United States Military Academy
West Point, New York 10996

ANNUAL REPORT

OF THE

OPERATIONS RESEARCH CENTER

FOR

ACADEMIC YEAR 2000

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PART I - The Operations Research Center of Excellence (ORCEN)

Purpose of the Operations Research Center

The purpose of the Operations Research Center is to provide a small, full-time analytical capability to both the Academy and the United States Army. The Operations Research Center helps to fill several Academy needs:

(1) enriched education for cadets;
(2) enhanced professional development opportunities for Army faculty;
(3) strong ties between the Academy and Army agencies; and
(4) the integration of new technologies into the academic program.

By being fully engaged in current Army issues, the Operations Research Center assures that systems engineering education at West Point remains current and relevant. The one-year experience tour with the ORCEN offers officers assigned to the Academy as faculty the opportunity to engage in meaningful applied research and problem solving activities that both further enhances their soldierly professional development and keeps them current in their discipline. The Army's return on its investment is meaningful career development experiences for officers, especially those in Functional Areas 49/51/53, and important investigation of vital Army problems at far less cost than would be required through civilian contracts.

Operations Research Center projects provide the faculty and cadets with the opportunity to investigate a wide spectrum of interdisciplinary, systemic issues and to apply many of the systems engineering, engineering management, and operations research concepts studied in the classroom to real-world problems of interest to the Army. These projects demonstrate for both cadets and faculty the relevance and importance of systems engineering in today's high technology Army.

Organization of the Operations Research Center

Personnel authorizations in the ORCEN are established by a Table of Distribution and Allowances (TDA). Funding support for the Operations Research Center is established by a Memorandum of Agreement with the Office of the Assistant Secretary of the Army (Financial Management & Comptroller). The Operations Research Center is organized under the Office of the Dean as an Academy Center of Excellence. A permanent Military Academy professor provides oversight and supervision to the Center. In addition, the TDA authorizes one analyst, O5; three analysts, O4; and one secretary, GS5. By agreement between the Department of Systems Engineering (D/SE) and the Department of Mathematical Sciences (D/MATH SCI), three analysts are assigned to the ORCEN by D/SE, and one analyst comes from the D/MATH SCI. The Department of Systems Engineering also provides the permanent faculty member to serve as the Director.

The Operations Research Center welcomes the opportunity to collaborate on Army-related projects with USMA teaching faculty from the Departments of Systems Engineering, Mathematical Sciences, and others. In addition, the ORCEN is able to provide Army officers attending graduate school and cadets enrolled in advanced individual study courses with real-world projects that are well suited for either thesis work or course projects. This in turn provides Army agencies with a greater range of expertise to address a wide spectrum of projects.

The Operations Research Center occupies office and laboratory space in the Department of Systems Engineering on the third floor of Mahan Hall. The Center includes offices for the director and analysts, and a briefing area. The Department of Systems Engineering laboratories -- Combat Simulation, Systems Management and Design, Computer Aided Design, and Installation Management and Engineering -- are located within easy access to the Operations Research Center.

The Operations Research Center is sponsored by the Assistant Secretary of the Army (Financial Management & Comptroller). Fully staffed and funded since Academic Year 1990-1991, the Operations Research Center has made significant contributions to cadet education, faculty development, and the Army at large.

Personnel

The following is a list of the Operations Research Center positions and personnel assigned during FY00.

CONTRIBUTING ORGANIZATION	NAME	PHONE	EMAIL
Head, DSE:	COL Michael L. McGinnis, Ph. D.	688-2701	fm0768@usma.edu
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Analyst (DSE):	MAJ Murray P. Starkel	688-5941	fm7485@usma.edu
Analyst (DSE):	MAJ Kevin E. Dice	688-5663	fk7008@usma.edu
Analyst (DSE):	CPT John B. Willis	688-5661	fj4238@usma.edu
Analyst (D/MATH SCI):	CPT Douglas Matty	688-5616	ad8780@usma.edu

These full-time analysts are augmented by permanent faculty who serve as senior investigators for each project, as well as by instructors from the Department of Systems Engineering, the Department of Mathematical Sciences, and other departments who work as primary analysts or co-analysts on ORCEN projects. Contributors for AY00 are listed in the following table.

TITLE	NAME	PHONE (DSN)	EMAIL
Professor	Gregory Parnell, Ph.D.	688-4374	fg7526@usma.edu
Academy Professor	LTC James F. Sullivan, Jr., Ph.D.	688-4754	fj2236@usma.edu
Associate Professor	John V. Farr, Ph.D.	688-5534	fj8305@usma.edu
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Assistant Professor	LTC Eugene P. Paulo, Ph.D.	688-2510	fe8547@usma.edu
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Laboratory Resources

Systems Management and Design Lab (SMDL)

This lab is designed to facilitate group design work, ideation and sharing. Presentation and conferencing facilities are part of the lab. The principle function of the lab is to facilitate cadets working as groups as they move through the systems engineering design process, particularly the formulation and interpretation of alternatives steps. A secondary purpose is to provide a sophisticated meeting and briefing place for all kinds of groups with the capability to enhance their work. Lab equipment is designed to be reconfigurable to accommodate different size groups and organizations.

The lab's 17 workstations are IBM-compatible personal computers with a Pentium/300 processor, 64 MB RAM, 4.3 GB hard disk drive, 3-1/2" floppy drive, CD-ROM, SVGA graphics card, 17" multisync monitor, and SMC ethernet card. This capability allows cadets to use advanced software and peripherals for high-speed data processing and high quality graphics. One of these workstations is used as the facilitator's workstation while the others are nodes in the CSCW software package (GroupSystems V).

Installation Management and Engineering Annex

The Installation Management and Engineering Annex (IMEA) to the SMDL provides cadets and faculty with the tools needed to study installation management and power projection related issues. Engineering Management cadets use Geographic Information System (GIS) and other engineering analysis software in the Introduction to Systems Design for Engineering Managers (SE411) as well as in the follow-on capstone design courses (SE421). Other cadets use the facility to conduct in-depth research in advanced individual study courses (SE 489).

The hardware configuration of the IMEA consists of five high-end PC based graphics workstations. These include a Intergraph TD 300 graphics workstation. The TD300 supports the graphic intensive software programs in Intergraph's MGE product suite, in addition to the underlying ORACLE databases. In addition to the GIS, these workstations also run MS Project, AutoCAD, and software specific to installation management.

Combat Simulation Laboratory

The Combat Simulation Laboratory (CSL) offers state-of-the-art simulation and analysis tools for virtual prototyping, testing and evaluation in distributed and non-distributed environments. Cadets combine premier Army simulations and commercial-off-the-shelf (COTS) modeling tools to gain insight into real-world Army problems. Cadets build a foundation in Combat Modeling (SE 485) and apply their knowledge in System Design I and II (SE 402/403) and in Advanced Individual Study in Systems Engineering or Engineering Management (SE 489). ORCEN analysts and department faculty use the facility to approach a variety of problems.

Janus, ModSAF, NPSNET, EADSIM, and ITEMS are the primary simulations. JETS, the Janus Evaluator's Tool Set, is the main analysis tool and simulation browser. Simulation output may be analyzed directly through JETS or exported to a variety of other tools, such as Minitab. COTS tools include MultiGen II and MultiGen II Pro 3D modeling software. Hardware includes an Onyx Infinite Reality graphics supercomputer, 6 Silicon Graphics Indigo II workstations, 2 Hewlett-Packard K-class superminis and an HP 735 computer, 2 Sun SPARC 10s, a SPARC 2, and a 670MP server, 11 X-terminals, and a pentium PC. All hardware is networked through a Cisco 5000 switch to the internet via fiber optic cable.

PART II - Principal Research Activities for AY00

Measuring Financial Management Performance at ASA (FM&C)

Client Organization: The Assistant Secretary of the Army for Financial Management and Comptroller – ASA (FM&C)

Points of Contact:

Name:	Address:	Phone:	Other:
Ms. Barbara Bonessa	Chief, Financial Management Integration and Evaluation Division	DSN 227-5071 (703)697-1730	bonesbl@hqda.army.mil

Problem Statement:

ASA (FM&C), is attempting to assess its performance as an organization with a rigorous comparison against other organizations. Specifically, the ASA (FM&C) is seeking valid performance measures to help provide a basis for assessing the economy, efficiency, and effectiveness of services provided by their organization. These measures will then be used to benchmark their performance against that of other similar or somewhat dissimilar organizations. Benchmarking is a widely used tool in the private sector for organizations to assess their performance compared to that of their competitors and other "world-class" organizations, then develop a plan to improve performance.

Proposal of Work:

Research the performance measures of similar government organizations inside and outside the DoD and "world-class" financial management organizations in the private sector and advise ASA(FM&C) on which other organizations and metrics should be used. Specifically:

- Perform an extensive literature search and meet with other organizations to establish a set of valuable performance measures that are relevant, understandable, comparable, timely, consistent and reliable.
- These elements of performance measurement should include
  (a) measures of service efforts (input indicators),
  (b) measures of service accomplishments (output and outcome indicators),
  (c) measures that relate service efforts to service accomplishments (efficiency and cost-outcome indicators), and
  (d) explanatory information.
- Gain consensus from potential participants to provide quantitative and qualitative data to measure their performance using the metrics selected

Senior Investigator: LTC Mark J. Davis

Principal Analyst: MAJ Murray P. Starkel

Status: Complete.

Summary:

As the federal government continues to improve its financial accountability to the taxpayers, the Department of Defense (DoD) is also trying to increase its efficiency. Within DoD, the Department of the Army and specifically, the Office of the Assistant Secretary of the Army for Financial Management and Comptroller (OASA(FM&C)) are critical participants in this search for better business practices and enhanced control over the Planning, Programming, Budgeting, and Execution System (PPBES), which is the Army's process for obtaining the funds required to complete its mission. The ASA(FM&C), Mrs. Helen McCoy, wants to improve the performance of her organization in managing the Army's budget.

Mrs. McCoy seeks to measure her organization's performance with respect to her peer organizations in and out of the federal government. However, in order to benchmark OASA(FM&C) against other entities, the internal processes, products, and services must be examined and thoroughly understood. This examination should include an assessment of the user's requirements for each of the products and services OASA(FM&C) provides, and a description of the qualities and attributes associated with these products and services. Once this analysis is complete, then OASA(FM&C) can compare its performance against its peer organizations.

This report studies the process of developing performance measures for financial management in the federal government, and contrasts this process with the methodologies and performance measures used in the private sector. Performance measures and practices currently in use by other organizations are reviewed, and lessons are extracted from the relevant literature. A case study of one segment of OASA(FM&C)'s customers is presented, and performance measures are proposed. Finally, conclusions from this case study are drawn, and topics for further research are suggested.

Presentations and Publications:

- Starkel, Murray P. Technical Report: *Performance Measurement in the Office of the Assistant Secretary of the Army (Financial Management and Comptroller)*, December 2000
- Starkel, Murray P. Presentation at the Military Operations Research Society, Working Group 24 (Measures of Effectiveness): *Measuring Financial Management Performance at ASA (FM&C),* United States Air Force Academy, Colorado Springs, CO, June, 2000

Personnel Briefed:

- Mrs. Erin Olmes (Principal Deputy – ASA(FM&C) *IPR and Interim Analysis of Interviews* – 17 May, 2000

- Mrs. Helen T. McCoy (ASA(FM&C) *Customer Survey Results* – 1 August, 200
- Mrs. Erin Olmes (Principal Deputy – ASA(FM&C) *Strategic Performance Measures Plan* – 18 December, 2000

Enlisted Bonus Distribution Model (EBDM)

Client Organization: United States Army Recruiting Command (USAREC)

Points of Contact:

Name:	Address:	Phone:	Other:
COL Greg Parlier	Headquarters, United States Army Recruiting Command (USAREC) 1307 Third Avenue Fort Knox, KY 40121-2726	DSN: 563-0325	
MAJ Mark Young	USAREC PA&E	DSN 563-0325	Mark.Young@usarec.army.mil
MS Claudia Beach	USAREC PA&E	DSN 563-6839	Beachc@usarec.army.mil

Problem Statement:

Develop a dynamic model which will enable USAREC to efficiently allocate its roughly $60 million annual recruiting budget among the possible enlistment incentives. A mix of the available enlistment incentives is used to attract the required number of enlistees for all critical MOSs. The model must evaluate 194 entry level MOSs and 8 different enlistment incentive packages. Evaluate the usefulness of the current Choice Based Conjoint (CBC) analysis and recommend improvements. Consider incentives used by other organizations competing in the same market segment and propose more effective enlistment incentives.

Proposal of Work:

Develop in conjunction with USAREC, a dynamic pre-emptive goal program, which has two goals. The first goal is to minimize the deviation from the target number of enlistees and the total enlistment incentive budget. This goal attempts to achieve the target number of enlistees required for each critical MOS as the first priority while remaining within or below the budget is a second priority. The second goal is to minimize total cost without falling below the minimum required number of enlistees. Design and evaluate two alternative competing models. One model will allow solutions that exceed the budget while the other will only consider solutions which are less than the budget. Both models will be dynamic in that the MOSs will be represented by binary variables allowing the user to select which MOSs are critical and allocate the budget among only these critical MOSs. Conduct an analysis of other incentives used by other organizations that have the same market segment.

Senior Investigator: Dr. Gregory Parnell

Principal Analyst: MAJ Kevin E. Dice

Status: Completed, follow-on work with USAREC

Summary:

Periodically, representatives from the United States Army Recruiting Command (USAREC), the Office of the Deputy Chief of Staff Personnel (DCSPER) and the Personnel Command (PERSCOM) meet to form the Incentive Review Board (IRB). The task of the IRB is to determine the enlistment incentives to offer for each MOS to ensure the Army meets recruiting goals while remaining within the recruiting budget. This task has become increasingly harder as evidenced by the failure of the Army to meet recruiting goals in three of the last five years. The IRB requires a decision support tool that will assist the members in doing the following: (1) predict the number of individuals who will enlist into a given MOS over a certain time of service for a given incentive; (2) determine the optimal mix of incentives to offer for each MOS to meet its recruiting goal; (3) minimize the deviation from the recruiting goals for each MOS to remain within the recruiting budget. This paper describes the methodology used to create such a decision support tool, known as the Enlisted Bonus Distribution Model.

USAREC contacted the Operations Research Center to develop and test such a decision support tool. This report outlines the methodology used to determine that a binary integer goal program is the best decision support tool available. USAREC also requested the decision support tool be flexible and 'user friendly'. In addition, USAREC requested a tool that would accommodate as many decision variables as possible. Of the competing decision support tools evaluated, the binary integer goal program proved to accurately model the recruiting environment and also met all of USAREC's other requirements.

The binary integer goal program was developed using Microsoft Excel® and an upgraded solver produced by Frontline Systems Inc. The model can evaluate 194 entry-level MOSs and over 330 incentives, which results in over 64,000 decision variables. The model performed well in the solution space and produced reasonable answers after executing 1,000 sub-problems. The run times using a 400MHz desktop PC averaged about 15 minutes. The model uses results from a choice-based conjoint study to predict the number of recruits per MOS, incentive and term of service. The model also sums the costs both at the aggregate and individual MOS level. It is relatively easy to change any of the input data fields, which allows the decision-maker to conduct scenario analysis or contingency planning. The add-in solver using Excel® operates exactly like the default solver found on any Excel® version. The model is also flexible and can be updated with new information without changing the basic structure of the model.

Presentations and Publications:

- Dice, Kevin E. – Delivered *Enlisted Bonus Distribuion Model (EBDM)* to United States Army Recruiting Command – February, 2000

- Dice, Kevin E. Technical Report: *A Decision Support Tool for Determining Army Enlistment Incentives for FY 2000,* March,2000
- Starkel, Murry P. – Presentation at Military Operations Research Society Symposius: *Enlisted Bonus Distribution Model (EBDM),* United States Air Force Academy, Colorado Springs, CO – June 2000

Personnel Briefed:

- COL Parlier, United States Army Recruiting Command (USAREC), *Enlisted Bonus Distribution Model (EBDM)* – May 2000
- MAJ Mike Nelson, LTC Mark Young, Ms. Claudia Beach, United States Army Recruiting Command (USAREC), *Enlisted Bonus Distribution Model (EBDM)* - 20, October, 2000

Warrior Extended Battlespace (WEBS) Initiative: Distributed Sensor Networks on the Future Battlefield

Client Organization: US Army Research Laboratory (USARL)

Points of Contact:

Name:	Address:	Phone:	Other:
John W. Hopkins	2800 Powder Mill Rd, Adelphi, MD 20783/ Attn: AMSRL-SE-SS	DSN 290-3196 (301)394-3196	jhopkins@arl.mil
Jerome Gerber	2800 Powder Mill Rd, Adelphi, MD 20783/ Attn: AMSRL-SE-SA	DSN 290-2624 (301)394-2624	jgerber@arl.mil

Problem Statement:

The USARL, CECOM and the DBBL are executing the WEBS program. The objective of the WEBS is to demonstrate a family of sensors based on micro electronics and micro electro-mechanical systems (MEMS) technology, to enable overarching situational awareness and provide a common operational picture across all echelons of the Army. WEBS is a five year program covered by a STO and a DTO and is currently in the first year.

The goal of West Point's participation in WEBS is to develop an understanding of the optimal methods to employ WEBS on the battlefield. Understanding how to properly employ improved sensors on the battlefield is an essential fundamental of the WEBS program. Consideration will be given to identifying functions appropriate for WEBS to perform, selection of sensor types and their distribution/location for each function. Consideration will be given to the Anti-Personnel Landmine Alternative program (APLA) since many requirements will be similar.

Proposal of Work:

Phase 1 - Concept Evaluation (Jan 00; ORCEN Analysts)

- Identify functions that distributed sensor networks might serve on the 21st century land battlefield (new or existing functions).

Phase 2 - Scenario Development (Jan 00 through Jun 00; ORCEN Analysts)

- Develop realistic scenarios in which the WEBS would operate.
- Consider current U.S./allied threats and likely OOTW missions.

Phase 3 - Modeling & Simulation (Jun 00 through Jun 01; ORCEN Analysts, Faculty Research and Cadet Capstone Groups)

- Develop computer models and simulations of the distributed sensor networks.
- Evaluate their efficacy to the battlefield functions in the associated scenarios.

Phase 4 - Physical Experimentation (AY 01 through AY 02; AIADs, Faculty Research and Cadet Capstone Groups)

- Test and evaluate physical experiments.
- Utilize indicated by the results of the simulation-based experiments.

Senior Investigator for Overall Project: LTC Mark J. Davis

Principal Analyst: CPT John B. Willis

Status: Continues through FY 2001

Summary:

Key to achieving the Army Chief of Staff's vision are systems capable of providing commanders with information necessary to achieving local if not global superiority in decision making efficacy and efficiency. This capability will enable commanders to lead their forces in the conduct of decisive extended and close range engagements. On the battlefield of the future, advanced sensors connected to intelligent networked arrays, on manned and unmanned platforms, will be linked to commanders by enhanced communications and will provide timely knowledge of terrain, battlespace conditions, and forces. These highly automated sensors will be dispersed by ground troops, helicopters, and artillery or integrated with small, unattended aerial or ground vehicles (UAVs/UGVs). Responsibility for the employment of the sensor networks will likely fall to the Reconnaissance, Surveillance, and Target Acquisition (RSTA) Squadron of the proposed Objective Force Brigade Combat Team (BCT). This paper highlights the historic uses of sensors, desired sensor functions and capabilities, and the developing sensor technologies that will enable commanders to effectively employ the new medium-weight force in decisive engagements with less risk to military personnel. It further suggests a program of study related to composite sensor systems including UAVs, robotic UGVs, Future Scout and Cavalry System (FSCS), and manned systems.

Presentations and Publications:

- Willis, John B. – Presentation to Systems, Man and Cybernetics Society of the Institute of Electrical and Electronic Engineers, Inc. (IEEE-SMC) - 10 October, 2000
- Willis, John B. – Technical Report: *Distributed Sensor Networks on the Future Battlefield*, May 2000
- Willis, John B., Davis, Mark J., Presentation at the 68th Military Operations Research Society Symposium, U.S. Air Force Academy, Colorado Springs, CO, June 2000.

Personnel Briefed:

- Mr. John Hopkins, Army Research Library – Sensors & Electronic Devices Dictorate (ARL-SEDD), Adelphi, MD – April 2000
- Mr. Gerry Gerber, Army Research Library - Sensors & Electronic Devices Dictorate (ARL-SEDD), Adelphi, MD – April 2000

Area Denial Systems (ADS) Experiment

Client Organizations: US Army TACOM Armament Research, Development and Engineering Center (TACOM-ARDEC).

Points of Contact:

Name:	Address:	Phone:	Other:
Mr. Victor Kokodis	TACOM-ARDEC Improved Sensing Munitions Team, AMSTA-AR-FSP-I, Picatinny Aresenal, NJ	DSN 880-6776 (201)724-6776	vkokodis@pica.army.mil
LTC(P) William McCoy	Deputy Director, Battle lab Support Element, Ft. Leonard Wood, MO	DSN 676-4086 (573)563-4086	mcmoyw@wood-vines.army.mil

Problem Statement:

This work is in support of the Office of the Under Secretary of Defense in response to Presidential directives to establish alternatives to anti-personnel landmines and in support of the U.S. Army Engineer School's Unmanned Terrain Domination initiatives. Goals are to establish a system of sensors, communication links and shooters, with man-in-the-loop capability, that will meet the mission requirements usually accomplished by landmines. The objective is to develop the baseline concepts that address the need for alternatives to conventional mining operations, reduces logistics burdens, eliminates de-mining problems and addresses the post war civilian mine threat. The final product will be a system of sensors and communication links that will couple with munitions or munitions platforms with man-in-the-loop control. Maximum use of commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) will be stressed when determining the sensors and communications systems as well as leveraging on-going programs.

Proposal of Work:

Phase 1 - Concept Evaluation and Initial Experiments (Oct 99; ORCEN Analysts)

- Evaluate the baseline concepts of the proposed system
- Gather and evaluate results of an initial set of experiments conducted at NIST Headquarters in Gaithersburg, MD. In addition to ARDEC and NIST, other agencies involved in the ADS experiment include Tracer Round Associates; Sentech, Inc.; McQuiddy Associates; Naval Surface Warfare Center, Dahlgren, VA; Robotic Technology, Inc. (RTI); soldiers from 1-115th Infantry, 29th ID, Maryland National Guard; and the Illinois Institute of Technology Research Institute (IITRI).

Phase 2 - Scenario Development (TBD)

- Develop realistic scenarios in which the ADS would operate.
- Consider current U.S./allied threats and likely OOTW missions.

Phase 3 - Modeling & Simulation (TBD)

- Develop computer models and simulations of the ADS sensor-shooter networks.
- Evaluate their efficacy to the battlefield functions in the associated scenarios.

Phase 4 - Physical Experimentation (TBD)
- Test and evaluate physical experiments
- Utilize indicated by the results of the simulation-based experiments

Senior Investigator: LTC. Mark J. Davis

Principal Analyst: CPT John B. Willis

Status: Complete

Summary:

The Area Denial Systems (ADS) Science and Technology Objective (STO) supports the Office of the Under Secretary of Defense in response to Presidential directives to establish alternatives to anti-personnel landmines and supports the U.S. Army Engineer School's Unmanned Terrain Domination initiatives. Goals are to establish a system of sensors, communication links and shooters, with man-in-the-loop (MITL) capability that will meet the mission requirements usually accomplished by landmines. Systems will allow for reduced logistics burdens and will be recoverable.

In order to support this effort, the United States Military Academy (USMA) Operations Research Center of Excellence (ORCEN) agreed to take on a study to analyze ADS concepts and experimental results.

The objective of ADS is to develop the baseline concepts that address the need for alternatives to conventional mining operations, reduce logistics burdens, eliminate de-mining problems and address the post war civilian mine threat. The final product will be a system of sensors and communication links that will couple with munitions or munitions platforms with man-in-the-loop control. Maximum use of commercial off-the-shelf (COTS), Government off-the-shelf (GOTS) and non-developmental items (NDI) will be stressed when determining the sensors and communications systems as well as leveraging on-going programs.

ADS consists of a network of sensors that will provide detection and tracking information through a communications link to a control station. A control station will then, depending upon the target threat, launch and/or initiate an appropriate type of engagement munition against the threat target. The range of the system will be evaluated with regards to systems effectiveness and logistics factors. Threat targets will consist of personnel and a range of vehicles from heavy and light armor to trucks and rocket launchers. The munition functioning could be via the man-in-the-loop (MITL) or an autonomous decision from the sensors or sensor gateway. Key to the system operation will be to adequately classify, range and track the target to assure maximum P_k and minimize attack against friendly or civilian population. Lethal force against personnel targets will require positive identification. Robotic platforms will be considered to maximize maneuverability of the system. Communications range could be 30 km or greater. ADS will leverage work being done in the Intelligent Minefield, Acoustic Overwatch Sensors, Rapid Force Projection Initiative and SADARM programs. The ADS meets the objectives of several Engineer and Maneuver Support Battle Lab Future Operational Capabilities (FOC).

The STO will produce simulation packages that will allow the alternative concepts to be evaluated in the Distributed Interactive Simulations (DIS) Master Plan as well as participation in Advanced Warfighting Experiments (AWE). Technologies for different deterrent concepts, communications and sensors will be prototyped and demonstrated. As this concept will be addressing both personnel and vehicle threats across different ranges of the battlefield, delivery systems will also be assessed and prototype systems tested.

The ADS Experiment conducted on August 28, 1999 at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland revealed great potential for the system to detect, classify and engage enemy forces. This paper identifies these strengths as well as a number of issues to address with future work.

Presentations and Publications:

- Willis, John B. – Technical Report: *Area Denial Systems (ADS): Concept & Experiment Evaluation* – October 1999

Personnel Briefed:

- Victor Kokodis, Tank Automation and Armament Command – Armament Research, Development and Engineering Center (TACOM-ARDEC), October, 1999

Reconnaissance, Surveillance, and Target Acquisition (RSTA)

Client Organizations: None

Points of Contact:

Name:	Address:	Phone:	Other:
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MAJ. John Willis	ORCEN Department of Systems Engineering US Military Academy West Point, NY	938-4311	fj4238@usma.edu

Problem Statement:

The primary source of battlespace intelligence for the Army's proposed Interim Brigade Combat Team (BCT) is the Reconnaissance, Surveillance and Target Acquisition (RSTA) Squadron. The fundamental role of the RSTA Squadron is to provide detailed situational understanding to the BCT Commander facilitating freedom of maneuver and the concentration of combat power at the decisive time and place. Technologically advanced systems should substantially enhance RSTA Squadron operations. Among the proposed systems in the Squadron are the Future Scout and Cavalry System (FSCS), tactical unmanned aerial vehicles (TUAV), ground-based networked sensors (acoustic, seismic, magnetic, infrared, radio frequency), radio frequency (RF) detectors, and nuclear, biological and chemical (NBC) reconnaissance systems. This paper outlines the process used to date for designing the RSTA Squadron and proposes an alternative approach: a systems engineering methodology to formulate, analyze and interpret RSTA Squadron design alternatives.

Senior Investigator: LTC. Mark J. Davis

Principal Analyst: CPT John B. Willis

Status: Complete

Summary:

The Army's requirement to satisfy Joint Vision 2020 and to achieve effective full spectrum strategic responsiveness demands an improved capability for the rapid deployment of highly-integrated, combined arms forces. These forces must possess overmatching capabilities, exploiting the power of information and human potential, combining the advantages of both light and mechanized forces across the full range of military operations. Meeting this requirement and providing warfighting Commanders-in-Chief (CINCs) with a decisive contingency response option is the Army's central near-term objective in developing full spectrum medium weight brigades, known as Brigade Combat Teams (BCTs) [1].

The Army will rapidly and simultaneously develop two initial BCTs during the course of FYs 00 and 01 on the basis of two existing brigades at Fort Lewis, Washington. Simultaneous development will reduce costs and create an environment wherein parallel efforts based on differing organizations can inform and expedite the overall developmental process. As a result of their accelerated development, the initial BCTs will also jump-start the development of doctrine, tactics, techniques and procedures associated with the transformation force.

A. *Brigade Combat Team Organization*

Given an initial orientation on small-scale contingency operations (SSCO) in urban/close terrain, with the associated requirements for high tactical mobility and robust dismounted assault capability, BCT design efforts to date have resulted in the creation of a mounted infantry organization. Major sub-elements within these designs include:

- three motorized, combined arms infantry battalions, each composed of three combined arms rifle companies and a headquarters company (the latter includes a reconnaissance platoon and a mortar platoon);
- a reconnaissance, surveillance, and target acquisition (RSTA) squadron; an anti-tank company;
- an artillery organization;
- an engineer company;
- a brigade support battalion;
- a military intelligence company;
- a signal company; and
- the brigade headquarters and headquarters company.

The primary combat platform—a medium armor vehicle (MAV)—has not been selected at this time. The MAV will serve as the platform for the infantry carriers, mobile gun platoons, mortars, RSTA elements, anti-tank carriers, cannon artillery, engineer mobility support vehicles, and most of the command and control carriers within the BCT.

B. *Reconnaissance, Surveillance, and Target Acquisition (RSTA) Squadron Concept*

Recent analysis has demonstrated that situational understanding is the fundamental force enabler across all BCT battlefield operating systems and the foundation for risk mitigation with respect to BCT vulnerabilities [1]. The BCT must have the capability to achieve information superiority and deny an adversary the ability to achieve surprise or to template the force and engage it effectively. The BCT will likely employ a multi-level, integrated suite of intelligence, reconnaissance, and surveillance (ISR) capabilities to develop and disseminate a common operational picture throughout the force, achieving situational understanding (SU) through the application of the commander's judgment and experience. Current plans are for this capability to be provided by a *Reconnaissance, Surveillance, and Target Acquisition (RSTA) Squadron.*

The RSTA Squadron would provide the essential building block capabilities required to achieve SU, including an in-depth understanding of the tactical and operational non-military factors that influence operations within an asymmetric environment. SU and information superiority enable the BCT to avoid surprise, develop rapid decisions, control the time and place to engage in combat, conduct precision maneuver, shape the battlespace with precision fires and effects, and achieve decisive outcomes.

The RSTA Squadron should support SU of the *operational environment* in all its dimensions—political, cultural, economic, demographic, as well as military factors—rather than a narrow focus on the adversary and his capabilities. This multi-dimensional reconnaissance requirement means that RSTA elements must promote understanding of *not just what* is happening, but *why*. The squadron's efforts will likely be complemented by direct access to intelligence and information sources outside the BCT focused by the intelligence, surveillance and reconnaissance (ISR) integration and management elements at BCT level. In an asymmetric environment, identifying enemy centers of gravity, decisive points, and the means to influence enemy will and behavior are critical contributions that the squadron can make to BCT success. RSTA efforts to *assess the actual effects* of BCT and joint battlefield operations are also important. The squadron's ability to confirm intelligence viewed or acquired by strategic and operational assessment tools is paramount. Data fusion and SU developed at division/corps level must be available and leveraged by the BCT.

THE ARMY'S BCT AND RSTA SQUADRON DESIGN PROCESS

The BCT concept grew out of plans developed in the late 1990s for a full spectrum rapidly deployable combat unit initially labled "Strike Force" [2]. A versatile and capable force was needed to operate in complex terrain environments and to support SSC operations such as the contingency operations in Bosnia and Kosovo. The term "Strike Force" gradually fell out of favor and between August and October 1999, senior military officials, including the commander of Training and Doctrine Command (TRADOC) crafted the core capabilities required for the BCT. Representatives from TRADOC, the Directorates of Combat/Force Development at Fort Knox and Fort Benning, the Armor and Infantry Schools, the Army Battle Labs, and the Combined Arms Support Command (CASCOM) were among the early developers of BCT concepts and force design [3].

The BCT development process took place in a much more compressed timeline with respect to the creation of other combat developments. Traditionally, force design has followed a three-year cycle. The early BCT design was crafted in sixty days. Developers employed force effectiveness models as well as constructive simulation such as Modular Semi-automated Forces (ModSAF) and Janus to model and evaluate BCT unit designs. The modeling varied platform types and quantities but not organizational structure. Modeling primarily focused on the number of named areas of interest (NAIs) that could be monitored with a given number of personnel/systems. The ModSAF and Janus simulation efforts did not account for all recognized C4ISR force multipliers/enablers. Valuable insights were gained through the wargaming of likely BCT operational scenarios such as the contribution of unmanned aerial vehicles and ground sensors to the BCT commander's ability to detect and destroy enemy reconnaissance assets [4].

The Army's Battle Labs and TRADOC Systems Managers (TSMs) have contributed significantly to the BCT/RSTA Squadron development process. The battle labs have conducted rock drills and provided initial analytic support. TSMs for UAV, Common Ground

Station (CGS), and other systems established system requirements in partnership with Army training institutions that may dramatically influence force design and doctrine [5].

Initial designs had as many as 4,800 soldiers assigned to the BCT but that number has been reduced over time to approximately 3,500. Rationale for the changes in personnel size for the BCT included the battlefield footprint of the force, METT-TC (mission, enemy, terrain and weather, time, troops available and civilians) considerations, and the capability of the force to receive augmentation from higher echelons [6]. Other changes to the BCT have included moving elements within the BCT such as the counterfire radars' shift from the RSTA Squadron to the field artillery battalion. Unfortunately, it is extremely difficult to uncover the methodology and logic used to develop the RSTA Squadron force structure.

The RSTA Squadron is an organization designed to satisfy a set of operational requirements. Among these requirements is the ability to simultaneously reconnoiter nine routes or conduct surveillance of 18 designated areas on a continuous 24-hour cycle. The latest RSTA Squadron design incorporates three Reconnaissance Troops, each of which includes JAVELIN anti-armor and 120 mm mortar support. In addition, a Surveillance Troop incorporates an unmanned aerial vehicle (UAV) platoon, a multi-capable sensor platoon, and a nuclear, biological and chemical (NBC) reconnaissance platoon. The UAVs enable the unit to expand its eyes considerably while mitigating the absence of rotary-based reconnaissance. The NBC element provides the BCT's core capability for detection and early warning of chemical and radiological contaminants, plus some forms of biological agents.

PROPOSED SYSTEMS DESIGN METHODOLOGY

Systems engineers employ a variety of design methodologies, each tailored to a specific use. Among several methodologies are those described by Armstrong and Sage [7], Hall [8], Good and Machol [9], Chestnut [10], Wymore [11], Churchman [12], and Blanchard and Fabrycky [13]. The common thread between them is a framework that encompasses defining the problem, generating alternative solutions, analyzing the alternatives and selecting the best alternative. This framework is not only useful in the design of multidisciplinary engineering systems, but is appropriate for use in approaching many of the large-scale, complex problems faced by the military. The design methodology we propose for the BCT RSTA Squadron is depicted in Table 1 and summarized below. It is known within the Department of Systems Engineering at the U.S. Military Academy (USMA) as the Systems Engineering Design Process (SEDP).

Table 1. Systems Design Methodology

Step	Activity	Result
1.	Problem Definition	Engineering Problem Statement
2.	Functional Decomposition	Hierarchy of Functions
3.	Value System Design	Value Hierarchy
4.	Alternative Generation	A set of alternative solutions / architectures
5.	Input - Output Modeling	I-O Models
6.	Process Flow Diagramming	Process Flow Diagrams
7.	Selection of Models	A suite of models to evaluate alternative performance
8.	Analysis of Alternatives	Completed Raw Data Matrix
9.	Decision-making	Completed Decision Matrix / A recommendation or decision
10.	Plan for Action	Plan for future work/requirements to implement the selected alternative
11.	Record Results	Technical Report that captures/documents work completed

The USMA Systems Engineering Department has applied the SEDP to a number of projects in recent years, among them: Land Warrior simulation, unmanned systems modeling and analysis, and headquarters design for the Joint Strike Force.

We now present descriptions of the SEDP steps and details about their application to the design of the RSTA Squadron.

Step 1. Problem Definition

The most important step in any design or decision process is to identify and understand the problem. In order to gain a clear understanding of the problem, we need to conduct research into the problem area and interact with the relevant stakeholders to determine their needs and objectives. The result of these efforts should be an *engineering problem statement* that both the client(s) and analysts can agree to that captures the essence of the problem at hand.

The primary purpose of stakeholder analysis is to identify the people who are relevant to our problem and to determine their needs, wants and desires with respect to it. Typical classes of stakeholders include clients, sponsors, decision-makers, users and analysts. During stakeholder analysis, we will identify the system's effective need as well as critical assumptions and constraints on our problem. These may come from a variety of sources and might include assumptions ranging from strategic to tactical. While time and money are the most typical constraints, we must also consider physical, legal, environmental, social and technological constraints that may be relevant.

Stakeholders for the RSTA Squadron include decision makers (Army Chief of Staff, TRADOC, etc.), warfighting CINCs, tactical-level commanders and soldiers, Force/Combat Development Directorates, Battle Labs, TRADOC Systems Managers, Program Managers, and analysts.

While we do not want to box ourselves in to preconceived solutions at this early stage in the design process, we stand to gain valuable insight by looking at similar problems, both past and present, to gain a better understanding of the issues involved.

Step 2. Functional Decomposition

The primary purpose of this step is to identify and decompose the critical function(s) of the system. We can think of functions as purposeful actions of the system that involve the transformation or alteration of material, energy, information, and/or other resources [7]. A function implies some input that undergoes a transformation process to produce a desired output.

In conducting a functional decomposition, it is important to remember to look at "what" the system must do but not "how" the system will function. We must avoid the temptation to work our way into solutions.

The outcome of our functional decomposition is a Hierarchy of Functions. This hierarchy (or tree) captures the results of our decomposition by showing the top-level functions required of our system broken down into sub-functions.

Some possible functions of the RSTA Squadron include:

- Developing 'grass-roots' neighborhood level situational understanding of the political, cultural, and human environment within the area of operations.
- Conducting reconnaissance operations to detect enemy dispositions, organizations, weaknesses and vulnerabilities.
- Conducting limited security operations (screens) to protect the front, flanks or rear of the BCT formation. Augmentation will be required to execute guard and cover missions.
- Countering enemy R&S forces.
- Maintaining contact with a retreating enemy.

Step 3. Value System Design

The primary purpose of this step is to develop a *Value Hierarchy* that we can use to evaluate potential alternative solutions and ultimately select the best alternative. The value model is a reflection of the needs and objectives of the critical stakeholders. Some key terms used in value modeling are:

- **Value Hierarchy**: A pictorial representation of the structure of the functions, objectives, and evaluation measures.
- **System Function:** An activity that the system must be designed to perform (e.g. *Detect targets*) that is an evaluation consideration for alternative system designs
- **Objective:** a preferred direction of attainment of an evaluation consideration (e.g. *Higher probability of detection*)
- **Goal:** A desired threshold of achievement for an objective (e.g. *Probability of detection* $\geq$ *0.95*)
- **Evaluation Measure**: A scale used to measure the degree that we attain an objective (*Probability of detection*). Also known as Performance Measure, Measure of Effectiveness, Measure of Merit, or metric. (Figure 2 is an abbreviated example of a value hierarchy.)

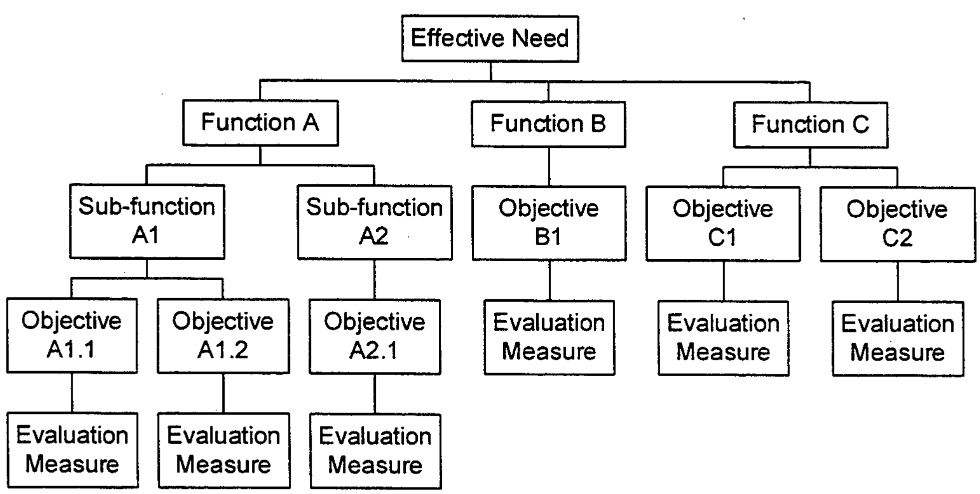

Figure 2. Example Value Hierarchy

We have to ensure that the hierarchy we develop is reflective of the values of our critical stakeholders. Ultimately, the decision-maker will use the value hierarchy to decide on the best alternative to solve their problem. We want to make sure that it is*complete*. We want to ensure that our hierarchy is *non-redundant*. We want to make sure that our value hierarchy has *independence*, that is our preference for the level of one evaluation measure does not depend on the level of another evaluation measure. We must also ensure that the value hierarchy is meaningful and understandable to the people who will use it.

To construct a value hierarchy we should look for documents that lay out strategic objectives, a vision, doctrine, policies or a plan in our problem area. We should also interview senior leaders and critical stakeholders. If you are unable to find appropriate documents to provide the framework for your value hierarchy and you do not have access to the senior leaders and critical stakeholders, you may be forced to build your value hierarchy from the ground up. In this case, it might be useful to conduct group sessions with a large number of stakeholder representatives and inductively develop the value hierarchy using a technique called affinity diagramming.

RSTA assets are designed to provide battlefield commanders with information about the current situation that will assist them in decision making. Thus, *information gain* is a term used to define the measure of effectiveness of the information processes providing the commander with situational knowledge. Traditional measures of information gain have been based on detections of enemy forces by RSTA units or platforms. Measures of effectiveness such as "percent of enemy vehicles detected", "time required to detect a tank company in hull defilade", and "average range at detection" do not give credit for RSTA efforts that suggest that targets are *not* located in certain areas of interest to the commander. Finding that the enemy is not located in a certain area can be of considerable value, and it is desirable to devise measures of information that quantify such results.

In a given battlefield scenario, the commander has a state of uncertainty about his adversary in terms of discrete probability distributions over a space of possible states the adversary may occupy. There exists a finite set of states and a probability distribution over this set that may be updated as information about the state occupied is received. It would also be possible to consider continuous probability distributions and associated random variables.

Barr and Sherrill [14] define information gain/loss in a form of Shannon's entropy [15] from the prior updated distributions. For a mobile target at time t_0, but unobserved for subsequent times t, the information loss curve is of form $-ln(t^2)$, independent of the movement rate of the target. It is noted that information gain for a given target will be positive over time as reconnaissance and surveillance is conducted, however uncertainty can increase as additional operations are conducted and entropy can oscillate between increases and decreases (non-monotonicity). Bayes, combinatorial, or subjective updating can be used to iterate the process.

Step 4. Alternative Generation

Alternative generation is the process of bringing system alternatives or architectures into being. We avoid restricting ourselves to known or traditional alternatives. A common approach to generating alternatives or architectures is to identify the critical functions and sub-functions that the system under design must be able to perform and then brainstorming and/or researching alternative ways to perform those functions.

As you generate your alternatives it is important to ensure that they are *significantly different* from one another. Alternatives must be described in *sufficient detail* to allow us to model and analyze them in later steps of the design process. RSTA Squadron design alternatives may include variations in vehicles, weapons, equipment, personnel, and troop/platoon/team organization.

Step 5. Input/Output Modeling

Whether or not a component or subsystem actually belongs to a system is determined by the *system boundary*. The boundary separates the system from its environment. I-O diagrams help to define the boundaries and boundary conditions of a system and allow us to analyze inputs and demanded outputs.

In the Input-Output Model (Figure 3 below), the system or process is considered to be a "black box," to avoid prematurely accepting some conventional, familiar solution.

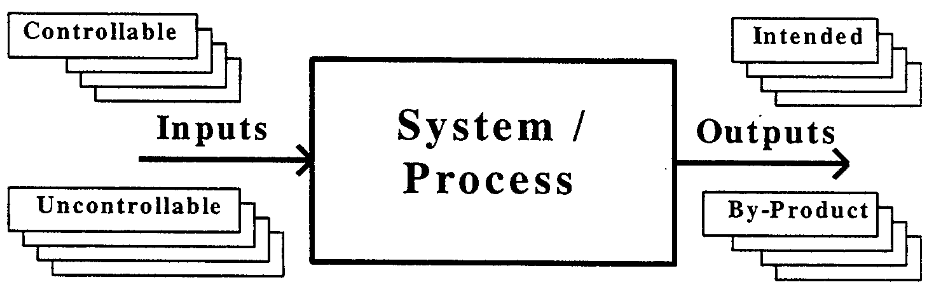

Figure 3. The Input-Output Model

The intended outputs may be considered goals or objectives of the system--what it is meant to accomplish (e.g. SU for the BCT). From these intended outputs, the analyst can begin to make a determination of what the system needs (inputs) in order to produce the desired effect/outcome.

Controllable inputs can be derived from the question "What is needed to start the process from which the outputs can be achieved?" We can classify controllable inputs into four categories: Physical, Human, Informational and Economic. Examples could include weapon/sensor platforms, soldiers, communications structure, and operations/maintenance costs.

Uncontrollable inputs are those environmental characteristics or tangibles that are available or that influence the performance of the system (e.g. weather, area of operations).

By-products are outputs of the process, unintentional or incidental, positive or negative, that are the result of the process.

Step 6. Process Flow Diagramming

During this step in the process, we take the functions and sub-functions identified earlier and visually depict them in the sequence in which they normally occur. Next, we identify and add the outputs generated by the performance of each function. Finally, we add the inputs to each function that are necessary for the function to occur.

Figure 4 provides the structure of a process flow diagram.

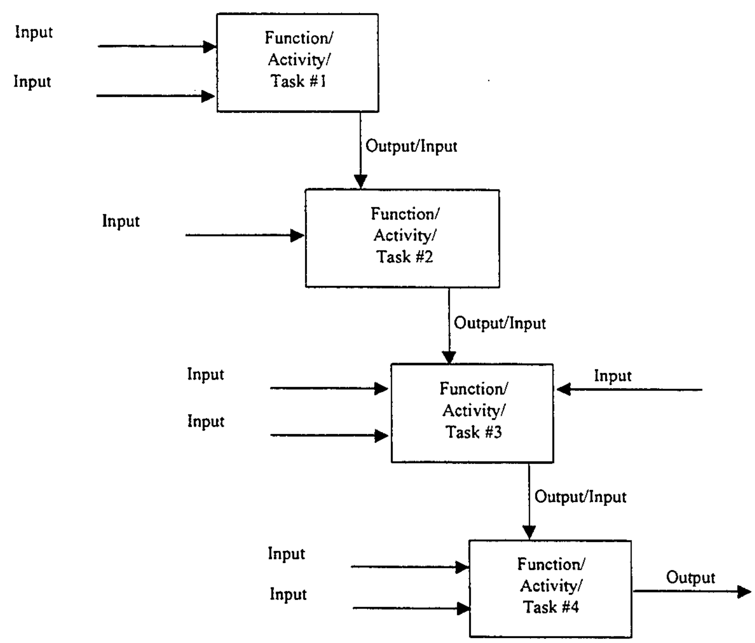

Figure 4. Process Flow Diagram Structure.

Step 7. Selection of Models

We use modeling as a means of predicting or estimating the performance of our alternatives with respect to the evaluation measures we selected in our Value Hierarchy. It is almost always cheaper and faster to work with a model than to directly study the dynamics of a large-scale system.

Whether we select models that already exist or develop the necessary models ourselves, it is very important that the model be properly formulated, used, and interpreted so that the results accurately reflect the characteristics of the real system. Virtual, constructive, and live simulation are typical models used to evaluate combat forces.

Step 8. Analysis of Alternatives

In October 1998, the Military Operations Research Society sponsored a workshop on Analyzing C4ISR in 2010 [16]. Among the objectives of the workshop were:

- identify metrics that are sensitive to the effects of C4ISR on force-level effectiveness;
- assess methodologies to analyze and quantify the effectiveness of C4ISR; and
- evaluate appropriate tools to measure the benefit of C4ISR.

Mr. Art Money, Assistant Secretary of Defense for Command, Control, Communications and Intelligence, identified the need to assess the Return on Investment (ROI) for C4ISR. He stated that we need better tools and methodologies to evaluate the contribution that C4ISR makes to force effectiveness and specifically highlighted the need for better models, simulations and measures.

A mix of tools will generally be required to compensate for the shortfalls of individual tools and to adequately represent Blue and Red processes. Table 2 below characterizes seven of the most common techniques [16]:

Table 2: C4ISR Evaluation Techniques

Technique	Resources	Breadth of Application	Replicability	Credibility
Expert Elicitation	Lowest	Very Broad	Limited	Variable
Wargame	Low	Very Broad	Limited	Fair
Analytical Models	Low	Broad	Fully	Fair
Constructive Simulation	Low-Mod	Broad	Fully	Moderate
Virtual Simulation	High	Moderate	With Difficulty	Potential for Good
Live Simulation	High	Limited	Little	Generally Good
Real Crises/Combat	N/A	Quite Limited	None	Excellent

The early stages of an analysis will need quick and inexpensive techniques, in order to efficiently explore the scenario space, determine what are the critical parameters, and design the follow-on in-depth analyses. In the later stages, the techniques will tend to be the more resource intensive constructive, virtual or live simulations. Most of the information we require to analyze and compare our alternatives is generated through the use of the models we selected in the previous step. The tool we use to organize this information is a *raw data matrix*. The raw score for each alternative's performance is recorded in the raw data matrix, regardless of whether it was obtained through research, direct measure or modeling. This matrix will eventually serve as the basis for a *decision matrix*.

Step 9. Decision Matrix

In most cases, we will be trying to compare alternatives where we have used evaluation measures that have different units of measure. Multi-Attribute Utility (MAU) is a tool we can use to do just this type of comparison.

Applying MAU to design problems will generally include these activities: (1) Characterizing a decision-maker's attitude, (2) Constructing a utility relationship for each criterion, (3) Converting raw scores to utility scores, and (4) Calculating an alternative's total utility score on a decision matrix.

The total utility scores, which reflect the performance of each alternative with respect to the evaluation measures, drive the decision-making process. Generally, the alternative with the highest utility scores wins. However, there is a need to do some sensitivity analysis to assess the sensitivity of the decision to changes in the performance scores of alternatives and the relative importance of evaluation measures. Ultimately, the decision maker will choose the alternative based on results of the MAU analysis and his/her professional military judgement.

Step 10. Plan for Action

With a recommendation and/or decision made, we turn our attention to planning for action. During this step, we assess the future work that still needs to be done. In addition to preparing to execute the decision, we may yet want to conduct additional research, develop and run simulations, and prepare to conduct experiments and other initial testing on prototype systems.

FUTURE WORK

Cadet teams from the U.S. Military Academy's Department of Systems Engineering will employ the systems engineering design process (SEDP) described in this paper to the task of designing the Reconnaissance, Surveillance and Target Acquisition Squadron of the Interim Brigade Combat Team. The goal of the effort is to demonstrate how a methodological systems approach can improve force structure design. This work builds upon previous USMA modeling and analysis work in unmanned aerial/ground vehicles and future combat systems.

Presentations and Publications:replace

- Willis, John B. – Presentation to the IEEE - Systems, Man and Cybernetics Society (IEEE-SMC), Nashville, TN – October 1999
- Willis, John B. – Presentation at the INFORMS 2000 National Confernece, San Antonio, TX – November 2000

Army Development System XXI: (WOPMS/EPMS XXI)

Client Organization: Chief of Staff of the Army (CSA)

Points of Contact:

Name:	Address:	Phone:	Other:
BG Adair	Director, ADS XXI	DSN 221-6776 (703)325-6776	adairl@hoffman.army.mil
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Problem Statement:

The Chief of Staff of the Army has established the Army Development System (ADS) XXI to integrate officer, warrant officer, non-commissioned officer and civilian development into a single, over-arching system. The WOPMS/EPMS XXI Task Force will design a warrant officer and enlisted development system for the Army of the 21st century, within time and cost constraints, that meets future warrant officer and enlisted management and professional development needs. The task force will recommend changes to improve personnel management and leader development systems while increasing soldier stability and readiness. The task force will recommend a framework which integrates concurrent leader development, character development and turbulence reduction initiatives. The task force will also develop an implementation strategy that seeks senior leader support and that provides a mechanism for periodic reviews and updates.

Proposal of Work:

The DCSPER of the Army has asked the Department of Systems Engineering to contribute systems engineering expertise to the Task Force effort. Work will initially consist of providing analytic support to the Manning the Force-Task Force created by the CSA and led by the A/DCSPER, MG Maude. This work will be analytic in nature and include assessments of the appropriateness of their system design, assumptions and constraints. We will also conduct some model testing. Subsequently, we will act as a conduit between this CSA Task Force and the WOPMS/EPMS XXI Task Force. The ORCEN will provide the WOPMS/EPMS XXI Task Force with focused systems engineering expertise and with specific modeling and analytic skills. The ORCEN analyst will guide the task force through the processes of:

(1) identifying enduring, imperative characteristics of the WODS/EDS,

(2) identifying near-, mid-, and long term- goals and objectives of the CSA and other stakeholders,

(3) identifying WODS/EDS design alternatives using appropriate measures of systems effectiveness, performance and cost,

(4) analyzing design alternatives,

(5) evaluating potential impacts of considered alternatives,

(6) recommending a design alternative for implementation,

(7) developing an appropriate action plan institutionalizing the process of reviews and updates and

(8) developing a marketing plan.

Senior Investigator: COL Mike McGinnis, Ph.D.

Principal Analyst: CPT Doug Matty

Status: Complete

Summary:

The Army has been undergoing a reinvention since the announcement of the Force XXI concept in the early nineties. Due to a number of environmental considerations, the army made the strategic decision to leverage technology to maintain the high level of readiness and combat power obtained by the end of the cold war (Sullivan and Harper, 1997). This paradigm shift provided control by defining a vision of the "end-state" for the pending draw-down. As operational experiments served to validate and refine the incorporation of information technology in the weapon systems of the evolving force structure, the draw-down decreased the army's manpower. After the Army conducted this preemptive draw-down in numbers, the Army leadership was convinced that changes in the management of its leadership were required to maintain its war-fighting capability. This resulted in the work of the Officer Professional Management System, OPMS, XXI Task Force that addressed the problem of competing requirements for increasing the tactical proficiency, but also increasing technical expertise for the officer corps of Force XXI. As the Army now continues this re-engineering under the recently announced transformation campaign plan, the Army Development System XXI Task Force conducted an assessment and reengineering of the Army's enlisted and warrant officer professional management systems. This paper reflects our work in support of this effort.

THE PERSONNEL MANAGEMENT SYSTEM IN TRANSITION:

A) Developing a Strategic Human Resource Management (SHRM) System

In each of the last three decades, there have been significant environmental changes that altered the fundamentals of the personnel system. In the early 19070's, the decision to implement the all-volunteer force required the re-invention of the Army's recruiting program. In the 19080's these recruiting and marketing strategy supported the military build-up. After winning the cold war, the inevitable call for a peace-dividend resulted in the cyclical peace-time draw-down. These were the major factors that help guide the Army leadership in refining the personnel management system. However the dynamic structure of the how the Army mans the force has not changed.

In 1997, while the OPMS XXI Task Force was reengineering the officer professional management system, the 8th Quadrennial Defense Review on Military Compensation convened. The recommendation proposed a strategic extension to the personnel management system that had evolved for the all volunteer force, AFV, for transition to a strategic human resource management, SHRM, system. The new model developing is shown below:

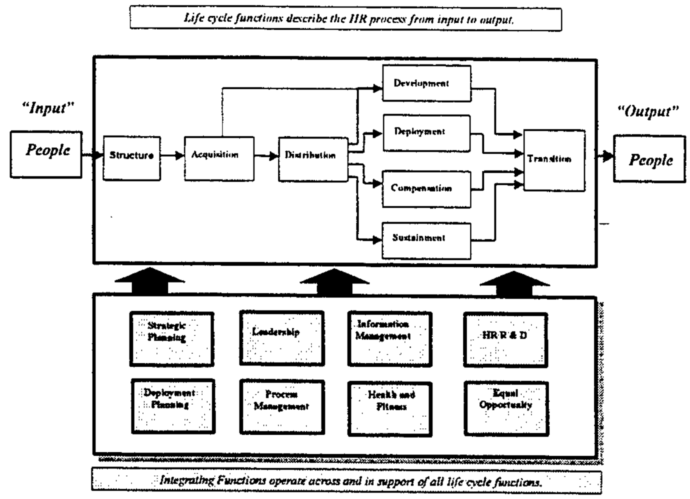

Figure 1. SHRM System

The army continued its efforts to restructure, but increasing manpower intensive deployments while downsizing the over-all force size forced an optimization mindset of "doing more with less". Due to decreasing personnel resources several war-fighting units reported readiness levels indicating the inability to accomplish their wartime missions, resulting in the Chief of Staff of the Army announcing manning the force as one of this primary imperatives. Department of the Army staffs determined that the current structure and inventory had grown too complex in the dimensions of grade, military occupational skill, and unit location and priority. This "curse of dimensionality" had over-constrained the feasible region for manning the force; matching the inventory with the dynamic structure. This situation was the catalyst for the chartering of the Army Development System XXI. The task force was asked to conduct a comprehensive study of the Enlisted and Warrant Officer Personnel Systems and recommend changes to ensure continued readiness in the future. Using the model in, the ADS XXI Task Force conducted its assessment by answering three basic questions: what is right with the current system; what is not right with the current system; what is currently right but needs changed for the future?

B) FOCUS ON THE FUTURE

This future environment will be shaped by of the results of the efforts for a "revolution in military affairs". Three themes of advancements in weapons systems guide this leap-ahead in capabilities: Precision-guided munitions; Command, Control, Communications, Computers and Intelligence; Surveillance, and Reconnaissance. All of these advances are based in technology and their integration in future force-designs. As a result of the analysis completed at the Center for Army Leadership focusing on the characteristics of the future soldiers the following skills, knowledge and attributes are considered essential:

Skills

Interpersonal:
Communicating, Motivating, Team-building, supervising, counseling, public speaking envisioning, teaching, group processing, collaborating, consensus building, persuading, mediating conflict, building interdependence

Conceptual:
Critical reasoning, problem-solving, creative- thinking, moral reasoning, forecasting, scanning, analyzing, synthesizing, learning, judging, perspective-taking, systems- understanding, critical-information discernment

Technical:
Operating equipment, employing equipment, resourcing, exploiting equipment, managing, operating, and controlling

Tactical:
Direct, organizational, strategic skills

Knowledge

Influencing:
Communicating, decision-making, motivating

Operating:
Planning, executing, and assessing

Improving:
Developing, building, learning

Attributes

Mental:
Will, self-discipline, initiative, judgment, cultural-awareness, intelligence, confidence

Physical:
Health fitness, physical-fitness, military bearing

Emotional:
Self-control, balance, stability

Values:
Loyalty, duty, respect, selfless service, honor, integrity, personal courage

Figure 2. SKA's for Future Force

This is a very ambitious requirement for any work-force. However the primary focus of the Army Development System is to produce leaders. With these needs, the task force began its system redesign to grow these future leaders that are already in our elementary and secondary schools.

SYSTEM ASSESSMENT

As mentioned previously there have been at least three major external factors that have impacted on how the army has manned its forces. However, even with these significant events, the current system continues as closed and causal structure of two connected and dependent forces in the active component: the career and non-career forces (Kirby and Thie, RAND, 1996). These categories are quite apparent by examining the annual average continuation rates of personnel by years of service in Figure 3:

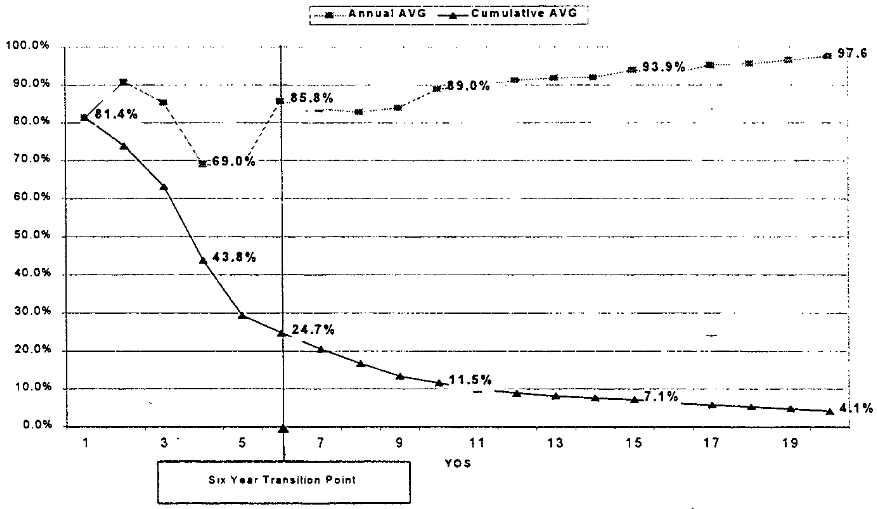

Figure 3. Average Annual and Cumulative Continuation Rates by Years of Service (1980-Current)

A soldier's reenlistment at the end of the first term of service, occurs most commonly at the fourth year of service, is the transition point between the non-career and career force (note: 1 term enlistment contracts are signed only up to 6 years.) Using the average cumulative continuation rates for yearly cohorts, it is apparent by the second order difference the slope of the line when the population commits to work toward a career in the Army. From Figure 3, it is readily apparent that upon continuing service past the initial term, the rate of attrition assumes a much flatter descent rate. To have a mutually exclusive definition of these two populations, the career force is defined as those with six years or more of active service (Kirby and Thie, RAND, 1996). This decrease in attrition for year group 1980 was demonstrated with a cumulative continuation rate of 19.6% at the six-year mark and reaching a career of twenty years of service at 4.1% of the cohort remaining. Interestingly this is lower than the proposed target of 12% (Kirby and Thie, RAND, 1996). This would seem to indicate that the Army is deficient in terms of populating the career force. However, looking at the total active, it is clear that the career force has in fact increased its relative size for the Army.

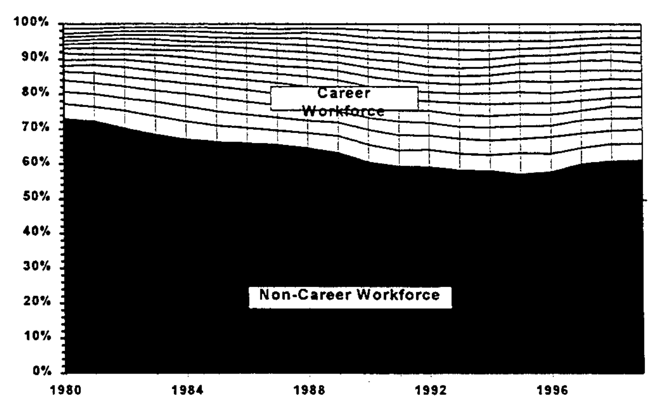

Figure 4. Strength of Army Enlisted Personnel by Years of Service

From 1980, the career force composed 25% of the enlisted personnel on active duty, has grown to comprise 37% of the force. What system dynamics would cause this inflation in the soldiers' age of service? Looking at the 1980's, the growth of the career force can be directly tied to the expansion of the institutional force. And in the 1990's, the trend continued as the Army chose to control downsizing by lowering its accessions and keeping trained soldiers already serving.

Once the new soldiers join the non-career force, the next life-cycle function is development. There are three pillars supporting the Army's development program, institutional (specific instruction provided by cadre or instructors), organizational (experience gained through training in an assignment) and self-development (including correspondence courses or civilian education). Before assignment to their first unit, soldiers are trained through the institutional pillar by attend their basic training course followed by their respective specialty's advanced individual training course, AIT. Some specialties combine the two courses in One Station Unit Training, OSUT. There are 241 specialties that are managed for distribution after completion of this initial training. The level of exposure to their skilled tasks for the AIT classes varies corresponding to the level of technical difficulty in the specialty as shown in Figure5..

This is due primarily to the trade-off for resources in terms of time and money. As one would expect, all the necessary specialty skills will be re-assessed and trained under the organizational aspect of development. This paradigm requires a large front investment by the Army in developing these specialists with an initial term of service length corresponding to the "value" of the training. An example of these long term enlistments for technical training is the Information Systems Operator-Analyst that are required to enlist for six years, to the edge of the non-career force.

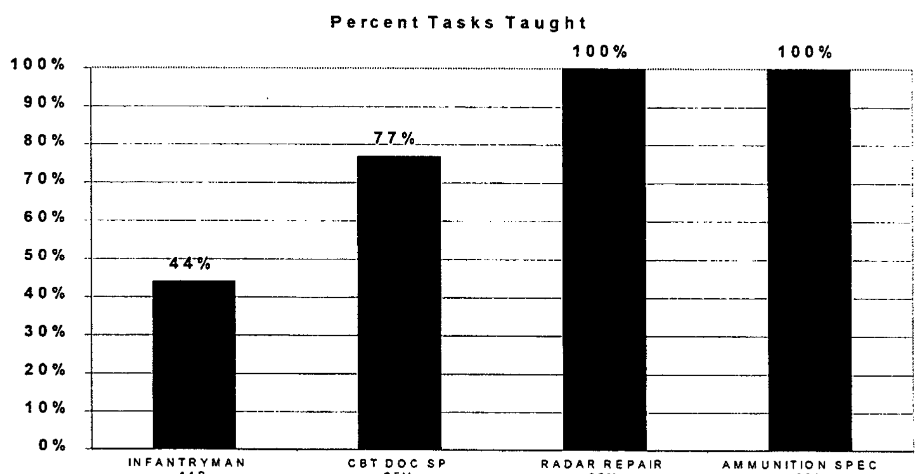

Figure 5. Completion of Skill Level 1 Tasks at AIT

CHANGING DRIVING FORCES

The Army's personnel strength management strategy can be identified in its decision support system. This system is a complex family of models that simulate and forecast the strength of the career force. Initially the models forecast the losses based on a weighted-average over the three previous years – these forecasts allow the models to determine s the accessions to fill these "holes". Once the required accessions are determined then the recruiting function has the mission to acquire the new enlistees to fill the training seats. This causes a pull-through effect; not only do the non-career force supplies the manpower to accomplish the labor tasks but also serve as the only resource pool to transition into the career force. Together this system produces the power for the Army. Based on the forecasted strength, the Army was able to control the flow of new non-careerists via the draft and later in the successful recruiting market. Recently, this ability to control the flow has diminished. This is due to a number of market dynamics such as higher college enrollments, decreasing unemployment rates, and a decreasing propensity for service. This impact on the personnel system input has strained its ability to meet manpower requirements. This market impact has also showed signs of decreasing the quality of the workforce. As recruits are entering the service, they are tested to determine their aptitudes in various skill areas. The following figure depicts the trends during the draw-down and recent years.

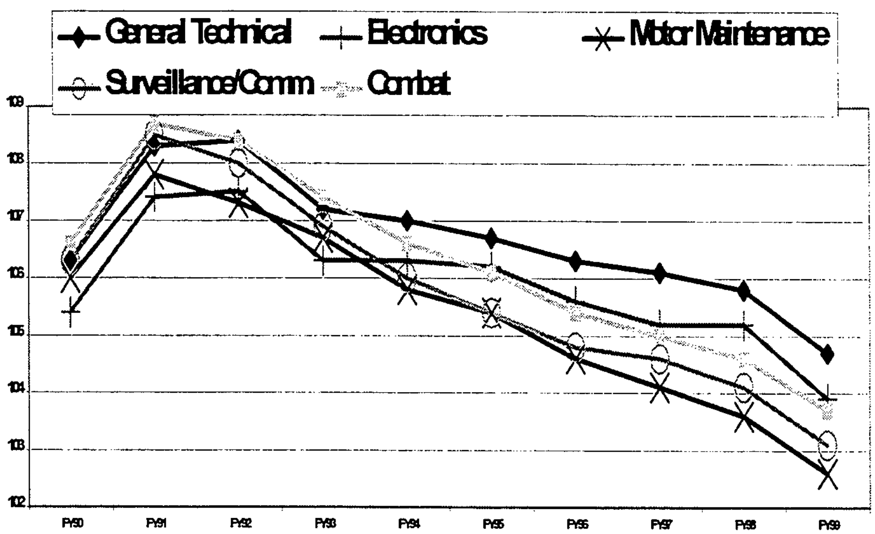

Figure 6. Mean Values for Recruit Aptitudes

This decrease in aptitudes for the current environment is not significant, the maximum is 7%; however given the need for an increase in the capabilities of the soldier for the force that is currently being designed, this trend is significant. Focused on the personnel system's inputs, the U.S. Army Recruiting Command has proposed several programs that are designed to tap into the "new" market of college students. Although this adjustment to the system is focused at the entry-level due to the system's causality would have a positive effect over the entire force given the program's success.

This type of adjustment still leaves the Army susceptible to the external market dynamics of America's youth. Recently the Army has been able to meet manpower requirements through the success of its retention function. This success directly corresponds to an expansion of the career force. In fact several policy changes have been enacted that drastically change the "up-or-out" flow. Two in particular are presented. The adjustments for the retention control points that now allow promotable sergeants, those that have been recommended for promotion by a local unit level promotion board, to remain on active duty until twenty years of service. Secondly, granting indefinite status for soldiers over ten years of service eliminates the decision for re-enlistment. Data is still being gathered to evaluate the results of these policy changes but estimates show an annual population increase of 1.5% for the extended retention control point.

Now that more soldiers are in the force longer we can continue to develop them. This is accomplished since the Army has expanded its personnel management system to include a development function. This process prepares the non-careerist to assume leadership roles in the careerist force, and further develop the career force for positions of greater responsibility and expertise. The Army made the decision in the early 1990's to stop administering the skills qualification test, SQT. The test was designed to measure the technical and tactical proficiency of its career force. An alternative performance measure for the effects of development and training across all ages of service is the Army Physical Fitness Test: physical fitness is a vital skill. Using the scale for the age group with highest raw score required for a maximum-scaled score in each event of any age group, the highest raw score for the other age groups were then scored on the selected age group scale.

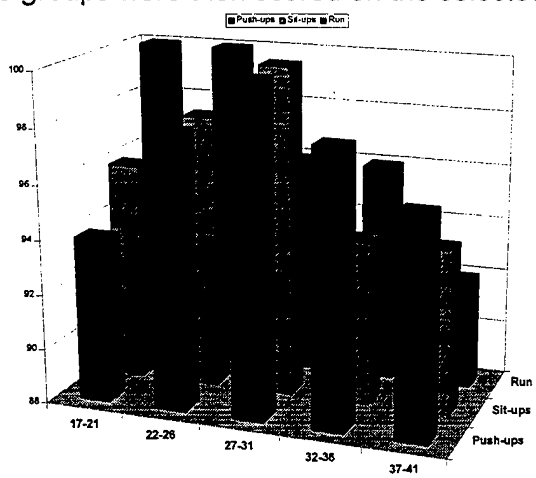

Figure 7. Physical Fitness Test Maximum Scores Comparison

In two of the three events the effect of training is apparent. In terms of physical development a maturing force reaches its peak at the ten-year mark. As stated, there is no data to measure the performance of accomplishing military tasks at the soldier level; the training approach is very similar to the repetition conducted during physical training. This seems to support an increased proficiency from a more experienced and developed force. This also contradicts the "young man's game" mind-set, but there is still the question of cost.

At this time there is still analysis to be conducted in terms of using appropriate cost factors. The Army currently uses the Army Military Civilian Cost System from the Cost and Economic Analysis Center. A cursory review of a sample of military occupational skills produce a factor between 2 and 3 times as much for the senior level Sergeant First Class a reasonable goal for current enlisted soldiers, compared to the entry level privates. There is undoubtedly an increase in performance and development between these levels. A more appropriate comparison of the cost for a technical specialty such as Information Systems Operator-Analyst (74B) shows privates (E1 – E3), $38,887, to sergeants (E-5), $60,697. Understand that the privates not only have a lower level of proficiency but also put a demand for sergeant s to provide the necessary leadership and supervision. Also given the low continuation rate for transitioning into the career force, it would appear that it would be better for long range planning to increase your population of sergeants than to cycle through several privates.

RECOMMENDATIONS

This work demonstrates that a recommendation for the changes of force structure and development are needed. Based on the need to increase continuation rates to meet manpower requirements, increased development for tactical and technical proficiencies for the emerging force and produce the leadership necessary to accomplish the missions for the army in the future. This new system should allow the bulk of the new soldiers to serve in less resource intensive initial training/positions and focus on beginning the leadership development of the required skills, knowledge and attributes. Prior to completion of the end of the initial term of service, the soldier is then accessed into their career field for advanced training in a more specialized field. This would greatly increase the return on investment from the army's perspective in that there is a much higher continuation rate and the organization can expect a longer lifetime contribution. Obviously, this would require an expansion of the current retention function. From the soldiers' perspective this also increases their intrinsic benefits by allowing, based on job requirements, to select their long-term career field. Collection of data continues in this area of the success of reenlistment options for choice of specialty. Initial analysis demonstrated a significant increase for retention of soldiers that were voluntarily reclassified into specialties versus those that were involuntarily told their specialties for any reasonable level of significance. The cost analysis is being developed. Once these factors are obtained there is extensive work in math modeling for optimizing force and grade structures.

Presentations and Publications:

- Conducted Workshop, October 1999 for WOPMS/EPMS XXI Task Force
- Matty, Doug – 68th Military Operations Research Society Symposium (MORSS) "*Joint Analysis: QDR 2001 and Beyond*"- February 2000

Personnel Briefed:

- BG Adair, ADS XXI Research IPR – January 2000
- ADS XXI Task Force, review research and prepare for next phase and IPR to Gen Shinseki – March, 2000

Part III - Documentation

Technical Reports

The Operations Research Center and the Department of Systems Engineering publishes interim and final results from projects and studies in the form of Technical Reports. Below is a listing of the reports published during AY00.

TITLE	AUTHORS
Measuring Financial Management Performance at ASA (FM&C)	MAJ Murray P. Starkel
Enlisted Bonus Distribution Model	MAJ Kevin E. Dice
Warrior Extended Battlespace Initiative	CPT John B. Willis
Area Denial Systems (ADS) Experiment	CPT John B. Willis

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