) while

their mass reduction was determined using an-Thermogravimetric Analyzer (TGA) as these parameters were exposed to slow burning-rates in an air environment. Evolved gases from the TGA/DSC experiments were analyzed using a Mass Spectrometer (MS).

Using NATO F-76 diesel fuel as the basis fuel, GO and G additives were mixed with the fuel in quantities from 0.1 wt% up to 3.0 wt%. For comparison with F-76 neat, their thermal behavior was also studied using DSC, TGA and MS. It was found that in all GO-mixed fuels (0.1, 1, 2 and 3%), energy output during combustion at slow burn-rates improved over that of F-76. For the G-mixed fuels the results were less consistent, showing improved energy output only for samples with additives in 0.1 and 2%. TGA for all mixtures showed a complete weight loss in a single step for all samples. The MS analysis showed that the mass loss observed was related to water and carbon dioxide. Conclusions from these studies indicate that 0.1wt% GO and G mixtures should be studied further in practical combustive reaction settings and compared to F-76. Those samples contain the minimum amount of additive but still showed an increase in the heat flows measured when compared to legacy fuel.

Preparation of 1.5-liter quantities of 0.1wt% GO/F-76, 0.1wt% G/F-76 mixtures, and F-76 neat were done to conduct analysis of cetane number, gross heat value, and net heat of combustion. Through a high burn-rate process, data showed there was no conclusive evidence of changes in any of these parameters against F-76.

Studies were also conducted on biofuel, Hydrogenation-Derived Renewable Diesel (HRD) with only 0.01 wt% of GO and G as additives; results showed that Graphene has the potential to increase the cetane number of mixtures.

The F-76 GO and G mixtures' performance were also studied in a practical setting, namely, using a Detroit 3-53 marine diesel engine. Of note, it was found that the fuel/water separator on the engine was separating an unknown amount of the additives from the fuel/additive mixtures, when pumped from the sample mixture tank, though the fuel in the engine's gravimetric measurement holding tank still contained some additive. Parameters measured included: cylinder pressure, start of injection (SOI), maximum rate of release (MRR), oxygen content (lambda value) of exhaust gases, heat of release relating to energy output, and ignition delay. Findings:

- Slight increases in peak pressure (PP) for both GO-mixed and G-mixed fuels over F-76, relating to the possibility of higher heat releases, while the angle of peak pressure (AOP) changes were minimal.
- Decreased MRR for both GO-mixed and G-mixed fuel over F-76, relating to more complete combustion cycles and decreasing the likelihood of engine knocking.
- Consistent SOI points around 14° before Top Dead Center (TDC) and consistent strain inside the cylinders for the enhanced fuels and F-76, relating to decreased likelihood of injection problems and thermal damage inside the cylinders.
- There were no differences found in the heat of releases or start of combustion points for either of the additive mixtures against F-76 at either 1100 or 1700 revolutions per minute (RPM).

- Decreased lambda values for both GO-mixed and G-mixed fuels over F-76 when compared at the same speeds and torques, and decreased lambda values as speed and torque increased overall. This relates the possibility of more complete combustion inside the cylinders.
- As there were no differences in heat of release or SOC, the ignition delay for both additive mixtures were similar to that of F-76.

Recommendations for Further Research
Future work is recommended in two areas. The first is with the experimental setup. We had issues with the GO and G separating in the fuel/water separator. An evaluation of the diesel engine setup should be done to determine a more appropriate method of fuel injection to fully evaluate the potential of using these additives.

Second, the quantity of the fuel samples in which this study used was minimalistic. Larger quantities (gallons) should be created in order to obtain many cycles of data in the diesel engine to further develop data, which could better represent the potential of these additives. The use of grater graphene additive weight percentages in biofuel mixtures is recommended for future research, given that the small (0.01) wt% used in the present study showed an increase in cetane number.

Aircraft Carrier Group (CVN) Speed of Advance Project

Researchers: Alan Howard

Student: LCDR Warren Blackburn

Project Summary
As a means to improve the operational capability of the Aircraft Carrier Group or CVN's escorts, in this project, we study factors that could increase carrier strike groups (CSGs) efficiency conducting transits. We specifically analyze implementation of the Transit Fuel Planner (TFP) and transit speed limits. Increasing transit fuel efficiency enables additional hours on station, which could improve operational range and effectiveness. Based on our interviews with Surface Warfare Officers (SWOs), we also look into CSG operations because their input reveals the potential for substantial fuel savings in this area with minimal changes.

Background
During transits the CVN sets the speed for the group with no regard for the efficiency of its escorts. During CSG operations, excessive fuel use is caused by guided missile cruiser (CG) and guided-missile destroyer (DDG) escorts tending to run full plant (all engines online) at all times in order to have maximum responsiveness in case the CVN accelerates suddenly. By altering these practices, it is possible to improve the fuel efficiency of the escorts and increase time on station.

Findings and Conclusions (to include Process)
We model transits and CSG operations through utilizing the Fuel Usage Study Extended Demonstration (FUSED) program, which has been developed at the Energy Academic Group at NPS. We incorporate different cases enforcing maximum transit speeds and specified times allotted to catch up with the front of the Plan of Intended Movement (PIM) window. We compare these cases with transits that use the TFP, which can accomplish efficient transits by alternating speeds and utilizing the most efficient engine configurations. The comparison suggests that the use of TFP saves many hours on station with respect to total transit time when compared to a case that has a high maximum transit speed and a small catchup to PIM window time.

To measure the potential fuel savings during CSG operations, we model a scenario where the escorts use trail shaft and split plant engine configurations when possible, and compare it to models where the escorts are constrained to only using full plant. Comparing the models' results suggests that by using an optimal engine configuration, CGs and DDGs would be able to spend between 18 and 98 percent more time conducting operations before needing to refuel, depending on operational conditions. Due to these results, we highly recommend that CGs and DDGs utilize an optimal engine configuration when accompanying a CVN on flight operations, or at least alternate between full plant and split shaft.

Recommendations for Further Research
In order to facilitate the use of trail shaft and split plant during CSG operations, we recommend research into establishing a set of policies and practices that would allow this change without potentially hindering operations. We also recommend limited trials of using the TFP on well-known transits to gauge its effects.

Removal of the Plan of Intended Movement (PIM) Moving Window

Researchers: Alan Howard

Students: LCDR Warren Blackburn

Project Summary
This project compares the fuel consumption of transits constrained by the Plan of Intended Movement (PIM) window against transits where the window wasn't enforced. We also compare fuel consumption under enforcement of PIM window scenarios and when the Transit Fuel Planner (TFP) is used. The TFP is a tool that shows how many hours a ship should spend at which speeds in order to travel a given distance in a set time using the least amount of fuel. To determine fuel consumption under different constraints, we model the transits using the Fuel Usage Study Extended Demonstration (FUSED) tool. FUSED is an Excel/VBA-based tool that allows users to model the effects of different policies and actions on carrier strike groups or groups of cruisers and destroyers.

Background

The Plan of Intended Movement (PIM) requires ships to stay within a four-hour window so that search parties will know approximately where to look in the event of loss of contact. To accommodate the completion of drills during transits, ships will often move between the low speeds required for their drills and high speeds to return to their desired position within the window. This causes groups to use their fuel inefficiently as a ship's fuel consumption increases exponentially with increased speed.

Findings and Conclusions (to include Process)

We observe that the PIM window creates incentive for captains to transit in an inefficient manner. Captains like to stay at the leading edge of the PIM window because unexpected events like mechanical breakdowns can cause them to fall out of their window. When a group completes a drill that requires low speeds, most captains will then rush to return to the front of the window quickly instead of moving at a lower speed for a longer time. Some captains recognize this and will travel at the slower speeds, but they seem to be the minority. Using the TFP prevents inefficient fuel usage by dictating the speed and can be used regardless of whether or not the moving window is enforced. For example, in a transit of 3262 nautical miles with a PIM window speed of 15 knots and 20% of time spent on drills[1], a cruiser using TFP uses 23% less fuel, or enough to allow an extra 69 hours on station, when compared to a cruiser whose captain rushes to the front of the window as quickly as possible after drills.

Recommendations for Further Research

We recommend the removal of the PIM window policy and the implementation of the Transit Fuel Planner. Using the TFP will force captains to travel efficiently but still allows them the freedom to conduct their drills. Removal of the PIM window allows captains more freedom for scheduling drills and allows longer drills that would otherwise conflict with the window. We recommend implementing these changes on a well-known transit in order to test our findings in the field and then consider further implementation.

[1] Engineering drills at 5kts in blocks of 4 hours, 2000kW generator output

Fleet Training Fuel Efficiency Metrics & Cost Benefit of Conus Hot Fuel Pit Sites

Researchers: Dr. Robert Eger, PI Dr. Tom Albright and Dr. Stephen Hansen

Students: LCDR Brian Blaydes USN, LCDR Eric Bondurant USN, LCDR Matthew Clark USN, LT Luke Donahue USN, LT Luke Farrell USN, LCDR Daniel Rosborough USN and LCDR George Zintac USN

Project Summary
The U.S. Navy Aviation Energy Conservation (Air ENCON) Program is designed to optimize fuel consumption without adverse implications on either mission objectives or safety. By analyzing historical flight data, we develop fleet 'training efficiency' metrics that link squadron fuel consumption to operational Training & Readiness (T&R) outcomes and pilot proficiency. After addressing efficiency metrics we offer a cost-benefit analysis (CBA) of hot pit locations in continental U.S. (CONUS).

Background
The current volatility of oil prices, the Navy's increasing use of petroleum, recent budgetary pressures, increased political pressures to reduce carbon emissions, and our nation's reliance on foreign sources of oil have all led to a renewed focus on reducing the Department of Defense's (DOD) energy usage.
The overall aim of our research is two-fold: (1) to develop alternative metrics for T&R that assess both consumable assets (fuel) and enhance pilot proficiency and (2) to assess hot pit locations in CONUS. In the development of alternative metrics for T&R within naval aviation units, we concentrate on two gross metrics:

1. Fuel consumption across various training mission areas
2. Fuel burn rates across various training mission areas

In the assessment of CONUS-based hot pit locations we rely on the current limited literature. Our background research focused on cost-benefit analysis for previous work performed on the issue of hot pit utilization. We supplemented this literature using government publications, such as the Naval Aviation Maintenance Program (4790 series) as well as the Office of Management and Budgeting Circular A-94.

Findings and Conclusions (to include Process)
Fuel consumption - and fuel burn rates across various training mission areas, offer insight into potential fuel saving areas within squadron shore-based unit-level training (ULT) missions. The fleet training fuel efficiency metrics are developed through statistical analysis of flight hours, fuel consumption, and mission type data from Sierra Hotel Aviation Report Program (SHARP) and Naval Aviation Logistics Command Information System (NALCOMIS), provided by Commander Naval Air Forces Pacific (CNAP) Flight Hour Manager and Air ENCON. These fleet training fuel efficiency metrics provide mission-specific baseline fuel consumption numbers for naval aviation units across several different training mission areas. These baseline fuel

consumption numbers can then be used by the fleet to compare fuel efficiency across various ULT missions and squadrons. Through these comparisons, it is possible to identify and act on areas of potential fuel savings without decreasing the quality of training accomplished by aircrew.

The resulting outcomes, with respect to developing fleet training efficiency metrics, indicate concerns with the availability of required data, accuracy of flight data recorded on stand-alone platforms and across naval aviation databases.

There are multiple issues to consider when considering the costs and benefits of hot refueling for both the East and West Coast F/A-18 communities. The major take away for both regions is that there is a tangible, although difficult to quantify, benefit to dropping live ordinance overland for training and proficiency reasons. In order to support that benefit, hot pit sites at Naval Air Station Jacksonville and Naval Air Weapons Station China Lake will need to be prepared and improved to handle more aircraft and increased training requirements safely and efficiently.

- Overall, the Pinecastle proposal stands to produce a total net benefit of $2,528,000 over the next 10 years.
- Overall, the China Lake proposal stands to produce a total net benefit of $232,028,000 over the next 10 years.

Recommendations for Further Research
We argue that if the Commander of Naval Air Forces (CNAF) and the Naval Acquisition Executive (NAE) can accurately determine, measure, track, and compare fuel consumption within naval aviation training missions, then achievement of DON energy goals by 2020 are improved.

N8: Integration of Capabilities & Resources

Developing Synthetic Theater Operations Research Model (STORM) Analytic Utility, Phase II

Researchers: Dr. Thomas Lucas, Dr. Susan Sanchez, Dr. Paul Sanchez, Mary McDonald and Steve Upton

Students: LT Christian Seymour USN and LT BJ Bickel USN

Project Summary
Office of the Chief of Naval Operations (OPNAV) N81 conducts analyses to inform senior leadership on decisions that could shape the U.S. Navy for decades to come. These analyses are exceedingly complex, involve numerous unknowns, and must adhere to strict study

timelines. To support these studies, OPNAV N81 regularly uses the modeling environment Synthetic Theater Operations Research Model (STORM). The objectives of this Phase II effort were to build on the STORM post processing analysis tools developed in Phase I, rigorously test the new capabilities, assist OPNAV N81 in applying them in their studies, and facilitate their use in the broader STORM community.

To enable STORM users to quickly obtain insights from a set of STORM replications, a software tool called STORMMiner was developed, refined, tested, and delivered to OPNAV N81. STORMMiner is a collection of unclassified, non-proprietary, government-owned R and scala scripts. STORMMiner presents to the user a number of analysis artifacts (tables, graphics, etc.) that more quickly and effectively bring the analyst to "insights." These insights may help illuminate "dark corners of the scenario" no analyst has yet seen or recognized, and thus help with quality control, debugging, and highlighting areas for additional scrutiny. These tools, in combination with new management constructs, have enabled OPNAV N81 analysts to complete their studies "approximately 33% faster and 16% less expensive" (Morgan, B. L., et al., 2016)

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 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 and strict study timelines. The primary goals of this effort were to extend, test, and apply prototype tools and processes developed in Phase I to (1) 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. Adding these capabilities requires developing STORM- and case-specific software to automate the post-processing of the output data. In addition, NPS researchers facilitated expanding the use of the new capabilities in the broader STORM community.

Findings and Conclusions (to include Process)

A primary focus for Phase II was enhancing analysts' ability to assess STORM command and control (C2) rules and conditions. Consequently, many of the new additions to STORMMiner involved techniques to visualize how and when key command and control decisions took place. Some of the new capabilities STORMMiner provides include:

- dynamic sample size requirement determination with early termination option;
- a “quick look” dashboard;
- time series plots, histograms, killer/victim scoreboards, and summary statistics and indication of outliers for losses and key metrics;
- unit and event execution graphs;
- cluster analysis to highlight common characteristics shared by bifurcated results (if present);
- campaign progression and event heatmaps that indicate the status of resources and campaign objectives over time and the location of casualty occurrences; and
- classification and regression trees (CART) that identify patterns in key outcomes as a function of scenario inputs and events.

STORMMiner can be instantiated on a desktop or laptop running the Linux operating system. It typically has a runtime of one to three hours, based on the number of key metrics selected for analysis and approximately 50GB of output. To facilitate the use of STORMMiner by analysts at OPNAV N81, NPS – Simulation Experiments Efficient Designs (SEED) Center researchers worked directly with members of N81’s analysis team. Moreover, a user’s manual for STORMMiner was developed and delivered (SEED Center, 2015).

Recommendations for Further Research

The prototype tools developed have already been used to support N81 studies. While the new capabilities have already proven themselves, much more is possible. In particular, the research so far has focused on identifying events and trends within a set of replications. For example, identifying which events and decisions are associated with winning outcomes. Much more could potentially be learned by designing experiments that look over a breadth of input combinations. Indeed, there have been dramatic developments in recent years in the ability to explore high-dimensional computational models. In addition, if given 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.

N9: WARFARE SYSTEMS

Representing Uncertainty of Hierarchical and Response Surface Models to Improve Design of Experiment

Researchers: Dr. Thomas Lucas, Dr. Susan Sanchez, Dr. Paul Sanchez, Mary McDonald and Steve Upton
Students: Lt. Russell Pav

Project Summary
The Office of the Chief of Naval Operations (OPNAV) uses a hierarchy of simulation models as part of scenario-based planning to help decide how the Navy should be equipped, organized, and employed. Simulation is used throughout the acquisition process, from platform design to force structure. In hierarchical combat modeling, the mean outputs of lower-level, higher-resolution models are typically used as inputs to higher-level, lower-resolution models. The objective of this process is to inform Navy leadership on how detailed design changes ultimately impact campaign effectiveness. Unfortunately, by ignoring variability in linkages between layers in the hierarchy, the results may bias campaign-level outcomes and/or dramatically understate the final variability (or risk) estimated by the campaign-level model. Consequently, the goal of this research was to design and run experiments to better understand the impacts on the hierarchical modeling process associated with error propagation methods and design of experiments techniques.

To empirically explore a host of different error propagation approaches, this research conducted thousands of experiments using a two model hierarchical structure in an Anti-Submarine Warfare (ASW) setting. The results indicate that the sampling methodology has a significant impact on the mean probability Blue wins the campaign, as well as the mean number of losses Blue takes when it wins. In addition, the sampling methodology has a significant effect on the standard deviation for the probability Blue wins and the amount of losses Blue expects to take when it wins. Moreover, different metamodels were developed using different design of experiment techniques. While this initial effort involves just a single set of experiments, the results suggest that hierarchical combat models should adopt methods that include the entire distribution of lower-level model outcomes in order to better represent risk. More research is needed to determine how best to accomplish this.

Background
The Navy uses families of models of varying detail to analyze forces and operational concepts. The information gleaned in these model-supported studies helps shape the composition of the future Navy and how it will fight. The current practice in the higher-to-lower-fidelity sequence of modeling is to use point estimates of more focused higher-fidelity model outputs as the inputs for the broader lower-fidelity models. It is vitally important to understand how these lower-level model errors are propagated through the series of models, and consequently how

decisions are affected. This research reviewed previous efforts related to propagating errors in hierarchical models and empirically explored the effects of multiple approaches. The research was guided by application to the ASW mission area.

Findings and Conclusions (to include Process)

This research explored how error propagates through hierarchical simulation models at the mission and campaign levels. First, we developed a mission-level model for one-on-one submarine duels using the Map Aware Non-Uniform Automata (MANA) agent-based software that facilitates explicitly modeling the different physical characteristics and behavioral postures of submarines. The outputs of the mission-level model are mean time to kill (MTTK) and the average probability each side wins. Variation in the outputs was obtained from two different designs of experiments, nearly orthogonal Latin hypercubes (NOLHs) and resolution V fractional factorials (R5FFs).

We also built a stochastic Lanchester campaign-level simulation involving 18 Blue and 25 Red submarines in a blockade of an island scenario. The attrition coefficients (i.e., inputs to the campaign-level simulation) were determined by the outputs of the mission-level MANA model. Many sampling approaches were used to account for the distributions of MANA output. The results demonstrate that the sampling methodology has a significant impact on the probability Blue wins the campaign and the amount of losses Blue takes when it wins. In addition, the sampling methodology has a significant effect on the standard deviation for the probability Blue wins and the amount of losses Blue expects to take when it wins (Pav, 2015). In summary, the reported risk changes significantly based upon the method used to link the models in the hierarchy.

In some situations, the error propagation occurs by making use of metamodels to quickly allow the estimation of model outputs at previously untried combinations of model inputs. In these cases, the results of the error propagation will also depend on the type of metamodel used. One form of metamodel that is often used for deterministic computer models is the Gaussian process (GP) metamodel, also called a kriging metamodel. It has the benefit that it fits all observations exactly, and is more flexible than low-order polynomial models in the types of surfaces it can capture well. Recent work has extended this technique to stochastic models. However, GP metamodels are not a panacea. In an investigation by Duan et al. (2016), it became apparent that different software packages produced different kriging results for the same data sets. In some cases these differences appeared substantial, and it was not immediately clear whether there was a one-to-one translation, or whether some of the software platforms were outperforming others. A comprehensive investigation is currently underway.

Recommendations for Further Research

The models employed in this research were developed to explore error propagation in hierarchical combat models. As such, they were much simpler than the models that are actually used. Nevertheless, they provided useful insight into the practice of hierarchical combat modeling. Constructing and examining other variants (e.g., land combat or air combat) may be useful in establishing the robustness of the initial sea combat findings. In addition,

numerous other experiments could be done exploring many other design of experiment approaches. Ultimately, these simple experiments should be repeated using the more complicated simulations actually used in OPNAV's studies.

Analysis of Pricing Models in the Defense Industry to Support Cost Projection

Researchers: Kyle Lin

Students: No students participated in this research project.

Project Summary
This study aims to develop a mathematical model to describe the interactions between defense contractors and the government, in order to estimate cost and schedule for developing a technologically advanced weapon system. The research goal is twofold: (1) Explain why the development of a new weapon system is often subject to cost overrun and schedule delay; and (2) Identify market mechanisms to improve the efficiency of the bidding and contracting process in order to better manage risk.

Background
The pricing models in the defense industry cannot rely on basic economic principles such as supply and demand, since it involves advanced technologies that are pertinent to national security. The cost estimation of developing a technologically advanced weapon system is typically done based on component cost, labor cost, inflation, cost to acquire new technology, and opinions of subject matter experts. Since not all necessary technologies are in place at the onset of the system development, there is a lot of uncertainty in the total program cost and completion time. If a technological hurdle cannot be overcome in time, the whole program may suffer substantial delay and cost overrun.

Besides technological uncertainty, developing a technologically advanced weapon system also involves a lot of political uncertainty. The budget needs to be approved on a yearly basis, and sometimes a program may get cancelled. This uncertainty puts pressure on defense contractors to secure sole-source contracts when competing against the other contractors. However, once becoming a sole-source contractor the contractor's main motivation is to complete the scheduled tasks on time in each fiscal year, but not to deliver the final product as soon as possible.

Findings and Conclusions (to include Process)
We develop a mathematical model, in which the government manages a program to develop a technologically advanced weapon system in two phases: the competition phase and the sole-source phase. Each phase consists of three steps, which are described below.

1. The government funds a few defense contractors to develop a prototype for a technologically advanced weapon system in the competition phase. At the end of the competition phase, the government selects a sole source to develop the final product.
2. Each contractor may or may not be motivated to exert extra effort in the competition phase in order to improve its chance of winning the sole-source contract.
3. At the end of the competition phase, each contractor demonstrates its product prototype. The quality of the prototype depends on the contractor's design capability and also its luck to overcome technological hurdles.
4. Based on the prototype demonstration, the government selects a sole-source contractor to develop a final product. The program enters the sole-source phase.
5. The sole-source contractor continues to develop the weapon system. The progress may be affected by fiscal-year budget constraints, as well as the contractor's capability and luck to overcome technological hurdles.
6. The payoff of the government depends on the total program cost and program completion time. The government prefers to spend less money and complete the program sooner.

By using probabilistic modeling to capture the uncertainty of developing technologically advanced weapon system, we are able to quantify the effect of several model parameters on the eventual program cost and completion time. After analyzing the model, we ran a simulation study to gain insights into the entire process, and identify three main reasons why such a program often suffers cost overrun and schedule delay.

1. The selected contractor tends to be luckier than usual in the competition phase, so the government tends to overestimate its capability.
2. Once a contractor becomes the sole source, its goal is to complete the scheduled tasks within each fiscal year on time, but not to deliver the final product as soon as possible.
3. The contractors may be motivated to exert extra effort during the competition phase in order to improve its chance of getting selected as the sole source, which may result in an overly optimistic estimation on program completion time.

Based on a cost structure, our model offers recommendation on the optimal length of the competition phase, and the number of contractors to invite, in order to minimize the program completion time and total cost.

Recommendations for Further Research

Our model assumes that the government announces the length of the competition phase in advance, and selects one contractor at the conclusion of the competition phase. An alternative approach is to review each contractor's progress on a yearly basis, and decide which contractors to fund for another year. In addition, if the government has some prior knowledge about each contractor’s capability, then a Bayesian approach may produce a more reliable estimate on the program completion time. A separate study is needed to explore these issues.

Atmospheric Characterization of the Marine Base Layer for a Submarine Based High Energy Laser

Researchers: Dr. Joseph Blau and Dr. Keith Cohn

Students: LT Daniel Martell

Project Summary

Building upon our past research into directed energy weapons and atmospheric propagation of high-energy laser (HEL) beams, we have analyzed the performance of a notional 30 kilowatt (kW) to 50 kW HEL weapon with emission from a submarine platform. This analysis modeled the laser from its source on the submarine's mast to targets at various ranges and elevations. We estimated the performance of the laser in a wide variety of configurations, mast heights, weather conditions, and engagement geometries using the ANCHOR (Atmospheric NPS Code for High Energy Laser Optical pRopagation) code developed by the NPS Physics Department. Since a submarine-based laser would be fired from a beam director located up to 15 feet from the ocean surface, characterization of the turbulence near the surface is critical. To do so, we used Navy Atmospheric Vertical Surface Layer Model (NAVSLaM), a turbulence model developed by the NPS Meteorology Department that has been experimentally validated near the surface, and then incorporated the output of NAVSLaM into ANCHOR.

Background

The feasibility of using HELs in a maritime environment against relevant asymmetric targets has recently been demonstrated. The U.S. Navy has initiated efforts to develop a prototypical laser for surface and helicopter platforms to combat airborne and surface maritime threats. While these efforts mature, the Division of Undersea Warfare (OPNAV N97) desires to investigate the feasibility of implementation of a HEL system on Virginia Class Submarine (VCS) Block V platforms and beyond. In parallel with an investigation into the viability for ship integration of a HEL weapon into a VCS, Concepts of Operations (CONOPS) are being refined for this potential capability. These CONOPS will be informed by the limitations of HEL systems imposed by the physical environment. This study seeks to characterize the relevant atmospheric propagation phenomena at the marine base layer (ocean surface up to 15 feet) for the purposes of estimating laser performance. This, in turn, will inform CONOPS for employment of a 30 kW to 50 kW HEL weapon from a submarine.

Findings and Conclusions (to include Process)

We used climatological databases and NAVSLaM to characterize the turbulence across the entire Arabian Gulf at different heights above the water. The severity and behavior of turbulence as a function of height depends strongly on the air/sea temperature difference. This temperature difference varies significantly across the Gulf depending on the time of day and season of the year. We used this information to model a submarine-based laser in the variety of conditions likely to be encountered near the Strait of Hormuz.

The significant findings of this project are the following. For unstable turbulent conditions, when the air temperature is less than the sea temperature at the surface (common in the winter), turbulence tends to be strong right at the surface but decreases significantly for altitudes just a few meters above the surface. Under these conditions, increasing the mast height correlated with an increase in the effective range of the laser, especially against surface targets. Increasing mast height, however, increases the risk that an adversary may detect the submarine.

For stable conditions, when the air temperature is greater than the sea temperature (common in the summer), turbulence is nearly constant with increasing altitude up to about 50 meters above the surface. Therefore, mast height has much less of an impact on effective laser range. Furthermore, for a given magnitude of temperature difference, the laser performance is more strongly reduced during stable conditions than unstable conditions, especially against aerial targets.

Recommendations for Further Research
This research can be expanded to include results from full diffraction codes to augment the results from ANCHOR. Also, this project only considered atmospheric conditions likely to be found in the Arabian Gulf, specifically near the Strait of Hormuz; it could be expanded to include other potential operational theaters.

Integration of a High Energy Laser into the Virginia Class Submarine

Researchers: Dr. Douglas Nelson, Dr. Robert Harney, Dr. Gary Langford and Mark Stevens

Students: LT Patrick Stone USN, LT Rafael Oyola USN, James Johnson CIV USN, William Millette CIV USA, Whitney Cox Contractor, Brian Cox Contractor, Jeremy Shattuck CIV USN, Bradley Fiedler CIV USN, Victor Garcia CIV USN, Eric Tsai CIV USN, LT Joel Kent USN, Kimberly Martinez, Contractor, Mitchell Pawlowski Contractor, Jovan Zamora CIV USN, LT Andrew Hankins USN, Martin Rivas CIV USN, Andres Lozano CIV USN, Nicolas Purdon CIV USN, Eric Reyes CIV USN, Amirul Islam CIV USN, Dante Manalo CIV USN, Seth Bourn CIV USN, Darron Baida CIV USN, Socrates Frangis CIV USN, Bridget Grajeda CIV USN, Brian Meadows, CIV USN, Matthew Sheehan, CIV USN, Virginia Shields, CIV USN

Project Summary
A combat systems engineering approach was taken to determine the viability of integrating a high energy laser weapon system on a submarine. Several research, capstone and thesis efforts provided valuable insight and enhance the process going forward.

Background
The Division of Undersea Warfare (OPNAV N97) wants to investigate the feasibility of installing a high-energy laser (HEL) system on Virginia Class Submarine (VCS) Block V platforms and

beyond. Challenges common to all maritime platforms are mitigating the effect of the ambient environment including sea state, atmospheric optical turbulence and atmospheric transmission. In addition, the system will require innovative design and implementation to operate effectively with other combat systems while also being properly integrated with other submarine systems. A key requirement will be the ability for the system to engage threats from the surface.

Findings and Conclusions (to include Process)
The following are steps in the combat systems engineering approach:

- Define the mission through user input, context definition, identification of constraints including propagation effects (e.g. atmospheric optical turbulence), concept of operations and scenario generation.
- Analyze the mission through mission functional/timeline analyses, generating a design reference mission, operations analyses and performance requirements definition.
- Establish or validate system level requirements through system functional and timeline analyses including functional allocation.
- Synthesize concepts by identifying alternatives, assessing technology, generation of schematic block diagrams and selection of major alternative system suites.
- Evaluate concepts through selection of measures of performance/effectiveness, trade studies, performance analyses, cost-effectiveness analyses and selection of preferred alternatives.
- Refine the concept architecture, integration concept, preliminary system layout and concept of operations with documentation of decisions.

Capstone and thesis efforts as well as underlying research in the area of context definition provided progress in the process outlined above.
The high-energy laser submarine (HELSUB) Team of Distance Learning cohorts 311-124O, 311-124G and 311-133O completed Capstone on Integration of a High Energy Laser into a Future Class of Submarine (Distribution D). This project included combat systems activities at a top level through concept synthesis with three candidate concepts for integration.

LT Patrick Stone completed a more detailed mission definition and analysis in his thesis, Combat Systems Engineering Conceptualization of a High Energy Laser Weapon System on a Submarine. The integration of a high energy laser weapon system with a submarine was conceptualized through a parametric analysis to illustrate potential utility. A combat systems engineering process was undertaken to examine the added benefits that a laser weapon system may provide for two potential submarine operations.

Measurements of atmospheric optical turbulence over Lazer Bay on San Nicolas Island were conducted providing diurnal and seasonal data through approximately six months. Analysis indicates that prevailing conditions provide near maritime measurements along the propagation path. These measurements and analysis are ongoing including measurements at lower propagation path heights.

Associated thesis and capstones provided additional progress in several steps of the combat systems engineering process described above. These efforts have applicability in the effort to determine viability of a high energy laser weapon system on a submarine. One associated thesis effort was completed by Jeremy Shattuck with his development of a Virginia Class Submarine Situ Environmental Sensing System (SubSEnSS) (Distribution D). This SubSEnSS provides environmental information to the submarine to aid in operational decision making including assessment of conditions for possible high energy laser weapon systems employment.

Several associated capstones were completed by Distance Learning Cohort 311-133O. One of these was Distance Support In-Service Engineering for the High Energy Laser. This capstone assessed the feasibility and ownership cost savings in implementing a distance support framework tailored to the high energy laser weapon system. Another effort was Comprehensive System-Based Architecture for an Integrated High Energy Laser Test Bed. This capstone developed a conceptual architecture and requirements for testing and evaluating high energy laser weapon systems including those integrated into submarines. Finally the capstone, Increasing the Kill Effectiveness of a High Energy Laser (HEL) Combat System, assessed the capability of a kill assessment system to improve the efficiency of high energy laser weapon system employment.

Recommendations for Further Research
Additional analysis is needed to complete the combat systems engineering process from synthesis to full system realization into all of the potential benefits and unforeseen difficulties that a high energy laser may offer a submarine.

Traceability of Funding Lifecycle

Researchers: Dr. Gary Langford and Dr. Robert Eger III

Students: LCDR Manny Lamberty USN, LT Patrick Stone USN, LT Gilberto Viera USN and LCDR William Harley USN

Project Summary
This research examines new methods to improve traceability and transparency throughout the funding lifecycle for projects, contracts, and tasks through the tenets of lifecycle systems engineering. The approach is to apply the general theory of integration enacted through the lifecycle of funding, to determine the allowable interactions with regards to effectiveness of traceability and transparency. Three tasks were outlined in the original proposal: Task 1 – Develop the artifacts to determine the measures of effectiveness (MOEs) and their utility; Task 2 – Derive a preliminary model to capture the lifecycle issues; and Task 3 – Estimate the impacts of the lifecycle model on the traceability and transparency of use of budgets.

Background:
Naval Operations for Warfare Systems (OPNAV N9) wants to gain adequate visibility and traceability of maintenance and operational funds from the Program Objectives Memorandum (POM) and DOD's Sustainable Procurement Program (SPP) build through execution. The issue with the current models that are used to develop requirement funding profiles and the articulation of intended use of the funds is that these models are not maintained or respected in execution or actual expenditures, and consequently, there is no reconciliation to the original model inputs. Aggregate workload and carryover (backlog) are tracked to inform Readiness metrics, but visibility on where the dollars went is lacking. A compounding issue is that different information systems are used for the Programming phase of the Planning, Programming, Budgeting, and Execution [process] (PPBE) cycle than are used for funds execution, in addition to having multiple activities involved in execution which have differing accounting systems and varying degrees of business- or competition-sensitive data (e.g., man day rates, etc.). The problem is that this lack of traceability potentially masks inaccuracies in the models used to generate the requirement, which could lead to inability to identify cost drivers in sufficient time to address in the subsequent POM cycle, which in turn, creates an operational gap in fulfilling mission requirements. The purpose of this research is to develop measures of effectiveness (MOEs) that reflect the various stakeholder perspectives, to provide the requisite force structure, tools, and techniques to determine the level of assurance that objectives will be met. The goal of this research is to manage and to improve the fidelity of the lifecycle model and its analyses for sustainment and operations. The integration of sustainment strategy with necessary traceability and transparency will provide better assurance through full system of systems integration. The emphasis for this research is on developing a standardized framework from which repeatable, reliable MOEs can be attributed to compliance and traceability activities. Specifically, the underlying narrative of an MOE is to determine the greatest benefit from acquisitions at the execution cost. Compliance with Federal regulations and traceability to motivate compliance are the two central themes of this research.

Findings and Conclusions (to include Process):
General Discussion of Tasks:
A stakeholder analysis (Task 1.1) was drafted, along with a functional analysis (Task 1.2) and process analysis (Task 1.3) in order to develop a preliminary set of requirements for traceability and transparency on a lifecycle basis. While it is often the case with a systems engineering approach to draft quickly so as to scope the project work, this effort was cursory to keep within the time constraints imposed on our availability due to our work schedules. The stakeholder analysis focused on the general type of participants who are involved directly and not the secondary and tertiary participates who have sometimes significant influence on the outcomes. This first iteration provided the basis for developing a perfunctory set of requirements that captured only the most obvious enactments that needed to be tracked. To that end, Task 1.4 (map functions and processes) and Task 1.5 (integrate top-level requirements) were drafted so that work could begin on a general formulation for measures of effectiveness (Task 1.6). That formulation does show how to develop MOEs through the technique of systems engineering integration and their relevance to traceability and transparency on a lifecycle basis. Task 1.6 is the primary output thus far from the work on Task 1. In keeping with the spirit of this

streamlined approach due to continued and severe time constraints on the amount of work that we are allowed to do, only a cursory look at Task 2.0 (derive a preliminary model) and Task 3.0 (impacts of lifecycle model) are expected.

Introduction

Syphoning of funds from their intended appropriated uses (termed syphonage), malfeasance, misfeasance, or the non-productive use of funds that do not fulfill the needs of the officially designated customers reduces the effectiveness of the acquisition process. In the main, we strive to be effective through authorized and appropriate use of funds, the results of which are often scrutinized in both real time and then retrospectively from sometime in the future. A measure of effectiveness is the enactment of a system of traceability and transparency to carry out the expenditure of funds as they were intended by the officially designated customers. There seems to be no standard, no systematic means of measuring effectiveness. Previously, the practice of determining effectiveness methods was not grounded in theory, had no validated approach, and was not evaluated with a standardized framework that reflected the various perspectives of legitimate stakeholders, i.e., those that were intended by the appropriations and budgets. This research presents progress toward such methodology.

Measures of Effectiveness (Task 1)

This research indicates that measures of effectiveness can be standardized when viewed within the proper formulation of an evaluative framework based on physical objects mapped to processes. This framework can be used by legitimate stakeholders (with differing perspectives) to compare means of traceability and transparency on a lifecycle basis of funds. The lifecycle is from the appropriation to the consequences of the work performed with funds from the appropriation. Therefore, for the first time, measures of effectiveness can be determined for all processes (i.e., managed activities that are charged as labor) as well as across a standardized set of measures for all products developed with that labor and the materiel and corporeal purchases of goods and services.

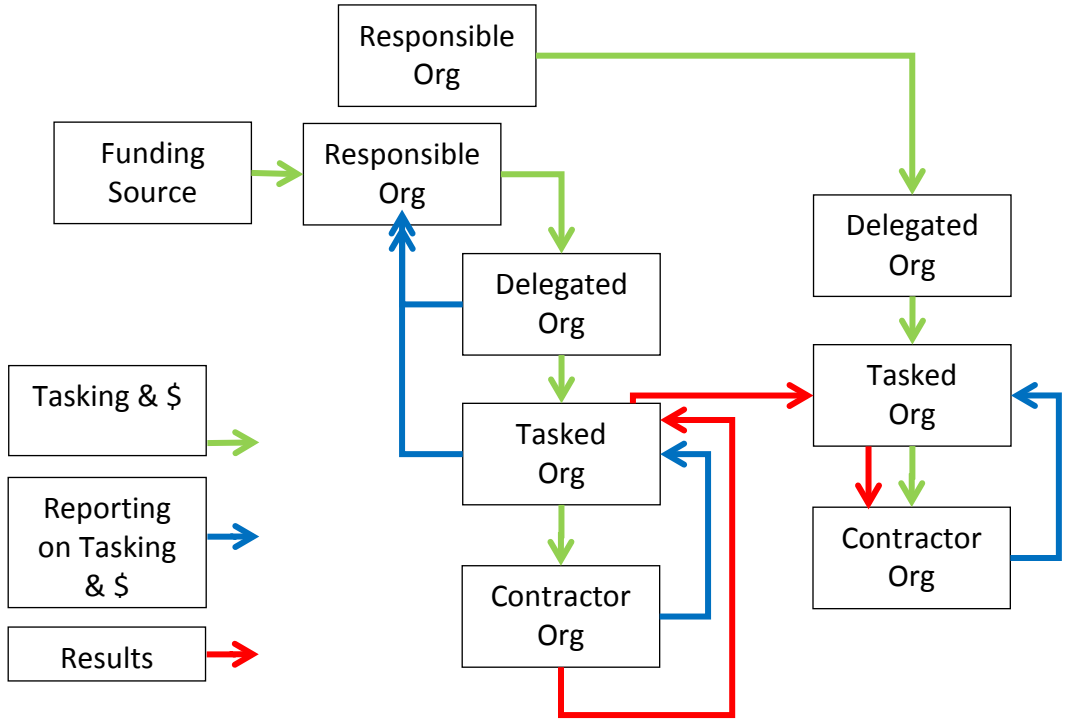
The effectiveness of traceability and transparency depends on the (1) identification of the significant measures of causality that drive the uses of appropriated funds, (2) interpretation of the measurements of traceability and transparency, and (3) perspective from which the measures and measurements are observed. These three factors reveal the functions and processes of traceability and transparency that determine the degree of influence of syphonage, misuse of funds, malfeasance, and misfeasance. From a functional and process perspective of the social and psychological issues (i.e., mechanisms) pertaining to these three factors, a warning (perceived or real) of a problem with traceability or transparency will be invariably linked through these social and psychological mechanisms. That warning may be general in nature, resulting in a need for a sustained level of vigilance or be quite specific, resulting in heightened awareness or the enactment of additional measures to track and evaluate. It is through the analysis of functions and processes that the harbingers of misuse can be observed.

Measures of effectiveness are intended to determine to what extent objectives are accomplished and how well the results compare with the desired results. Measurement of effects is a combination of measures that embody the approaches of outcome-based, information-based, and scenario-based determinants. Outcome-based measures are oriented toward results, i.e., the observation of appropriate use and misuse of funds. These results are shown by competencies and proficiencies as demonstrated by performances of what is done. All actions are observable given the appropriate measures and measurements. Knowledge-based measures are premised on existing level of knowledge (rules of thumb and rules of dumb, i.e., best practices) that are then extended to new regimes through exploratory thinking, copy-cat behaviour, or rationalized action. Knowledge-based measures are based on what is known about the processes of moving money and the measures of detection, enforcement, and consequences. Scenario-based measures capture the social customs and habits that result in repeated social behaviors. It is the context, environment, and trends that enable scenario-based measures for determining effectiveness of traceability and transparency. Each type of determinant addresses a different aspect of effectiveness, all of which need to be considered from various stakeholder (legitimate as well as others) perspectives.

Our inability to predict the consequences of our achievements confounds the utility of measures of effectiveness. This difficulty in predicting consequences means the measure of "good enough" is challenged by what to measure, what the measurement means, and what quality of measurement is sufficient. This research opens the discussion as to what constitutes the benchmark of adequate and sufficient assessment. This theme is enduring and has only been addressed in this preliminary fashion.

Models of Traceability and Transparency (Task 2)
Two models of organizational entities were developed to illustrate the flow of tasking and money; reporting on tasking and money; and results of tasking and money. Figure 1 models the perfect situation where there is complete transparency, effective traceability, and proper sharing of results (compliance).

Figure 1. Complete Transparency, Effective Traceability, and Proper Sharing of Results

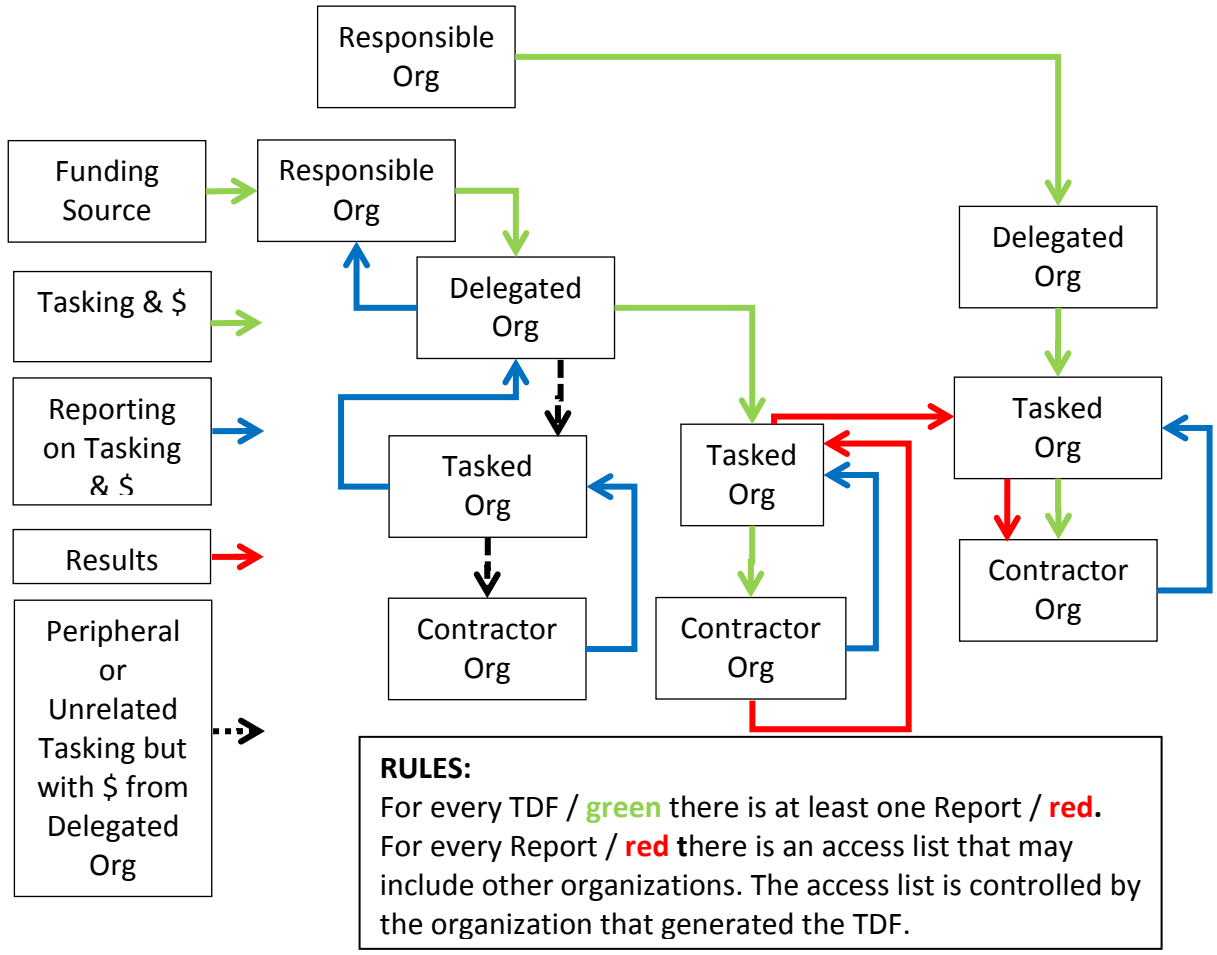


RULES:
For every TDF / **green** there is at least one Report / **red.** For every Report / **red t**here is an access list that may include other organizations. The access list is controlled by the organization that generated the TDF.

(Compliance)
Tasking, dates of performance, and funding (TDF / **green**) and are sent from organization to organization to accomplish the work. Reporting on TDF / **blue** is sent to the appropriate organizations (typically the organization that sent the TDF / **green**. Distribution of the results of the TDF / **green** is coordinated with other organizations with a Report / **red** that require awareness, perspective, support, stimulus, or corroboration.

Figure 2. depicts what is thought to be the actual movement of tasks and money and sharing of the results of the work performed.

Figure 2. Incomplete Compliance, Ineffective Traceability, and Improper Sharing of Results



These two models will be reconciled, the differences being slated for the first enactment of measures of effectiveness to determine traceability, transparency, and compliance.

Financial Status:
Of the original $348,170 proposed and initially authorized for the work, $58, 438.65 was allocated to the account for this research subsequent to long periods of time when there was no ability to work on the contract. Of the $58,438.65 authorized, $21,622.52 has been spent on the work of Task 1 and Task 2 as of 7 March 2015.

Ongoing Research:
The work outlined above in Tasks 1, 2, and 3 will be completed by 30 June 2016 and a draft of the final report will be submitted for review by N9I.

ASN (RDA): Research, Development & Acquisition

Ballistic Missile Submarine Surface-Transit

Researchers: Donald P. Brutzman and Terry Norbraten

Students: LT Marlon Heron USCG

Project Summary

This research produced tools that can model, simulate, visualize, analyze, and evaluate security measures for ballistic-missile submarine surface transit. The project extends prior work that specifically established baseline capabilities supporting the visualization and security needs for a weapons handling operational area, using a standards-based extensible architecture and conceptual design that can be tailored for a wide variety of naval support activity locations. NPS researchers have produced a tool suite and model library capable of supporting a capability and gap analysis for independent system of systems (SoS) that identify dependencies and potential limitations in the topic areas of interest.

This work also designed and considered conducting a crowd-sourcing inquiry among relevant personnel working with SSP commands in the Navy, Marine Corps, Department of Homeland Security (DHS) and civil authorities using the Massive Multiplayer Online Wargame Leveraging the Internet (MMOWGLI) tool. With effective access controls in place, such crowd-sourcing techniques have been shown to be effective in identifying problems and exploring potential solutions that are beyond the scope or visibility of any single department or agency.

Full project details beyond this synopsis are available in a For Official Use Only (FOUO) report, available on request.

Background

This project has built a suite of tools that enable modeling, simulation and visualization of scenarios of interest to this project. Many components are linked together to build libraries of interest that can be repeatably used.

- Entity capabilities plus Tactics Techniques and Procedures (TTPs) are expressed through Discrete Event Simulation (DES) models using Simkit and Visual Simkit (Viskit).
- 3D visualization models are created individually using X3D-Edit or converted from other sources, with a suite of X3D Quality Assurance (QA) tools applied to ensure correctness.
- Metadata is used throughout in order to enable customization, adaptable reuse, and strict accountability of asset pedigree. The Savage Modeling and Analysis Language (SMAL) defines these capabilities.
- Scenarios are designed and assembled using SavageStudio in concert with all other tools.

All tools are developed and maintained by NPS MOVES personnel, frequently utilizing outside open-source libraries and occasionally benefiting from open-source contributions by external contributing partners.

Findings and Conclusions (to include Process)

1. The project has demonstrated that modeling, simulation and visualization of important scenarios of interest is feasible using extendable tools and libraries designed for student and analyst support. The creation of Extensible 3D (X3D) Graphics models for visualization is now supported by strong Quality Assurance (QA) test suites and composable, coherent metadata strategies. Numerous follow-on activities and uses are envisioned.
2. Further improvements to the Savage model libraries and Visual Simkit are continuing. These tools are suitable for use by NPS students and (with training) external analysts supporting the topic sponsor.
3. The NAVFAC-administered SPIDERS3D online environment can benefit from continuing upgrades and software development. In particular, NAVFAC can remove a single proprietary software component (BS Contact) from the architecture to a related open-source solution (X3DOM) which also removes the need for Navy Marine Corps Intranet (NMCI) certification, a lengthy process that was successfully completed for the current generation of software.
4. NPS-produced software tools (Savage Studio, Visual Simkit, Simkit) and model libraries (Savage and FOUO SavageDefense) are compatible sources to produce behavior-driven models that can be collaboratively shared within the SPIDERS3D online environment.
5. The MMOWGLI crowd-sourcing tool has good potential but requires some additional work and a certified game-hosting capability in order to be useful for sponsor needs.
6. All progress demonstrated by NPS work in this project continues to be cumulative and provides long-term benefit, primarily thanks to an insistence on the use of open-source software in combination with stable international standards for the Web (HTML, XML and X3D graphics).

Recommendations for Further Research

1. Detailed findings, conclusions and recommendations are found in the master's thesis by LT Marlon Heron USCG. This work bears further review.
2. Additive Manufacturing (AM), 3D printing and 3D scanning will soon be at a point to augment scenario visualizations with physical models. Sand table approaches that use a downward-facing projector to overlay scenario information and tactical information can improve group understanding of sensitive evolutions. This approach will likely improve participant comprehension, adding value to pre-evolution briefings and post-event assessment reviews.
3. Continued thesis and scenario analysis work is warranted to continue building Savage/SavageDefense libraries of unclassified/FOUO behavior and visualization models. The components and products of each analyst report are suitable for future adaptation and re-use.

Additional potential benefits continue to emerge. Related Naval Research Program (NRP) work on 3D printing for additive manufacturing (AM) are likely to allow creation of a "sand table" using 3D-printed models together with projected simulation overlays, in order to evaluate whether improved scenario planning and understanding is possible. That work also includes student involvement. Progress details are reported separately in a recent EXWC technical report.

High Energy Laser Employment in Self Defense Tactics on Naval Platforms

Researchers: Jeff Kline, Dr. Tom Lucas and Dr. Paul Sanchez

Students: LT Steven Rockwell USN and LT Dustin Schultz USN

Project Summary

This research built upon previous work in solid state laser modeling and assessment by:

- Building an agent based model in coordination with Naval Surface Warfare Center Dahlgren K Department using their Orchestrated Simulation through Modeling (OSM) framework,
- Collecting solid state laser performance data against various threats,
- Constructing tactical situations to represent aerial and surface boat swarms along with anti-ship cruise missile attack in the OSM model,
- Using intelligent design of experiments to evaluate tactics to best employ the solid state laser when integrated into a guided-missile destroyer (DDG's) combat suite and providing a quantitative military assessment of the solid-state lasers (SSL's) value in these situations,
- Reported findings to ASN(RDA), Office of Naval Research (ONR), and the Naval Surface Warfare Development Command,
- Made additional adjustments to and providing a final model to Naval Surface Warfare Center Dahlgren Division (NSWCDD) - to add to their OSM library.

Background

The U.S. Surface Navy is vulnerable to unmanned aerial vehicle and small boat swarm attack, particularly when coordinated with a multiple anti-ship cruise missile attack. Shipboard high energy lasers 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, require intelligently employing a high energy laser system in coordination with other shipboard defense systems against a heterogeneous set of threats from a coordinated attack.

Findings and Conclusions (to include Process)
The "SSL in OSM" model is now developed by the NPS Simulation Experiments Efficient Designs (SEED) center in coordination with NSWCDD. LT Rockwell and LT Schultz completed their data collection, design of experiment work, and simulations in coordinated swarm attacks, each conducting different tactical situations.

Specific findings are classified, however the addition of a solid state laser to a DDG's combat suite made significant contributions to defending the ship against unmanned aerial vehicles and small boat threats. Recommended laser tactics have also been provided. LT Rockwell and LT Schultz jointly won the Navy Surface Association's Award for Excellence in Surface Warfare Research.

Findings have been briefed to Office of the Chief of Naval Operations (OPNAV) N81 B Mr. Chuck Werchado and his staff, NSWCDD staff, OPNAV N96 staff, ASN (RDA)'s Mr. John Burrows and ONR's Mr. Peter Morrison. OPNAV N81B requested a new threat profile be analyzed. That work was delivered in May 2015. Follow-on work requested by sponsors included modifying the solid state laser capabilities to a more powerful system, exploring adding two lasers to the DDG, and multiple ship operations. Follow-on work using ONR funding will address these issues.

This project's results will be used by OPNAV staff and ONR staff to provide quantitative military assessment and program justification for the solid state laser. Navy Surface Warfare Development Command will use it as a resource to develop surface SSL tactics. As ONR funding and students become available for additional research, we will continue enhancements to the "SSL in OSM" simulation and explore questions raised by sponsors.

Developing Resilience in a Ready Force: Assessments and Intervention

Researchers: Dr. Edward Powley and Dr. Frank Barrett

Students: LT Ian Barr USN, LT Chris Burt USN, LT Maribel Chalburg USN, LT Caroline Brown USN and LT Andrea Watling USN

Project Summary
Naval Service Training Command (NSTC) sought to understand the factors that contribute to resilience and identify ways to instill resilience during new recruit training. Our objective for the study was two-fold: (1) measure resilience and (2) develop interventions to increase resilience. The Recruit Training Command (RTC) and NSTC provided access to and significant opportunities for learning about the new recruit experience. The project involved surveys and interventions for several training divisions at RTC between January and July 2015. Using different approaches we were able to develop important ways to promote and instill resilience practices.

Background

Our study involved both qualitative interviews and a resilience survey. First, we conducted a qualitative study in which we interviewed recruits and recruit division commanders (RDCs) to learn about the challenges and struggles occurring during recruit training. Second, we designed a longitudinal quasi-experimental field study to uncover the effects of three resilience interventions on self-report measures of individual and organizational resilience. The results of the study show promise for instilling resilience. The interventions proved to increase resilience at different points in time during recruit training suggesting that an array of approaches is necessary to boost resilience during accessions training. The qualitative story compliments the field study findings. There are a number of practices and routines RDCs and recruits perform to increase resilience and thus enable recruits to overcome challenges.

Findings and Conclusions

The study revealed several interesting and important findings.

(1) In divisions where we had no resilience treatment, self-report measures of resilience show increases over time.
(2) In the divisions we studied, individual resilience increases early, but dips or holds steady just before graduation. Division resilience scores trend upward throughout the study period.
(3) Of the divisions that received an individually-based intervention (affirmative identity statements), the effect is positive, but is of short duration; that is, introducing the intervention early in recruit training without frequent follow-up does not produce positive effects in resilience at the end of training. Moreover, recruits who frame situations in a positive light and have a learning goal orientation are more likely to show increases in resilience within two weeks. Recruits who report higher degrees psychological safety also increase in resilience but the effect is longer (up to 4 weeks).
(4) Of the divisions that received a socially-based intervention (appreciative conversation), the effect has a longer shelf-life, that is, the effect of the intervention lasts over a period several weeks. The appreciative conversation intervention showed positive results at all three time points times, although it was not significant at T3. At T4, the effect was positive and significant. Moreover, in the appreciative conversation condition, the positive effect on resilience is more pronounced as the time goes by.
(5) Qualitative results highlight features of RDC behaviors and practices that encourage resilient approaches to help recruits work through challenges of boot camp. We found that RDCs in Fitness Improvement Training (FIT) do a remarkable job helping recruits find inner strength to deal with setbacks. We also found that the social dynamic and relationships among recruits in FIT are a primary resilience resource. They draw on mutual strength to help each other in their difficulties.

Recommendations for Further Research

Overall the results are promising, but require additional work to implement the interventions within the training environment.

(1) Introduce the affirmative identity statements early but follow-up frequently and ask recruits to revise and remember them more often than only at T1 or T2.
(2) Focus on helping recruits (1) develop positive framing techniques, (2) emphasize learning over performance of tasks, and (3) foster stronger sense of trust in leaders and peers.
(3) Introduce the appreciative conversation at different points in the training cycle to reinforce how their life experiences and social relationships function to support them during difficult times.
(4) Follow-on research might include observing trends in resilience of recruits from RTC to A-Schools to the fleet.
(5) Continue to explore the relationship between resilience and physical fitness outcomes.

Developing Flag Officers of 2025 and Beyond

Researchers: Dr. Peter Denning and Sue Higgins

Students: No students participated in this research project.

Background
Our Naval education systems, designed in the machine age, do not adequately prepare our military for the emerging new world. Our adversaries, who are not subject to our institutional constraints, are moving into the new age faster than we are. It is time for a new conversation about the design of military education.

Project Summary
We considered the question: Is military education keeping pace with the task of preparing military people for effective leadership in the emerging highly networked, highly unpredictable world? We examined the nature of the changing environment for military operations. We speculated about leadership identity needed in this environment, possible ways to cultivate the required sensibilities, and the possible role of technology in achieving it. We call for a conversation about how military leadership education might be redesigned and how we might get a new design in place. Our project met its final deliverable with a book chapter, Being in Uncertainty: Cultivating a New Sensibility in Military Education in "Innovative Learning: A Key to National Security (Higgins, Denning, & Miller, 2015)."

We participated in a commercial training course in which we read select books and articles, met online for bi-weekly conversations and attended a 2-day, face-to-face workshop. We explored skills for innovation and coping with change, pragmatics of communication and commitment, skills for orchestrating moods, and skills for cultivation of community and networks. Our classmates were a diverse group of fifty international business leaders, educators and military leaders.

Findings and Conclusions

We describe the skills of leaders needed to move effectively in an emerging, shifting, unpredictable world. The skills encompass new ways of thinking and interpreting. They embody new sensibilities about people's moods and possibilities in fast-changing networks. They cultivate moods that facilitate actions. They define a new way of being in and navigating an uncertain and unpredictable world. The new way is not obvious from the machine age in which we grew up and designed our education systems.

We outline five essential aspects of a leadership identity we think are needed in the new world: leader as innovator, navigator, historical agent, opener of possibilities, and appropriator. We refine these distinctions through ongoing conversations with an international group through which we extracted the ideas that are most relevant for our situation in military education. The need for these skills stems from a change in human dynamics as our world transforms with the help of dramatic advances in digital technology.

Contrasts between Machine Age and Network Age Perspectives

1	**INNOVATION AS IDEA CREATION**	**INNOVATION AS EMERGENCE**
2	**KNOWING MORE**	**EXPONENTIAL UNCERTAINTY**
3	**DIFFUSION**	**MOBILIZATION**
4	**DETERMINISTIC**	**UNPREDICTABLE**
5	**NO INTELLIGENCE**	**INTELLIGENCE**
6	**EFFICIENCY**	**EFFECTIVENESS**
7	**MANAGING TOWARD GOALS**	**NAVIGATING**
8	**RULE SETS AND END---STATES**	**COMMITMENTS, MOODS, POWER**
9	**SUSTAINING INNOVATION, BRANDS**	**SHIFTING IDENTITIES, DISRUPTION, AVALANCHES**

Recommendations for Further Research

1. The Navy should engage in future experimental courses and modules designed to teach network age skills. We speculate that by adding a few well-designed modules to existing Navy curricula, we could take significant steps toward the desired transformative effect.
2. We propose starting new conversations to cultivate network age leaders by designing workshops and symposia. This should begin with a broad conversation about the breakdowns currently experienced by military leaders, the nature of the world in which they will be leading future military operations, and the aspects of a leader's identity that our education programs should cultivate.
3. The Navy should explore a redesign of the Naval Academy engineering and leadership curricula and follow-on leadership schools to ensure network age skills are cultivated.

Climate Change Effects on Navy Island Bases

Researcher: Dr. Tom Murphree and Arlene Guest

Students: LT Rich Ilczuk USN and LCDR Jen Cline USN

Project Summary

The effects of climate change on Navy island bases are on-going and are likely to be substantial over the next several decades. These effects occur due to changes in sea level, storm activity, and other environmental factors that affect critical infrastructures (e.g., command and control, fuel, power generation, transportation, water resource, sanitation, and other facilities). In our study, we are identifying and assessing actual and projected macro-level effects of climate change on four Navy fleet concentration island bases: Joint Base Pearl Harbor-Hickam (JBPHH), Guam, Diego Garcia, and Okinawa to assist the Naval Facilities Engineering Command (NAVFAC) in planning for these bases.

Background

Our approach emphasizes: (1) quantifying relationships between specific aspects of climate change and their effects on critical infrastructure components and operations; (2) quantifying the uncertainties associated with projections of climate changes and their operational impacts; and (3) identifying methods for improving Navy planning for climate change.

We are leveraging prior and on-going studies, and exploiting existing and recently developed data sets and analysis methods.

The specific objectives for this study are to:

1. Identify and assess the macro-level effects of climate change on the four island bases (e.g., effects associated with sea level rise (SLR), changes in storm activity (e.g., changes in storm frequency, tracks, intensities), and associated effects on storm surge, inundation, flooding, and impacts on water resources (e.g., salt water intrusion, depletion of aquifers, etc.).
2. Review and synthesize relevant prior and on-going climate change studies and data sets (e.g., (SERDP), United States Army Corps of Engineers (USACE), Naval Air Station (NAS)/ Naval Aviation Enterprise (NAE) studies; reanalysis data sets, climate change projections).
3. Conduct analyses of relevant data sets (e.g., climate, water resource, base management data sets) to identify base-specific spatial and temporal patterns and processes.
4. Develop macro-level descriptions of the effects of climate change on the four island bases that have occurred and are most likely to occur over the next several decades, including assessments of associated uncertainties.
5. Provide report to NAVFAC, including recommendations for follow-on studies

Findings and Conclusions (to include Process)

We are conducting investigations of each island base and discussing our preliminary findings with NAVFAC. This has led to the identification of the following environmental factors and operational impacts for which climate change is most likely to be important for the island bases from a NAVFAC perspective.

Environmental Factors

1. Sea level rise (SLR) and related factors (including inundation, storm surge, coastal waves, flooding, etc.)
2. Tropical cyclones (TC) and other storms (including TC/storm numbers, tracks, intensities, etc.)
3. Precipitation (including intensity, flooding, drought)
4. Winds (including changes in wind speed and direction)
5. Salt water intrusion
6. Erosion (coastal and inland)
7. Sedimentation
8. Loss of land and land uses
9. Water resources (water quality and quantity)
10. Clouds and insolation (sunlight received at surface)
11. Other atmospheric factors, for example: air temperature, humidity, clouds, etc.)
12. Other ocean changes, for example: circulation changes and associated changes in ocean temperature, SLR, precipitation, storms
13. Other land changes, for example: subsidence, rising of land

Operational Impacts

Impacts of environmental factors on existing / planned infrastructure and operations:

1. Coastal structures (e.g., buildings, cranes, piers, pipelines, roads, etc.)
2. Water supply systems
3. Heating, ventilating, and air conditioning (HVAC) systems
4. Waste water / sewage systems
5. Conventional and renewable / alternative energy systems
6. Roads and ground surface transportation
7. Port operations (e.g., pier side ops, harbor movements, dredging, etc.)
8. Airfields and airfield operations
9. Operational impacts of the loss of land and of uses of land
10. Corrosion (e.g., changes in corrosion risks as environmental conditions change)

Recommendations for Further Research

We expect to recommend that future research be conducted to assess the impacts on planning and management processes --- for example, changes to processes to better account for the characteristics of:

1. Climate changes (e.g., the multi-decadal character of some changes, the episodic character of other changes, the uncertainties associated with projections of these changes, etc.)

2. Operational impacts of climate change (e.g., the multi-decadal character of many impacts, the episodic character of other impacts, the uncertainties associated with projections of these impacts, optimal formats for inputs to, and outputs from, planning and management processes, risk management approaches best suited for dealing with climate change impacts, changes to decision time scales and methods, etc.)

Submarine Pier Side Weapons Handling Risk Assessment

Researchers: Dr. Warren Vaneman, Joseph Sweeney, Dr. Gary Langford, Gary Parker and Chris Wolfgeher

Students: LCDR William Harley USN

Project Summary

This research examines new methods to assess and improve Physical Protection Systems (PPS). Specific elements include: paying specific attention to a Navy Level 3 Restricted Areas, a special type of industrial and refit zone that normally handles high value units such as aircraft carriers and ballistic missile submarines; utilizing Model Based Systems Engineering (MBSE) and System of Systems (SoS) theory to create a framework which couples architectural level PPS design with detailed discrete event security assessment; and prediction techniques in order to provide decision makers and acquisition authorities a more quantitative and effective method to holistically understand a PPS and the PPS's internal and external interactions. The combination of these elements would allow for improved capability and vulnerability analysis and the formulation of sound acquisition decisions.

This research investigates four key questions:
1. Are there gaps in the end-to-end security assessment process caused by Seemly Unrelated Security Violations (SUSV), separated by distance and time, which affect the total security of a system, which heretofore have not been identified but may be able to be identified with robust MBSE?
2. What artificial limitations imposed by traditional security analysis models can be removed by the utilization of a MBSE operational item centric approach?
3. What improvements can be realized for a System of Interest (SoI) by treating it as a SoS and artificially splitting it into two ontologically separate systems: the SoI and the security system?
4. What insight in security system design optimization can be gained from utilizing the loss function in conjunction with MBSE for the conduct of security system analysis of alternatives?

Background

The International Council on Systems Engineering (INCOSE) Systems Engineering Vision for 2025 states that today, "Engineers are hard pressed to keep up with the evolving nature and

increasing sophistication of the threats to our cyber-physical systems. Cyber-security is often dealt with only as an afterthought or not addressed at all" (INCOSE 2014, 36). The issues identified by INCOSE are both symptoms of the problem that security, like many modern engineering problems, is very complex – complex beyond our means. Current tools are insufficient to enable the effective design and analysis of system security, which further magnifies the complexity of this problem, and differentiates it from other similarly complex systems.

Security Systems are subsystems of a System of Interest (SoI), designed to act as a boundary, with boundary conditions, to prevent or control access. Simple system security may consist of just a wall, and are thus just physical objects. Most modern system security consists of a multifaceted network of barriers, sensors, and humans, all interacting to fulfill the specific purpose of the security system. Making these systems even more complex, the usage of networked computers as an essential part of system security provides an additional dimension of complexity, allowing threats to utilize cyber vulnerabilities to assist in overcoming reinforced physical security.

The objective of tools used to analyze security systems is to utilize different methods to simplify very complex, time-independent, and non-linear security systems, allowing for these systems to be evaluated in an efficient and meaningful manner. Most tools analyze the objects in the security system instead of the effectiveness of the function of security, making it nearly impossible to identify non-linear vulnerabilities, such as those resulting across security domains, or from Seemly Unrelated Security Violations (SUSV), which can occur over a wide range of distances and times. Therefore, the Systems Engineering Community is in need of an architecture based framework that enables the assessment of the security function of a Systems of Interest that contains multi-domain security sub-systems and/or security sub-systems that are vulnerable to SUSVs.

Findings and Conclusions (to include Process)
Research is in progress. Findings and conclusions will be available in the final report.

Recommendations for Further Research
This research proposes a methodological approach to address research questions 1-4. The Strategic Systems Program (SSP) Nuclear Weapons Security (NWS) has been engaged in a comprehensive effort to document the security architectures in a MBSE environment. Given the existing data, an extension of this research is to assist SSP NWS use the data in their MBSE environment to address nuclear weapon security issues using, in part, the methodology being proposed by this research. This effort was not envisioned during the proposal phase, but has been found to be necessary to implement these methodological approaches. As such, the team is working with SSP NWS to help them understand their MBSE environment. This work will continue after this NRP report is completed.

FLEET FORCES COMMAND

Analysis of Drug Trafficking Organization Behavior

Researchers: Dr. Michael Atkinson, Dr. Moshe Kress and Dr. Roberto Szechtman

Students: No students participated in this research project.

Project Summary
One of USSOUTHCOM's primary missions is to disrupt the flow of drugs from Central and South America to the United States via the southern approaches. The main question we address in this project relates to the interdiction efforts of USSOUTHCOM: how many cocaine-carrying vessels of a certain type are afloat in the area of operations at any given time? This information will provide insights to USSOUTHCOM on the relationship between force allocation and the effect on counter-drug operations. Our second contribution is the development of a strategic model that considers both the government and Drug Trafficking Organizations (DTOs) as decision makers.

Background
DTOs use both maritime and air conveyances and use a variety of vessel types to transport cocaine. USSOUTHCOM focuses on an area covering over 42 million square miles, and the U.S. invests considerable effort in searching and interdicting drug-trafficking vessels in the Caribbean and Eastern Pacific regions. While some vessels are indeed interdicted, resulting in confiscation of substantial quantities of drugs, many such vessels manage to avoid detection and arrive safely at their destinations in Central America and Mexico with their drug load intact. An important parameter for planning interdiction missions is an estimate of the expected steady-state number of the various types of vessels present in the search regions at any given time. In this project we use supply and demand data regarding cocaine, as well as technical and operational data regarding trafficking operations in the Caribbean and Eastern Pacific to estimate the steady-state number of drug-carrying vessels traveling from South to Central America

Findings and Conclusions (to include Process) The number of cocaine shipments range between three and five dozen a month, and at any given time there are between two and three vessels, of all types, on the high seas. The main caveat relates to velocity and capacity of DTO vessels. It is possible that those values are much lower than our baseline estimates, which could increase the number of monthly shipments to over 100. We further break down these numbers by vessel type (e.g., go-fast vs. Self-Propelled Semi-Submersible (SPSS)) and route (e.g., eastern Pacific vs. Caribbean).

To generate these numbers we collect data on the amount of cocaine produced and shipped out of Colombia each year and the routes and methods used to transport the cocaine out of South America. This information provides us with an estimate of the flow of cocaine. To

determine the number of DTO vessels on the water at any time, requires the average drug load of each vessel, fraction of flow transported via maritime conveyances, average duration of one trip, etc.

Our strategic model uses game theory to provide insight into how DTOs will react to different search and interdiction efforts by the government, which leads to a corresponding change in the interdiction rate. We also illustrate the value of information for the government to accurately estimate the true interception rate, so that the government can most effectively plan counter-drug operations

Recommendations for Further Research
The cocaine flow estimates we produce should provide insight for how to allocate Blue assets to search, detect, and interdict DTO vessels. We do stress that our numbers are based on the best available unclassified sources. USSOUTHCOM should have more detailed classified information. They can plug those numbers into our analysis to generate more accurate estimates of the number of shipments initiated per month and the number of vessels on the water. Future work could produce a planning tool that allocates Blue assets based on current flow numbers.

Future work could also compare our flow estimates derived from supply and demand numbers to the actual DTO trafficking data in the classified Consolidated Counterdrug Database (CCDB). If the flow estimates are much higher than the data in the CCDB, that would suggest there is a significant amount of unknown flow in the AO. We should take efforts to develop more intelligence sources to reduce the unknown flow. If the flow estimates are much lower than the data in the CCDB, that would suggest a non-trivial amount of the entries in the CCDB may be false. That is they represent shipments that never occurred. In this case, we would need to evaluate the intelligence collection and analysis process and examine why we incorrect count so many false shipments.

Fleet HF Capabilities, Skills and Effectiveness

Researchers: Dr. Shelley Gallup

Students: No students participated in this research project.

Project Summary
High Frequency (HF) communications is more than simply use of the 3-6Mhz spectrum. It is also a system, one that includes the interplay of multiple aspects and dimensions in order to deliver a capability. HF communications in naval (especially maritime) operations has devolved from a well-used and important capability of the past one hundred years, through much of the cold-war, to a little used, little practiced, and underfunded capability. Yet, in an “everybody knows” sense, HF communications are seen as important and necessary in anti-access, area

denial (A2AD) operations where there may be a lack of satellite access through a myriad of denial tactics by an adversary, or where existing bandwidth for current operations needs to be augmented to provide just what is needed for tactical operations. This report examines HF communications as a "system" where contributions from different dimensions are needed to create the capability. We use a model of organizational congruence as a framework for this examination, and propose a best fit of the components of the system to produce a working, capable, and employable communications system.

Background

Recent Fleet Communications Contested Environment (CCE) exercises such as Silent Banshee 2013, and Battle Force Tactical Network (BFTN) Initial Operational Test & Evaluation (IOT&E), identified that High Frequency (HF) communications (comms) skills in the fleet have atrophied due to reliance on satellite communications (SATCOM) for comms over the horizon. It is critical the Navy understand to what degree it can rely on HF as the only beyond-line-of-sight comms path available in a SATCOM-denied environment

HF communications were the backbone of shipboard communications for nearly 50 years, and U.S. Navy Radiomen were once acknowledged as some of the best HF operators in the world. This has changed with increased fleet reliance on Internet Protocol and high bandwidth satellite connections. Where can the USN best focus its efforts to revive the HF expertise and skill once common in the fleet?

In order to be competent in HF communications and operationally effective, the Navy must be equipped and trained to employ HF communications among its own forces, jointly with other U.S. forces and with Coalition forces who routinely employ HF communications. This means that U.S. Navy platforms must have the latest capability, including Digital Modular Radio (DMR), and the Battle Force Tactical Network –enhanced (BFTN-e) for voice and digital High Frequency Internet Protocol (HFIP) communications.

Perceptions by users and commanders that the HF frequency spectrum is less useful have created the situation where HF is not routinely practiced.

Findings and Conclusions (to include Process)

The problem with HF is a multi-layered problem, with many contributors. We use the Congruence Model as a framework to examine the contributing effects of history, resources, strategy, people, tasks, formal organization, informal organization, outputs, and measures.

The principle findings for this project are that there has been a lack of coherence between the diverse participants of resource sponsors, Fleet users, schoolhouses, acquisition managers and industry to create a capability, the potential for an effective HF system. This has been shifting with the stand-up of Navy Information Dominance Forces (NAVIDFOR) and renewed interest in the HF spectrum. However, there are still needs for renewed training and mandatory participation in HF monthly exercises. The Testing and Evaluation (IOT&E) of BFTN-e is essential, as this is the system on which sailors will need to train, and until this system is acquired there will be a continued perception that HF is not useful in modern warfare at sea.

Recommendations for Further Research

One of the deliverables of this project is a working HF laboratory at NPS.
Harris Radio Corporation has loaned an HF suite to the school, and has trained personnel to operate the system. In conjunction with Space and Naval Warfare Systems Command (SPAWAR PMW-170), testing will soon begin on the use of Near Vertical Incidence Skywave (NVIS) as a means to provide battle-group beyond line-of-sight (BLOS) communications in a satellite degraded, low-probability of intercept (LPI) environment. In addition, there is already interest that the NPS HF node will participate in upcoming USMC events. It is hoped that as we gain experience with the equipment, we will be able to provide a laboratory setting for continued research and thesis opportunities for students.

UNITED STATES MARINE CORPS

MARINE FORCES PACIFIC (MARFORPAC) & MARINE CORPS EXPEDITIONARY ENERGY OFFICE (E2O)

Transportation Analysis Exploring Alternative Shipping of Marine Expeditionary Brigade Forces to Sea Base in Contingency Response Scenarios

Researchers: Dr. Eugene P. Paulo

Students: Paul Bourgeois CIV, Bradley Kelly CIV, John Petrusky CIV, John Williamson CIV and Jonathan Yi CIV

Project Summary
This capstone report supports the needs of two United States Marine Corps Sponsors: Marine Forces Pacific (MARFORPAC) and the Marine Corps Expeditionary Energy Office (E2O). Marine Forces Pacific approached the Naval Postgraduate School (NPS) to provide a capability to model deployment scenarios and perform trade-off analysis between naval, maritime, and commercial shipping based upon expediency of expeditionary forces arriving at a designated sea base. Expeditionary Energy Office approached NPS to provide a capability to predict energy consumption of the Marine Expeditionary Force in support of reducing dependency on fossil fuels in a deployed environment. The needs of these two independent sponsors were combined based on planning guidance from the 35th and 36th Commandants of the Marine Corps (CMC) emphasizing the need to reduce fuel consumption during Marine Air Ground Task Force (MAGTF) operations and identify alternative shipping to augment the Navy's 33 ship amphibious force (Amos 2010; Dunford 2015). Based on the CMC planning guidance and the sponsors capability needs specific research questions were established to frame the scope of research to the assessment and selection of fuel efficient alternative shipping sufficient to transport Marines and their equipment from home port to sea base during a range of military operations.

Background
Five Marine Corps civilian Masters Students in the non-resident Systems Engineering program utilized a Model Based Systems Engineering (MBSE) methodology to investigate the problem space, identify requirements, develop alternative solutions, and compare these alternatives with respect to combinations of vessels and ship packages that provide both mission success and measureable energy efficiency. The MBSE methodology starts with a need for combat systems effectiveness as system characteristic inputs to a combination of measures that enable the tradeoff between energy efficiency and vessel selection and are measured in "force closure

time" and "fuel consumed at force closure." This report integrates processes and tools such as systems architecting and development, simulation technologies, and advanced statistical analysis to demonstrate ways to examine impacts of sea vessel tradeoffs, and include consideration of system effectiveness in multiple criteria trade space analysis.

Findings and Conclusions (to include Process)
Following the initial research, stakeholder analysis and functional analysis, the team scoped the research to humanitarian assistance/disaster relief (HA/DR) and anti-access/area denial (A2/AD) missions. Specific focus was on the Maritime Preposition Force (MPF) operations phases of *Planning, Marshaling and Movement,* and *Arrival* in order to accomplish the *Close* phase of sea basing operations (United States Marine Corps 2009). A collection of ship packages provided a sufficient set of shipping combinations from naval amphibious fleet, Maritime Sealift Command (MSC) maritime prepositioning ship squadron, commercial, and allied nation shipping to analyze force closure and fuel consumption from the seaport of embarkation (SPOE) to the sea base.

The objective was to represent transportation alternatives in a simulation model to support systems engineering analysis; allow comparisons of various transportation approaches; and identify trade-space between transportation methods, time to close force at sea base, and fuel consumption. The capstone team performed a systems engineering analysis of the application of amphibious, military sealift command, allied nation, and commercial shipping, as a means to move personnel and equipment from the unit's garrison location or forward deployed location to a designated sea base location in support of military operations. Two measures of effectiveness (MOEs) supported further systems engineering analysis. The first measure – MOE1 – focused on Total Fuel Consumption measured in gallons. The second measure – MOE2 – Total Time to Close Force at sea base measured in hours. These MOEs were applied to both HA/DR and A2/AD to identify the impacts, measured as fuel consumption at force closure and time to force closure, when selecting alternatives to traditional/doctrinal methods of transporting personnel and equipment to a sea base.

There was significant statistical evidence to suggest that the ship packaging in the A2/AD alternatives had different means. Furthermore, the Marine Expeditionary Brigade (MEB) Amphibious Ready Group (ARG) augmented by commercial shipping results in the mean time for force closure reduced by 70%. Similarly, fuel consumption is reduced by 80% when the MEB ARG is augmented with commercial shipping. For the A2/AD mission and force closure definition, the advantages of augmenting with commercial shipping are beneficial to reducing force closure time and conserving fuel.

Recommendations for Further Research
The research and analysis conducted as part of this capstone report focused on the *Close* phase of sea basing operations. Upon arrival at the sea base location and meeting force closure criteria for the defined mission, the *Close* phase transitions to the *Assembly* phase. Recommended follow-on research into the time to complete the *Assembly* and subsequent *Employ* phases of the sea basing operations will provide further insight into the effectiveness of

augmenting Naval amphibious ships with alternative shipping platforms and its impact upon ship-to-shore movement. Additionally, the ExtendSim model developed to support this research has the flexibility to analyze multiple shipping compositions and includes the number of connector platforms available (by type) for each ship. Extension of the simulation model to account for (1) available literage, (2) lift throughput of cargo cranes, (3) roll-on/roll-off capacity, and (4) transfer rates of personnel and equipment from each ship would provide data to determine the effect of ship composition alternatives on minimizing the assembly time of the sea base operation.

MARINE FORCES RESERVE (USMCR, MARFORRES)

Optimally Locating MARFORRES Units

Researchers: Dr. Javier Salmeron and Dr. Robert Dell

Students: Capt Paul M. Brisker USMC

Project Summary
The U.S. Marine Forces Reserve (USMCR, MARFORRES) is conducting realignment studies where discretionary changes may benefit from formal mathematical analysis. This study has developed an optimization tool to guide and/or support Commander, MARFORRES (CMFR) decisions. A prototype of the optimization tool has been tested with data from the units and Reserve Training Centers (RTCs) in the San Francisco, CA and Sacramento, CA areas.

Background
The siting of MARFORRES units and the potential regional consolidation of existing RTCs is critical to ensuring long-term sustainability of the units from both an economic and a readiness perspective. Realignment decisions rely on four main pillars: existence of adequate facilities; access to training areas; how realignment affects the people in each unit; and cost effectiveness. As stated in a recent CMFR Information Brief, related primary considerations also include demographics, specific RTC features required by a unit, and a variety of costs involved in siting a unit at a new RTC such as operational costs of the facility (e.g. utilities), improvements costs (e.g. reconfiguration, upgrading, or expansion of existing facilities) and the cost of new military construction (MILCON).

Findings and Conclusions (to include Process)

Data

- Initially, we (the Principal Investigators, PIs) anticipated that the optimization tool could employ all of the following inputs:
- A listing of supported USMCR units by unit identification code (UIC).
- A listing of current RTC locations.
- A listing and characteristics of supporting training areas within the region normally used by the units (e.g., live fire ranges, maneuver areas, military operations in urban terrain facilities, swim qualification pools, etc.).
- A listing and characteristics of supporting base and installations (e.g., Military treatment facilities, Commissaries, military housing, family housing, etc.).
- Current table of organization composition by UIC for each USMCR unit.
- Current personnel home address by UIC.
- Time and distance plots between RTCs and supporting training areas.
- Plots of all principle supporting road and highway networks in the region.
- Specific basic facility requirements - and facility characteristics (e.g., size, age, condition, etc.) for each RTC (e.g., privately owned vehicle parking, tactical vehicle parking, vehicle maintenance facilities, drill halls, classrooms, gyms, administration offices, command suites, equipment warehouses, armories, etc.).
- Historical usage and cost breakdown for commercial billeting in the region by unit.
- Historical usage and cost breakdown for commercial messing in the region by unit.

MARINE CORPS SECURITY COOPERATION GROUP (MCSCG)

Optimizing USMC Security Force Assistance (SFA) in the Philippines, Malaysia, and Indonesia

Researchers: Dr. Douglas Borer and Col Ian Rice USA
Students: Amrul Adriansyah TNI–AL, Djon Afriandi TNI-AD, Emmanuel G. Cabahug PA, Antione C. Fernandes USA, Don R. Meador USMC, Scott Leuthner USA, Oryan J. Lopes USMC, Benjamin Spera USA, Edy Suntoro TNI–AL, and Travis J. Taylor USA

Project Summary. During this research period, six NPS student thesis projects and one student article were completed. Additionally, one faculty research trip to the Republic of the Philippines yielded the theoretical basis for one doctoral dissertation.

Completed Projects.

1. "SOF Joint Combined Exchange Training from a Host Nation's Perspective" by Emmanuel G. Cabahug (Philippine Army) (Cabahug E. G., 2015).

2. “Dim Networks: The Utility of Social Network Analysis For Illuminating Partner Security Force Networks” by Antione C. Fernandes and Travis J. Taylor (U.S. Army) (Fernandes & Taylor, 2015).
3. “Joint Combined Exchange Trainings: A Crucial Tool in Security Cooperation Engagement” by Emmanuel Cabahug (Philippine Army), and Scott Leuthner (U.S. Army) (Cabahug & Leuthner, 2015).
4. “The Indonesian COIN Strategy: Failures and Alternative Approaches in Overcoming the Papuan Insurgency” by Djon Afriandi (Indonesian Army) (Afriandi, 2015).
5. “The Development of Indonesia’s Doctrine for Special Hostage Rescue Operations” by Amrul Adriansyah and Edy Suntoro (Indonesian Navy) (Adriansyah & Suntoro, 2015).
6. “The Last Mile: Extending Legitimacy Using the Principles of Disaster Relief” by Don R. Meador and Oryan J. Lopes (USMC) (Meador & Lopes, 2015).
7. “The Praetorian Trap: Post 9/11 U.S. SOF Efforts to Establish Elite Military Capabilities in West Africa” by Benjamin Spera (U.S. Army) (Spera, 2015).

Ongoing Research.

1. “Foreign Security Force Advisor Training, Doctrine, and Manning for 2015 and Beyond” by Gunnar A. Spafford (USMC) (Spafford, 2015)
2. “To Break or to Build: Aligning Goals and Outcomes during Military-led State-Building Efforts.” Doctoral Dissertation from University of California, Los Angeles by Ian C. Rice (U.S. Army and Military Faculty, Defense Analysis Department, NPS) (Rice, 2015).

Background

Examining prior illustrations of SFA can help policymakers understand the long-term effects of military assistance activities. Decisions to conduct military assistance activities often assume considerable political risks. In accordance with the publication of the U.S. Defense Department’s Strategic Landpower concept (authored by Generals James F. Amos and Raymond T. Odierno and Admiral William H. McRaven), this research supports assessing long-term effects of ongoing and future SFA programs. The intent behind the 2013 “Strategic Landpower: Winning the Clash of Wills” was to improve the United States’ “to leverage partners and populations to enhance local and regional stability. Moreover, effective engagement does not rest entirely on the forward stationing of large formations. Independent teams of conventional and special operations forces can build local forces capable of handling many situations that previously called for direct U.S. intervention…”(p.6) Thus, to improve future USMC SFA efforts it is critical to look closely at prior sub-optimal military assistance activities. By identifying what features impact the tactical operations of prominent states, this research can improve awareness of the impact of specific operational and tactical practices imparted during military assistance activities past, present, and future. Such analysis could then aid the USMC in developing its regional goals to include identifying partner nations to develop into lead actors in all expeditionary type missions: humanitarian assistance, disaster relief, maritime security, and amphibious landings with subsequent land based operations.

Findings and Conclusions (to include Process)

Our nine research efforts employed three different methodological approaches: comparative case studies (7), social network analysis (1) and manpower analysis (1). This research effort has yielded three thematic findings to consider for future U.S.-led Security Cooperation efforts. First, the objectives for United States Security Cooperation efforts at large often do not align with the objectives of the partner state's military. This should not be surprising, but is of interest, since this misalignment can impact the planning and execution of individual bilateral training events as well as United States efforts to develop the long-term capacity of partner security forces. This finding is supported in three different student theses; two that focus on U.S. special operations engagements in the Republic of the Philippines and a third focusing on the development of counter-terrorism forces in the Trans-Sahel region of Africa. In each study, the United States approached engagement with a partner in a manner that took little interest of that partner into account.

Second, the United States security cooperation managers do not maintain records of prior bilateral events that would facilitate developing future campaigns to improve engagement both regionally and in specific states. Limited data on prior security cooperation events was evident in three of the above studies. This is further complicated by the fact U.S. security cooperation planners do not appear to have a strong understanding of which specific partner forces should be engaged during bilateral training events. U.S. planners tend to seek out available partner units versus those units that will improve relations with the United State as well as most efficiently improve the security force institution in a given state.

Finally, because of what appears to be limited emphasis on developing an overarching security cooperation strategy regionally and in specific states, successes during U.S. security cooperation efforts appear episodic at best in terms of producing lasting outcomes that meet both the objectives of the U.S. and the specific partner. Additionally, these episodic successes also may have a darker side as evidence from capacity development efforts in Tran-Saharan Africa show that purposes envisioned for a U.S.-developed security force may be very different than how the partner state employs them. Though nothing new, the use of U.S.-trained forces in support of coups, sectarian violence, and regime survival efforts continues to be a concern for developing security forces.

Recommendations for Further Research

The two studies that focused on Indonesia both serve as great stage setters to involve future Indonesian students on similar topics especially U.S.-Indonesian bilateral military engagements. Both studies offer a glimpse into the mindset of the Indonesian military but also pave the way for future Defense Analysis students to examine the world's largest Muslem population one that is in direct contact with China the obvious regional hegemon.

It is clear from just this first iteration of research that the United States and its security cooperation programs require additional measures to improve developing theater and country specific strategies for bilateral engagements. This focus alone has numerous possibilities for future research to include mobile applications to better collect, store, and analyze security

cooperation event data that can be in turn, be employed to influence future events. Additionally, research is needed to better measure the effects of security cooperation events. The days of simply counting completed events and partner force soldiers trained have passed. A research agenda of its own could solely focus on how to measure the impact of security cooperation events especially those events intentionally executed in a supporting role where senior decision makers spend very little attention.

- Historical usage and cost breakdown for commercial transportation in the region by unit.
- Current RTC occupancy/utilization capacity rates.
- Current planned facility improvements and funding status by fiscal year.
- Historical annual operating costs by RTC.
- Planning figures for determination of facility expansion options (e.g., MILCON,
    - Facilities, Sustainment, Restoration, and Modernization, etc.).
- Planning figures for equipment transportation within the region.
- Notional retraining costs, if applicable.
- Indicator of disruption to existing commitments or battle rhythm, by unit, if relocated.
- Indicator of value for certain groups of units to be collocated (e.g., to enhance command and control between a company and its parent battalion).
- Indicator of risk of collocating certain units (e.g. due to friction from battalions from different Major Subordinate Commands)
- Demographic data: Recruiting ratios achievable at each RTC (e.g. one in each 300 members of the recruitable population: 17-24 year-old, high-school graduates). This number may be the same for all RTC if they are in close proximity, but different otherwise.

In May 2015, the Principal Investigators (PIs) joined a MARFORRES team on a trip to RTCs in the San Francisco, CA and Sacramento, CA areas, to conduct a site visit and collect part of the above data. Additional data was received through September 2015.

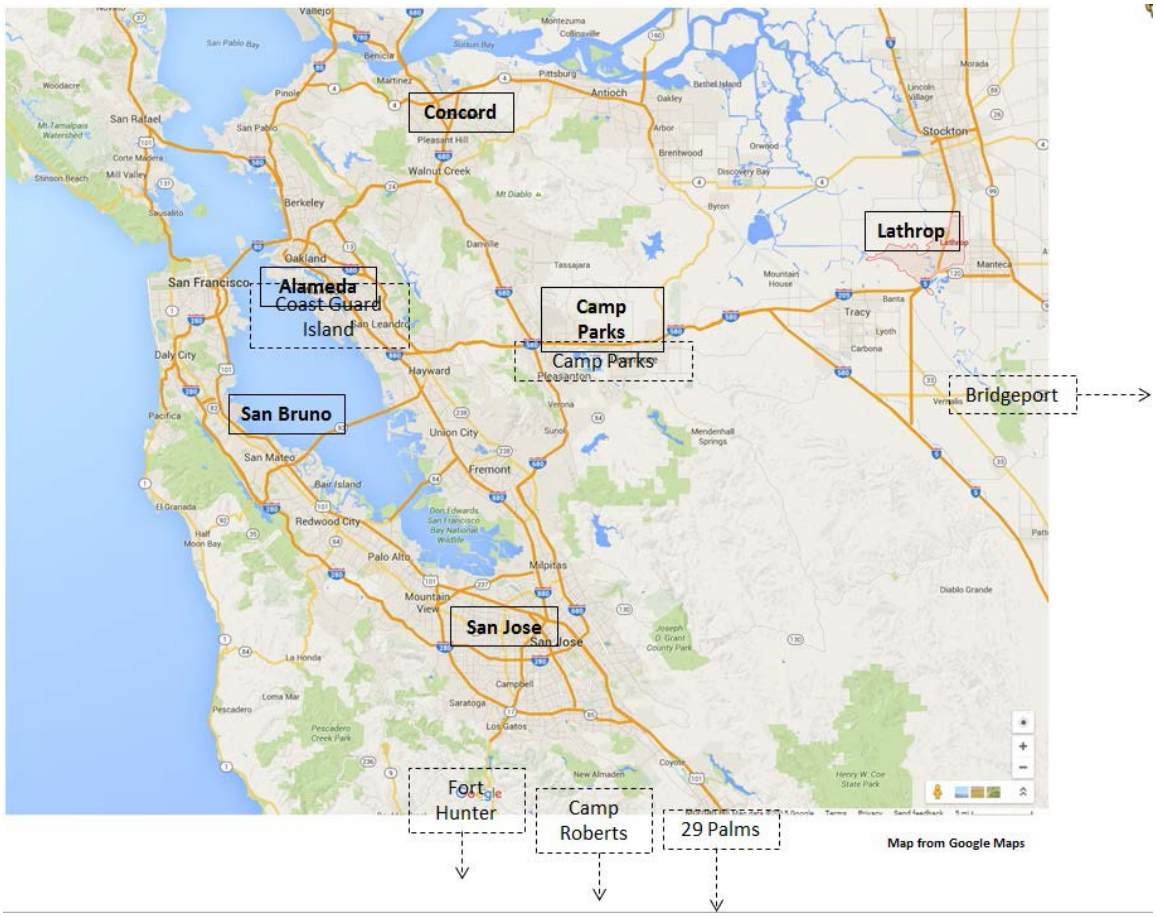


Figure 1. RTCs in the San Francisco, CA and Sacramento, CA areas

Optimization model

The PIs used the available data to build a prototypic version of Marine Corps Reserve Realignment Optimization Model (MCROM), with results based on several assumptions. Decision Variables (i.e., MCROM prescriptions):

- What RTCs remain open?
- How much expansion of each facility in each RTC?
- What UICs move?

As objective functions, we considered:

- Minimize total annual operating cost, composed of:
  - Fixed cost by RTC (we used annual services cost as a surrogate)
  - Variable cost by RTC (we used the current costs of the UICs in the RTC divided by military service personnel in the UICs as a surrogate)

    - Expansion cost of facilities (notional $1/unit of expansion across the board)
- Maximize total value
    - Value of co-locating units
    - Value of command and control and operations and training opportunity
    - Quality of life
- Minimize total distance to training areas

Constraints

We have included the following constraints in MCROM:

- Each UIC must be assigned to a unique RTC, and an RTC closes only if no UICs are stationed in it
- Total facility space (initial plus expanded) needed by UICs in each RTC is not exceeded
- Facility expansions in each RTC are within limits
- Limit the number of moves

MCROM results

MCROM was tested using the available data and a notable number of surrogates to complete unavailable data. Figures 2-7 show the prototypic results.

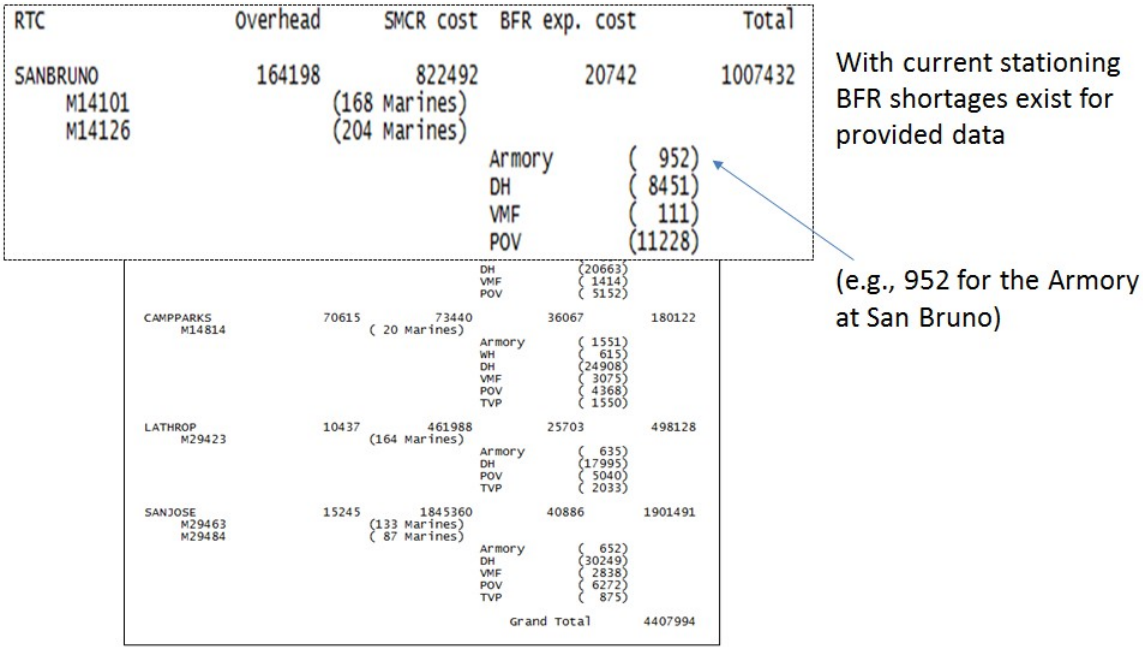


Figure 2. MCROM results with no moves

RTC	Overhead	SMCR cost	BFR exp. cost	Total
SANBRUNO	164198	822492	20742	1007432
M14101		(168 Marines)		
M14126		(204 Marines)		
			Armory (952)	
			DH (8451)	
			VMF (111)	
			POV (11228)	
ALAMEDA	22698	479584	34231	536513
M28352		(112 Marines)		
			Armory (1986)	
			DH (24622)	
			POV (7532)	
			TVP (91)	
CONCORD	140495	260434	80856	481785
M21629		(174 Marines)		
M29463		(133 Marines)		
M29484		(87 Marines)		
			Armory (2078)	
			WH (1637)	
			DH (59128)	
			VMF (6589)	
			POV (11424)	
CAMPPARKS	70615	73440	36067	180122
M14814		(20 Marines)		
			Armory (1551)	
			WH (615)	
			DH (24908)	
			VMF (3075)	
			POV (4368)	
			TVP (1550)	
LATHROP	10437	461988	25703	498128
M29423		(164 Marines)		
			Armory (635)	
			DH (17995)	
			POV (5040)	
			TVP (2033)	
			Grand Total	2703980

Two units move from San Jose (assumed highest cost per Marine, see below) to Concord (assumed lowest cost per Marine)

RTC	cost Per SCMR
SANBRUNO	2211
ALAMEDA	4282
CONCORD	661
CAMPPARKS	3672
LATHROP	2817
SANJOSE	8388

Figure 3. MCROM results with two units moving

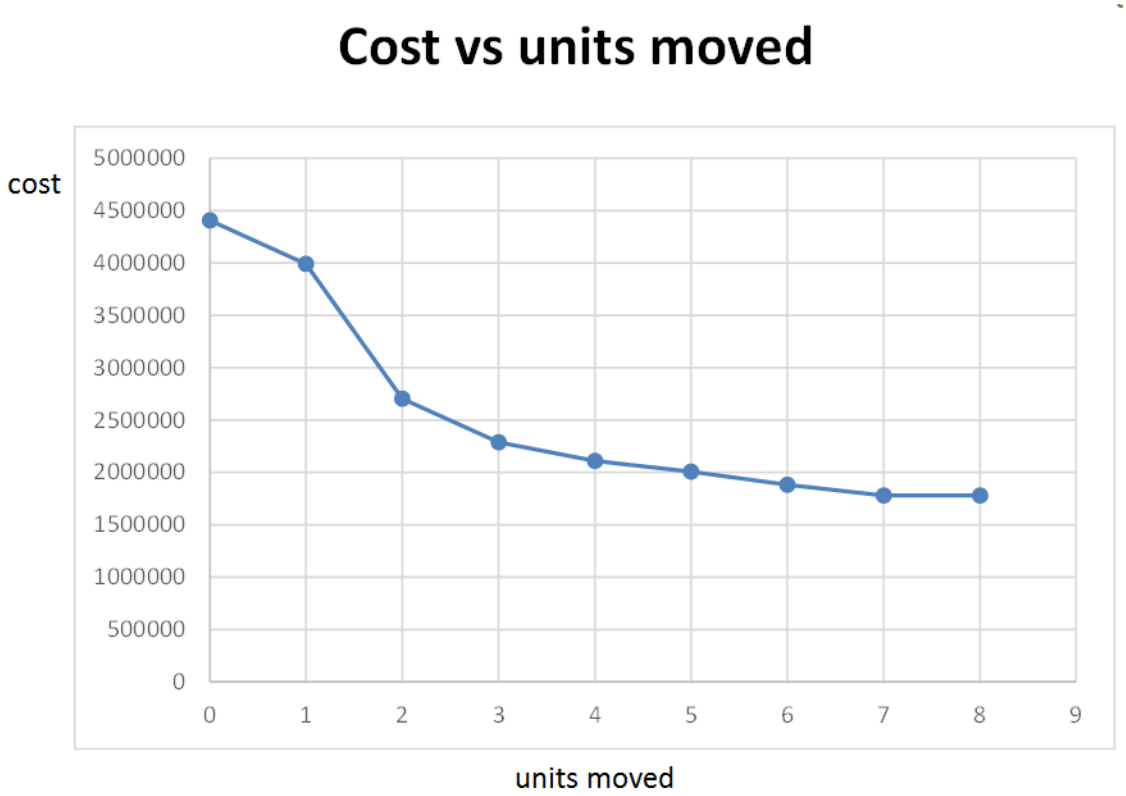


Figure 4. Cost as a function of units moved

RTC	Overhead	SMCR cost	BFR exp. cost	Total
SANBRUNO	164198	822492	20742	1007432
M14101		(168 Marines)		
M14126		(204 Marines)		
			Armory (952)	
			DH (8451)	
			VMF (111)	
			POV (11228)	
ALAMEDA	22698	479584	34231	536513
M28352		(112 Marines)		
			Armory (1986)	
			DH (24622)	
			POV (7532)	
			TVP (91)	
CONCORD	140495	115014	28799	284308
M21629		(174 Marines)		
			Armory (886)	
			WH (684)	
			DH (20663)	
			VMF (1414)	
			POV (5152)	
CAMPPARKS	70615	73440	36067	180122
M14814		(20 Marines)		
			Armory (1551)	
			WH (615)	
			DH (24908)	
			VMF (3075)	
			POV (4368)	
			TVP (1550)	
LATHROP	0	0	0	0
SANJOSE	15245	3220992	80921	3317158
M29423		(164 Marines)		
M29463		(133 Marines)		
M29484		(87 Marines)		
			Armory (1287)	
			DH (55851)	
			VMF (8013)	
			POV (11312)	
			TVP (4458)	

UIC	UIC	value
M14101	M14126	5
M14101	M29463	1
M14101	M29484	1
M29423	M29463	5
M29423	M29484	5
M29463	M29484	5
M21629	M14814	3

1 = Co-location Detrimental
3 = Co-location Neutral
5 = Co-location Beneficial

UIC	C2 Opportunity Index	Ops/Training Opportunity Index
M14101	1	1
M14126	1	1
M28352	1	1
M21629	5	5
M14814	5	5
M29423	3	5
M29463	1	5
M29484	1	5

1 = no opportunity
3 = Moderate opportunity
5 = Signficant opportunity

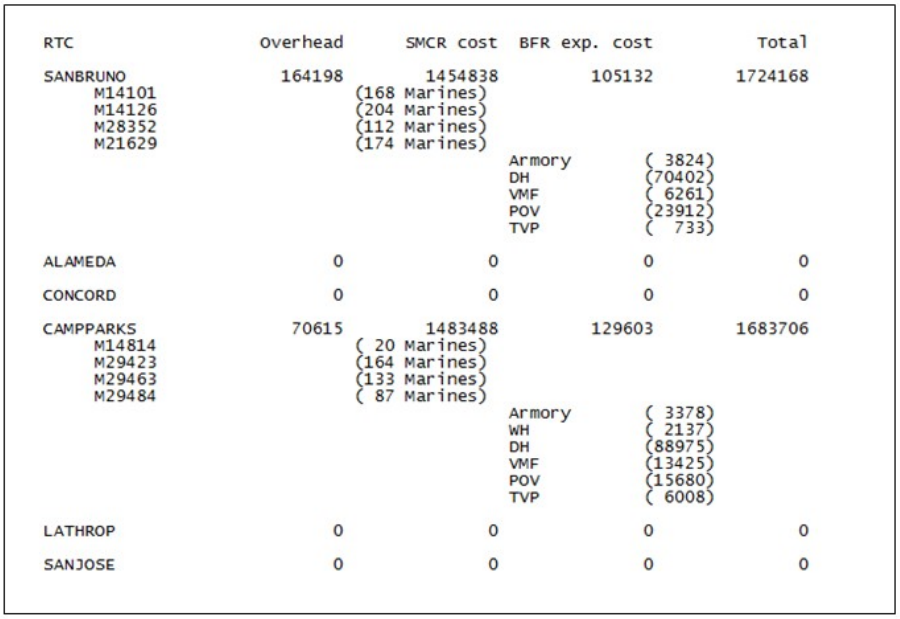
Figure 5. Different objective: Maximizing total value, with one move allowed

UIC	Range	KDRange	Maneuver	MOUT	Pool	CBRN	Amphib	Dive	Jump	JTAC/CFF
M14101	X	X	X		X	X	X			
M14126	X	X	X	X	X	X	X			X
M28352	X	X	X	X	X	X	X	X	X	X
M21629	X	X	X	X	X	X	X		X	X
M14814	X				X	X				
M29423	X				X	X				
M29463	X				X	X				
M29484	X				X	X				

Training Area	Code	Y/N
Camp Parks	Range	N
Camp Parks	Maneuver	N
Camp Parks	MOUT	Y
Camp Parks	Pool	Y
Camp Parks	Amphib	N
Camp Parks	Dive	N
Camp Parks	CBRN	Y
Camp Roberts		
Fort Hunter Liggett		
29 Palms		
Coast Guard Island		
NAS Fallon, NV		

RTC	Camp Parks	Camp Roberts	Fort Hunter	Bridgeport	29 Palms	Coast Guard Island
SANBRUNO	40	184	130	272	508	2.7
ALAMEDA	23	181	163	260	509	1.8
CONCORD	35	194	176	243	492	27
CAMPPARKS	0	173	155	231	489	23
LATHROP	44	207	192	195	470	61
SANJOSE	38	144	126	260	481	38

Figure 6. Data for minimizing travel distance for training. The top table indicates what UIC require certain training. The table on the right indicates where each type of training is available. The bottom table shows distances from RTCs to training areas.



RTC	Overhead	SMCR cost	BFR exp. cost	Total
SANBRUNO	164198	1454838	105132	1724168
M14101		(168 Marines)		
M14126		(204 Marines)		
M28352		(112 Marines)		
M21629		(174 Marines)		
			Armory (3824)	
			DH (70402)	
			VMF (6261)	
			POV (23912)	
			TVP (733)	
ALAMEDA	0	0	0	0
CONCORD	0	0	0	0
CAMPPARKS	70615	1483488	129603	1683706
M14814		(20 Marines)		
M29423		(164 Marines)		
M29463		(133 Marines)		
M29484		(87 Marines)		
			Armory (3378)	
			WH (2137)	
			DH (88975)	
			VMF (13425)	
			POV (15680)	
			TVP (6008)	
LATHROP	0	0	0	0
SANJOSE	0	0	0	0

Figure 7. Minimizing travel distance. For example, unit M29484 requires “Range”, “Pool” and “CBRN” training facilities. By moving to Camp Parks, it does “Pool” and “CBNR” at Camp Parks and Range at Fort Hunter Liggett (155 miles away). From its current location (San Jose), it does “Pool” and “CBNR” at Camp Parks (38 miles away) and Range at Fort Hunter Liggett (126 miles away).

Further Research

We recommend MARFORRES validates the existing data and collects requested data to enhance MCROM’s fidelity. All the data available could be incorporated into a future version. MARFORRES planners would also benefit from a graphical user interface to improve usability of MCROM by non-optimization experts.

HQMC INSTALLATION AND LOGISTICS (I&L)

USMC Distribution in the Battlespace

Researcher: Anthony Kendall

Students: Capt Margaret Snyder USMC and Capt Sarah Bergstrom USMC

Project Summary

The Naval Postgraduate School (NPS) research team is tasked to develop an information architecture that selects relevant information from the command and control (C2); command, control, communications, and computers (C4); In-Transit Visibility (ITV) databases and other logistic and sources to create an integrated Information System model that captures the information needed for the effective tactical distribution of supplies for ground and air supporting Marine Air-Ground Task Force (MAGTF). The researchers are documenting and providing an ETL (Extract Transformation Loading) framework strategy for the relational sources. The research is developing a "proof of concept" prototype that provides example analytics for the end user.

Background

Our previous research in decision support and knowledge management systems that support commands such as Space and Naval Warfare Systems Command (SPAWAR) used platforms based on Oracle Collaboration Suite and most recently Oracle Portal 11g and Beehive (collaboration platform). This work resulted in the successful implementation of a production decision support and knowledge management system, Forces Innovation & Research Enterprise (FIRE) used for fleet experimentation and acquisition decision-making. This technology is based on Rapid Application Development (RAD) technology as described below.

In FY13 we provided "proof of concept" analytics for the Global Combat Support Systems-Marine Corps ((Evaluating the Oracle Platform as a Decision Support System) using the relatively new form of information systems development, the Model View Controller(MVC)development pattern and the open source Java Platform, Enterprise Edition EE (J2EE) - web application standard that allows for robust and customizable platforms. This new technology makes it possible to implement systems in a more timely and cost efficient manner through agile development of web applications and analytics. The ability to rapidly customize information systems was not possible or difficult and expensive to implement when development focused on the three-tiered architecture. The technology implementation of MVC is through Oracle's ADF (Application Development Framework) a Java development platform that can be used to create dynamic content on portals including WebCenter. WebCenter is built on this ADF framework but comes out of the box with collaboration, analytics and decision support capabilities. Another application called Oracle BI (Business Intelligence) can be integrated to provide additional business analytics.

Findings and Conclusions (to include Process)- as of April 2016
This project was extended to June 2016 due to financial considerations. The project is on track to finish all deliverables by end of project including the thesis. In April 2016 the sponsors and researchers met via web conferencing for an initial project review (IPR) where the researchers conducted successful web software demonstration of the analytics developed by the thesis students. The software accessed both extracts from the TCPT (Transportation Capacity Planning Tool) and TBCMS (Theater Battle Management Core System) to provide transportation logistics metrics for basic decisions asked for by the sponsors. Extraction procedures and identified data problems are being identified in order to make a production version successful. The project has successfully demonstrated that the ADF development framework with proper data sources can provide useful transportation logistics. The current software is only a demonstration and much more analytics could be added if the database deficiencies are dealt with. Some of the database problems would go away if the prototype ran in a classified environment as the researchers did not have classified extracts of real data.

Recommendations for Further Research
Improvement of proof of concept to include more analytics and in a classified environment. Depending on the additional analytics wanted by the sponsor, additional data sources could be extracted besides those from TCPT and TBCMS. Cost-benefit analysis on using contractors to develop application versus sending individuals through Oracle based training to quickly develop their own applications using RAD (Rapid Application Development) methodologies.

HQMC PROGRAMS AND RESOURCES (P&R)

21st Century Retention: The Design of Tailored, Non-Monetary Incentives for Retention in the Marine Corps Cyber Community

Researchers: Dr. Thomas Albright and Anita Salem

Students: Capt Lucas F. Hernandez USMC and Capt Derek K. Johnson USMC

Project Summary Using human-centered design processes, we looked at the attitudes, beliefs, motivations, and behaviors embedded in the cyber community to help solve the problems of retaining high value cyber employees. The research consisted of three activities:

1. Student thesis (Hernandez & Johnson, 2014)
    - Conducted a review of relevant literature pertaining to the use of non-monetary incentives and deliver a thesis on the topic.
    - Interviewed cyber personnel

2. Developed a Design Thinking workshop (completed)
    - Developed a 3 day workshop based on earlier research that examined how to design solutions to the retention of cyber personnel (Completed).

3. Conducted a Design Thinking Workshop (completed)
    - Facilitated a workshop with 20 NPS students focused on designing solutions to cyber retention.

Background
United States Marine Corps Forces Cyberspace Command's (MARFORCYBER's) mission is to: plan, coordinate, integrate, synchronize, and direct the Marine Corps' full spectrum of cyberspace operations. MARFORCYBER is a young organization and faces a number of challenges in recruiting, training, equipping, and retaining cyber personnel. There is a pervasive national shortage of qualified cyber personnel, both in the Marine Corps and the Nation at large. To retain quality cyber personnel, the Marine Corps must identify those factors that cause cyber personnel to separate from active service and explore specific incentives to retain them. This research study used Design Thinking to look at how non-monetary incentives can be used to increase retention in the Cyber community.

Findings and Conclusions Based on the data gathered and analyzed during the design research phase, eleven themes emerged as considerable impacts to Marine cyber workforce retention. The themes included items related to incentives, personal factors, and organizational influences:

Key Incentives for Cyber Retention
- Monetary incentives
- Duty station preference
- Geographic stability
- Education
- Transferrable skills and external career opportunities
- Internal career progression

Important Personal Factors Impacting Cyber Retention
- Personal interests and goals
- Culture and relationships

Key Organizational Influences on Cyber Retention
- Access to technology
- Involvement in process development
- Command climate and bureaucracy

Once these eleven themes were identified, they were incorporated into a Design Thinking workshop where the goal was to design conceptual prototypes for improving retention in the DOD cyber workforce. These prototypes resulted in three retention solutions:

- **Career progression model:** Experts are developed by setting transparent expectations for career progression, training, and certifications. The model assumes changes in motivation throughout ones career.

- **Closed model**: Everyone is a Cyber Warrior and cyber expertise is developed internally, starting with targeted recruits and continuing throughout active service. This model relies on competition.
- **Fluid career model**: Support career change by extending outreach efforts to engage and recruit individuals at all stages of a career; align individual skills to organizational needs, and adapt processes to support changing career needs. The model includes multiple on-ramps and off-ramps to service.

Recommendations for Further Research

An acute understanding of extrinsic and intrinsic motivations is required when analyzing the value of incentives to cyber personnel. The unique characteristics and interests of cyber personnel influence these motivations. While the use of monetary incentives as extrinsic motivators is a concept traditionally used in military retention, it does have limitations. These incentives may not be sustainable during fiscally and politically constrained times. Further, this study aligns with previous studies to conclude that intrinsic motivators are equally important to cyber professionals. Specifically, we recommend the following:

Provide tailored incentives to motivate retention

- Combine incentives
- Support career change and growth
- Evaluate retention strategies for each community

Match talent and experience with the job

- Improve the detailing process
- Adapt lateral transfers
- Improve job recruitment and screening
- Groom up-and-coming talent

Create a better working environment with increased job satisfaction

- Provide fair-minded leadership
- Invest in highly skilled HR staff and HR technologies
- Modify work practices to increase job satisfaction

Build commitment to community

- Involve Service members in retention strategies
- Increase team-building activities while afloat
- Build career roadmaps based on community needs

I MEF

Captured Cost of Current Tactical OTH Communications Capabilities for Extended MAGTF Operations

Researchers: Dr. Gurminder Singh, Dr. Man-Tak Shing and John Gibson

Students: Capt Charles Casey, USMC, LT Carl Stokes USN and Jin Wei Lai INTCIV

Project Summary

The goal of the project is to analyze the fully captured cost (USMC and DOD enterprise costs) of current over the horizon (OTH) communication and its ramifications for equipping the Marine Air-Ground Task Force (MAGTF) during ship to shore operations in support of amphibious and Maritime Prepositioning Force (MPF) operations in conventional and Ship-to-Objective Maneuver (STOM) scenarios. The study will consider both attended and unattended communications systems. It will consider terrestrial, aerial, and space-based communications systems.

Background

The Marine Corps Air Ground Task Force (MAGTF), as "the Nation's force in readiness… will be increasingly reliant on naval deployment, preventative in approach, leaner in equipment, versatile in capabilities, and innovative in mindset." [Vision Statement, Marine Corps Vision & Strategy 2025, 2007] The mission sets for which the USMC MAGTF is responsible under the Extended MAGTF Operations (EMO) strategy to support Ship-to-Objective Maneuver (STOM) planning requires high capacity, reliable communications from the advance task elements operating at the tactical edge to the command and control (C2) elements afloat and ashore. The recent collection of field experiments conducted by the Infantry Officer Course and the Marine Corps Warfighting Lab underscore the need for response, high capacity communications within and between task elements, as well as reach back to higher headquarters throughout the wide area of operations associated with EMO (Waddell, 2014); (Waddell, ICCRTS paper, 2014). These experiments highlighted shortfalls in current capabilities that adversely impact the ability of small unit task elements to conduct operations when geographically separated from other units or command organizations.

Emerging commercial satellite systems, O3B [http://www.o3bnetworks.com] being one such network, are offering significantly higher bandwidth/throughput than current government systems. Previous thesis efforts explored the leveraging of small-unit-operated Unmanned Aerial Vehicles as a means of extending higher bandwidth capability to dispersed forces (Rao & Simmons, 2013); (Menjivar, 2012). These theses, through field experiments, explored the use of commercial-off-the-shelf (COTS) radios as a means of relaying tactical communications over-the-horizon (OTH) or beyond line of sight (BLOS). A baseline is needed by which to assess the value-added or increased-capability of candidate systems against current OTH/BLOS systems available for use by the MAGTF to support dispersed operations.

Findings and Conclusions (to include Process)
Two USMC Captains took this topic up for their M.Sc. (Computer Science) thesis; they are supervised by Dr. Gurminder Singh and Dr. Man-Tak Shing, and with assistance from Prof. John Gibson. The students have made significant progress on the topic and are in the process of writing their thesis. As of the writing of this report, they have completed advanced drafts of their thesis chapters 2, 3 and 4. This research started by reviewing current systems, their capabilities and associated costs. This was followed by developing a model which takes as inputs the desired parameters (cost, reliability, robustness etc.) and recommends systems that best meet the desired parameters. We expect to have the research completed and thesis published by June 30, 2016. We have also been in constant communication with the sponsor of this project and have been taking his input in to account for the research.

Recommendations for Further Research
Specific recommendations for Future Research are forthcoming in the report which is currently under preparation.

Extended MAGTF Operations Aerial Layer Communications Experimentation

Researchers: Dr. Gurminder Singh, Dr. Man-Tak Shing, John Gibson and Charles Prince

Students: Capt Jamie Claflin USMC, Capt Peter Bose USMC and Capt Ben Tuck USMC

Project Summary
This research explored current and emerging aerial layer communications, such as balloons or small form factor aerostats (tethered and untethered) and long-endurance UAVs, to provide high-capacity, high-availability communications support in satellite-denied terrain. Through field experiments of leveraging commercial-off-the-shelf (COTS) technologies, the study investigated the feasibility of purported aerial layer architectures. The results of the study provided specific filed experiment results concerning options to equip expeditionary forces with reliable Over-the-Horizon (OTH), On-the-Move communications to the tactical end user to address capability shortfall between stated priorities of Marine Corps expeditionary strategy and the demonstrated ability to conduct distributed command and control operations.

Background
Extended Marine Air-Ground Task Force (MAGTF) Operations require significant communications capabilities on forces that must be highly maneuverable and minimally equipped in order to satisfy the intelligence and command and control demands of fast-response forces. Several recent thesis efforts have explored possible alternatives for leveraging unmanned aircraft platforms as a means to extend communications beyond the capability of current tactical radio systems (Rao & Simmons, 2013); (Everly & Limmer, 2014). Further, emerging satellite systems, o3B [www.o3Bnetworks.com] being one such system, profess to provide near optical-fiber performance. However, mission constraints may prevent access to

such systems. An aerial layer network seeks to leverage other capabilities, perhaps in conjunction or in parallel with satellite systems, to meet the demand for high throughput, on demand data service.

The USMC tactical radio inventory lacks a system suitable for supporting OTH, high data-rate communications with on-the-move distributed combat elements. Recent experimentation by the Infantry Officer Course explored the utility of the Distributed Tactical Communications System (DTCS) radios, or Netted Iridium, to support on the move forces (Waddell, 2014). As it is a satellite-based system, Push-to-Talk broadcast voice capability it received accolades for its performance in Afghanistan (Rosenberg, 2010). However, the on-the-move distributed combat elements require high-speed data not available from current systems and satellite based systems may be vulnerable or otherwise inaccessible to tactical edge forces. Small form factor systems, requiring low power offer opportunities to leverage aerial systems as relay platforms. Depending on the size, weight, and power (SWaP) characteristics of these systems they may be suitable for small UAV or aerostat/balloon deployment.

Virtual Private Networks and other IP-based tunneling capabilities offer means of interconnecting current tactical data systems. Leveraging aerial platforms may allow the integration of disparate and geographically separated data networks, allowing remote combat elements to maintain critical command and control links to higher headquarters. Such integration efforts may make use of emerging commercial products to mitigate the cost and fielding-delays inherent in typical military communication systems without sacrificing the inherent security of existing military systems. Further, free space optics may provide a path to near optical-fiber data-rates between distant units. This research will explore such capabilities thorough field experimentation.

Findings and Conclusions (to include Process)
One USMC Captain took this topic up for his M.Sc. (Computer Science) thesis, –he was supervised by Prof. Gurminder Singh and Prof. John Gibson, and with assistance from Research Associate Charles Prince. The student completed his thesis in Jun 2015 (“High-Capacity and High-Availability Aerial Layer Network (ALN) Communications Support to The Tactical Level”). His thesis identified significant transmission range constraints for the COTS radio system employed as a payload on the Space Data Corporation SkySat high-altitude, untethered, balloon platform. Principal causes for the range issue is the available transmit power and low-gain antennas. Subsequent efforts on this project include investigation of the use of off-the-shelf tactical radios as a means of providing low bandwidth tactical chat capability to dispersed forces, as well as exploring better antennas for the Wave Relay radio system, to include an more capable radio, the 5th generation Persistent Systems Wave Relay 5100 radio. Additional field experiments, in concert with I Marine Expeditionary Force (I MEF) Science and Technology (S&T) are planned for this FY as part of the follow-on effort to this project.

We have also been in constant communication with the sponsor of this project and have been taking his input in to account for the research.

Recommendations for Further Research Specific recommendations for Future Research are forthcoming in the on-going follow-on project.

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NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL