Engineering Design Opportunities at the United States Military Academy

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Abstract

The United States Military Academy (USMA) at West Point has developed a program to promote academic activities beyond the basic requirements. With a three semester design sequence, this program can enhance student learning and experience with the design process and give students a head start on their capstone project. Although the academy's mission is to prepare cadets for future military service and provide them with an undergraduate degree, we have expanded the academic experience with opportunities to conduct research and design work with scientists and engineers in some of the nation's finest facilities. The Academic Individual Academic Development (AIAD) program is purely voluntary, but over half of the mechanical engineering majors give up free or leave time to participate in it every summer. The AIADs are usually three or four weeks in duration due to the busy cadet summer schedules, but this is ample time to allow the cadets to work on, and sometimes solve, an engineering problem. The Army Materiel Command (AMC) sponsors most of the AIADs, but there have been sponsors from private engineering organizations, NASA, national labs, and even the Air Force. This paper describes the AIAD program, and discusses how feedback from program sponsors can be used to measure student progress toward meeting ABET EC 2000 criteria.

I. Introduction

> "I learned a lot from my AIAD experience. The first and most important thing I learned was that engineering takes time and practice. You just cannot be a good engineer without getting your hands dirty."[1]

Educating cadets at the United States Military Academy is rewarding and challenging. With many mandatory activities and required classes in the humanities and engineering, finding more time for academics is not an easy task. Moreover, the academy is an undergraduate teaching institution, so some cadets may lack the exposure to graduate students and faculty advisors solving real world, detailed design problems. We currently offer the mechanical engineering majors a three course design sequence over a three semester time frame. The courses are *Introduction to Design*, which includes machine design, *Mechanical Design*, which exercises the

design process, and *Capstone Design*, which is a real world engineering problem or a design competition.

Some of the goals of the design sequence are for the cadets to understand better the complexities of engineering and design and how to solve a design problem through application of the design process. A one semester capstone project has limitations and is usually a focused project. We would like to link cadets with capstone projects early in the design sequence to promote their initial efforts and allow them to explore the capstone projects in greater depth. Ideally, if they identified their capstone project after the first course in design, they would exercise the design process over a longer time frame, internalize it, and advance their thought process on the overall project. With only a few two semester capstone projects, many cadets spend their time comprehending the scope and trying to "get their arms around" their one semester capstone.

Additionally, the internal support required for faculty to manage extensive design opportunities cannot be met. With USMA primarily a teaching and not a research institution, the faculty course load would be exceeded. The existing infrastructure (test and fabrication equipment, computer resources, and technicians) would require much upgrade to accommodate design team needs. We must look outside the institution to promote education in design.

One solution to the problem of increasing student exposure to design is to send cadets to a summer Academic Individual Advanced Development (AIAD). While many universities and college students participate in cooperative programs and internships during summer months, cadets at USMA can participate in a parallel program of shorter duration. They spend the bulk of their summers in military training, but with proper scheduling of training events, there are usually several weeks of free or leave time that cadets are willing to trade for the opportunity to participate in an AIAD. AIAD participation is planned before the senior year when most of the military graduation requirements have been completed, and the cadet has taken more engineering courses (Figure 1). If possible, the AIAD project generates enough interest with the cadet that he or she continues to work on it and progresses it into a capstone project during the senior year. This early exposure and identification of a project allows the cadet to work on a two semester capstone project if the AIAD partner provides a project of reasonable scope. Additionally, the cooperation with our AIAD partners and sponsors also allows more mentoring by true customers.

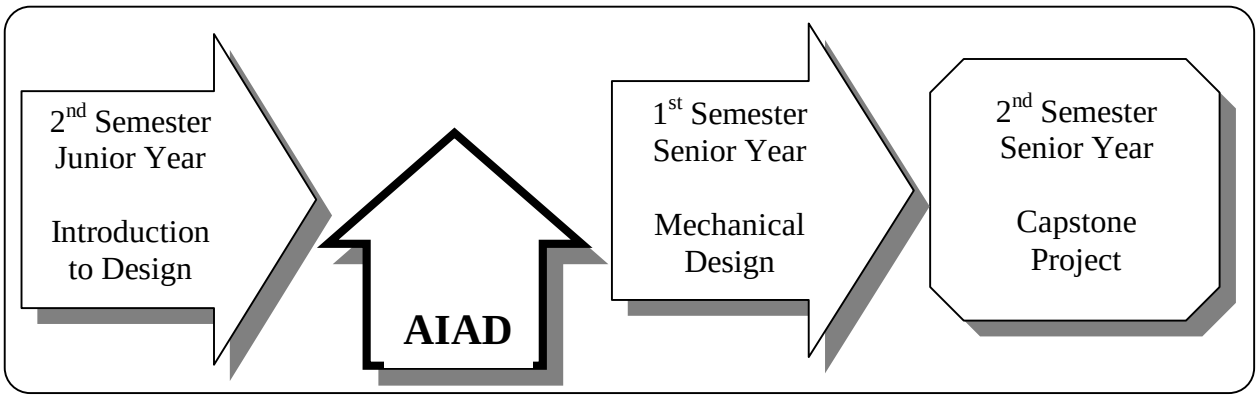

Figure 1. Design Sequence with AIAD

A three week AIAD offers 120 hours of exposure and work on a current engineering design problem. This is equal to the time a cadet spends in a semester course of 40 class meetings in a three credit course. Although the cadets do not receive academic credit for participation in an AIAD, they gain considerable knowledge on a particular problem, learn some new skills, usually function in a multidisciplinary team, and exercise the design process they only previously knew through classroom designs.

The amount of AIAD participation is dependent on the number of mechanical engineering majors. However it is not an entirely new program. Since 1989, The Department of Civil and Mechanical Engineering at USMA has encouraged academic growth beyond the classroom through AIADs. Our principal project sponsor is the U.S. Army Materiel Command (AMC). AMC is the Army agency that develops and purchases all Army equipment. AMC provided the Academy $2,000 for several cadets in 1989, but the program has grown to a current $100,000+ budget and included 64% of the mechanical engineering majors last year. Although AMC is still the main project sponsor for the mechanical engineering students, other agencies that can offer a valuable engineering experience to the cadets can participate in this program.

Although this paper focuses on the mechanical engineering experience with AIADs, other engineering departments at USMA use the AIAD model for design and research. The civil engineers work with the U.S. Army Corps of Engineers for project sponsors. The Departments of Electrical Engineering and Computer Science as well as Physics all receive the bulk of their projects through AMC, National Labs, and other Army agencies.

II. Project Selection

The AIAD process begins with a department representative from USMA contacting potential project sponsors. Some AIAD sponsors have participated in the program for several years and know exactly what to do. We try to expand the AIAD program by informing different agencies we contact on routine business, using alumni contacts in industry, faculty contacts at universities, and coordinating with other departments at USMA. This process is necessary when some projects are completed and new ones are needed to fill the voids and when a project sponsor decides not to participate anymore. Not all potential AIAD sponsors have military or defense related projects. Through personal or family contacts, some cadets initiate projects with an industrial partner. The department coordinator can accept the project if it will provide a meaningful design experience for the cadet. If a prospective sponsor has an AIAD project and would like cadet participation, we ask the agency to use our web site and enter project information (Appendix A)[2]. The main categories are: Agency Information, Project Information, and Cadet Sponsor Information.

The Agency Information simply states the organization that is providing this AIAD opportunity, its location, and a web address if cadets want to learn more about the sponsor. The agency is usually an AMC subdivision or an independent organization such as Lawrence Livermore National Laboratory or Boeing.

The Project Information is the most important category for both the cadet and project sponsor. It states the number of cadets that the sponsor will accept for the project. The project description is a free text area that basically “sells” the project. It must be written clearly to generate interest

with the cadets, and it cannot be too technical or it will steer away some. A typical cadet with interest in this program is a third-year student who has had an extensive undergraduate academic experience but little exposure to the higher-level research performed by these organizations. The project description usually appeals to the cadet by emphasizing the military and academic relevancy of the research. Cadets are very talented, but many are apprehensive about their technical qualifications. Descriptions should avoid unnecessary technical jargon or acronyms.

Additionally, this category also denotes any specific academic prerequisites for participation in the AIAD. Prerequisites must ensure cadets have the skills needed to participate effectively but be open enough not to unnecessarily exclude a potential candidate. Some AIADs require completion of certain courses such as Fluid Mechanics for the aerodynamics related AIAD projects, and some require a minimum GPA. Many projects just require an engineering major and appropriate coursework for a cadet just completing his or her junior year of school.

The Cadet Sponsor Information lists a project point of contact, phone numbers, and email. Cadets use this information if they want to know more about the project when deciding on an AIAD and to arrange participation dates if selected for the AIAD.

During this stage of project sponsor sign up, cadets are allowed to preview the project web site. Cadets have much interest in AIADs and attempt to plan their summers as early as the preceding November. At this point, cadets are doing nothing more than window-shopping; they cannot make selections, but are researching the projects to make a more informed decision at a later time. They often seek cadets who have participated in a similar AIAD the previous year to answer specific questions and form expectations. They are also encouraged to contact the project sponsors for any clarification. A completed project page is included in Appendix B[3].

Once the prospective project sponsors have entered their projects, faculty members within the mechanical engineering division screen the projects. We try to ensure the projects are of reasonable length and have academic merit. The scopes of some projects change often and specific details of the projects are difficult to predict six to eight months in advance. If necessary, we'll ask for clarification or rewording. For new project sponsors, this is often the first dialogue we have with a new agency. We try to provide the right guidance on projects and descriptions to attract cadets. Finally, we approve or reject each AIAD project in December or early January. Upon project acceptance, we insure funds are transferred to USMA from the AIAD sponsor. This is not a problem for the Army Materiel Command, but for smaller or private organizations, transferring funds early reduces the risk of funding cancellations and trying to find projects for cadets after the final selection process. A list of recent AIAD project sponsors is in Appendix C.

III. Cadet Selection of Projects

After cadets return for the spring semester, the cadet selection process begins. We advise them to prioritize their top four or five choices before they come to the department's initial selection. We use an order of merit system where the highest ranked cadet majoring in mechanical engineering gets the first choice of all the mechanical engineering related AIADs. The second highest-ranking cadet gets the second choice, and so forth. Many of these projects can accept

several cadets, so it is imperative to track the number allowed and the number of cadets that have selected one of these projects. Again, we must ensure AIADs with specific background requirements are matched to appropriate cadets. We conduct this initial selection face to face with all interested cadets and use a manual tracking system. Cadets are then instructed to go to a web page for final AIAD selection. There are four rounds for selection. Some cadets will change their minds about a particular project, some will participate in another department's project, or some will decide not to participate at all, and this creates opportunities for cadets who did not receive their first choice. Each round of the selection process lasts two days. We must go to the web site and approve cadets each day. This prevents the approved cadets from changing their minds and eliminates them from choosing any more AIADs. This procedure is necessary since it allows cadets in subsequent rounds to search for an available AIAD that they find more attractive than their second or third choices. The fourth round of selections is for cadets outside of our department that want to participate in one of our mechanical engineering AIADs and meet the background requirements.

We have matched physics and chemistry majors to some of the projects with outstanding results. All cadets must take an extensive amount of required math and engineering courses, so we try to match a cadet's desire to participate in a mechanical engineering AIAD. When cadets have been approved for their AIAD projects, we send notification to the cadets and the project sponsors. Also, in instances where there was no cadet interest in a project, we inform the project sponsor and invite them to submit projects again next year.

Upon notification of an AIAD project approval, cadets must contact the project sponsor and agree on participation dates for the summer. By March, cadets are very certain of their required summer military training and the corresponding dates. They must ensure there is a three to four week block of free time where they can travel to and participate in the AIAD. Project sponsors are very flexible with the dates and work well with the cadets. The projects are usually so large or will take so long to complete that shifting the cadets' availability date from the beginning of summer to the end has very little impact on any project. During this initial coordination, the cadets must also inquire about lodging and transportation requirements. If government lodging is available, cadets are required to use it. If the AIAD project location is too far from government lodging, cadets can use commercial lodging at a government rate. Many cadets drive their own cars at the AIAD sites. If cadets fly to the AIAD location or if they have no car, they can use a rental car to get to and from the work site. However, in some locations, such as in England, cadets must rely on project sponsors for transportation if they do not obtain an international driver's license. The cadet must be his or her own travel agent, inquiring, and coordinating for all these requirements. If an AIAD location is near a cadet's home or relative's home, the cadet can stay with the relative at no expense to the project sponsor. This is an ideal situation since it saves the project sponsor's money and allows cadets to visit relatives during the AIAD.

The cadets must notify the department's AIAD coordinator of any travel and lodging requirements. The AIAD coordinator issues travel orders with dates, authorizing funds for the least expensive form of travel to and from the AIAD site, lodging, food, and the appropriate ground transportation at the AIAD site (personal or rental vehicle). If the AIAD requires a special security clearance, the AIAD coordinator ensures the cadet has the clearance or initiates a

clearance for him or her. Security clearances at some of the project locations are not negotiable, and military travel orders must state the level of clearance. Once the cadets accepts the AIAD orders, they can arrange their travel schedules to best accommodate their other summer military training. They can fine tune and reserve travel and lodging arrangements.

IV. Project Experience

Upon arrival at the AIAD project site, the project sponsor quickly orients the cadet to the project. Work begins almost immediately. The cadets learn and use the Mechanical Design Process by David G. Ullman[4], and have a limited, working knowledge of a design process through some small classroom projects. However, the AIAD projects are well defined by the time the cadets arrive to work on them. AIAD projects usually have most of the customer requirements, engineering targets, and timelines determined. The project sponsors have had extensive communication with the customers, so cadets are primarily involved with conceptual and product design and some testing and evaluation of the product.

Cadets may conduct some design work of the initial phases of their project, but this is usually limited to scheduling issues and revisions or specification changes due to new customer requirements. The bulk of cadet AIAD experience is in evaluation of concepts, actual product design through simulation or testing, and evaluation of a final product. Cadets also have secondary tasks of ordering materials for constructing a product, running computer programs and writing subroutines, constructing CAD models, and delivering information briefings.

With these larger scale projects, cadets can personally experience a thorough, longer design cycle. Even though they may only see a limited portion of the overall design project, cadets gain an understanding and appreciation of the time frame and requirements for a major project. With design class projects limited to several weeks, they quickly change their first impression of working on a design project.

V. Costs and Benefits of the AIAD Program

The educational benefits to the cadets are varied, and experiences are unique to each AIAD project and cadet pairing. However, all cadets receive hands-on experience working on a real world project that usually has military application. The relevancy of the military problem to the cadets' future cannot be overstated: the cadets may help solve a problem that impacts their future. Additionally, the AIAD will probably be the first time the cadets function in a multidisciplinary team. AIADs also reinforce the knowledge and theory learned in typical engineering classes with practical applications to a real world problem. Many capstone projects in the ME Program at USMA tend to be focused, discipline specific projects. The nature of these capstone projects reduces the number of multidisciplinary design experiences available to cadets. The AIAD experience allows cadets to demonstrate their ability to function on multidisciplinary teams in fulfillment of EC 2000 Criterion 3 (d) [5].

Perhaps one of the largest advantages of the AIAD program is the feedback we collect from cadets and project sponsors alike. Soliciting information from both provides us with unique perspectives. Cadet feedback relates the relevancy of the project to engineering design. This

information tells us whether or not we should keep the project available to the cadets if offered again. Their feedback also gives us personal information about the project sponsor and whether or not we should ask the sponsor for future AIAD projects.

Project sponsor feedback is voluntary, and it provides us with an outside look at our academic program. When we send the cadets, who are products of our curriculum, out to an AIAD, we want to know if we are preparing them for engineering and design in the real world. Sponsors are asked to assess the cadets' abilities and our program objectives. Their feedback helps in our internal assessment of the department's goals, the level of student competence, and the scope of certain subjects. It helps the ME Program satisfy the requirements of EC 2000 Criterion 2 [5] as discussed below.

The AIAD program provides a client focused assessment of the skills West Point mechanical engineering students possess. This assessment is used to measure some of the outcomes required by ABET's EC 2000. An example of how the mechanical engineering program assessment system uses this information is shown below:

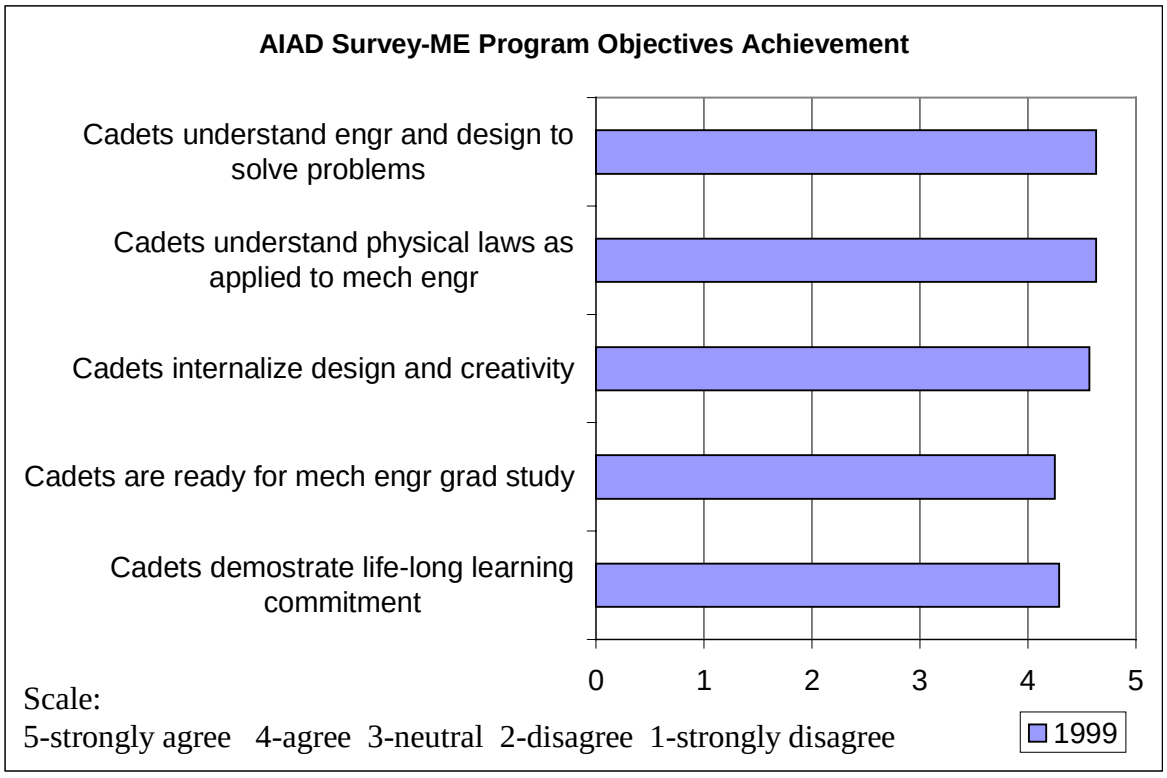

Figure 2. 1999 AIAD Sponsor Assessment

This abbreviated chart shows that USMA's mechanical engineering program is meeting its program objectives in the five areas on the chart. This information is valuable because it is an external look or independent view of the program and skills of the students. Since the AIADs occur early in the design sequence and the feedback is provided when the students are still in the

program, we can address areas of concern before they graduate. Compare the timing of this feedback to the feedback of a capstone course where the student may graduate before areas of interest receive attention. Questions submitted to project sponsors are in Appendix D.

This openness and communication through AIADs can strengthen the alliance between Army researchers and Army educators. There is a steady exchange of ideas and information about new technology between USMA and the project sponsors, and the engineering coursework and design become more relevant with actual design problems.

Some less tangible benefits of the AIAD program include the exposure cadets receive to different cultures in different parts of the U.S. or abroad. Cadets must travel, often for the first time, on their own in a business status. They learn to deal with the requirements of official travel for the U.S. government. As a result of these experiences, AIAD participants are better prepared for their duties following graduation when they must travel as officers.

All of these benefits, however, come at a cost. The AIAD program requires a great deal of administrative support. Each cadet's experience is a separate project to be planned and resourced. These activities can include coordinating summer schedules for several cadets participating in the same AIAD project or location. For the ME Program one faculty member devotes about half time to the program from October through May and about one fourth time the rest of the year. The administrative staff must develop official travel orders, submit changes to the travel orders, and check security clearances for over 64% of the ME majors in about a month every spring semester.

Although project sponsors fund AIAD projects, we try to minimize costs. The length and location of the project determine overall costs. In 1999, the 48 AIAD projects came at a cost of $109,000 for travel, lodging, and per diem.

However, we believe the benefits to the ME Program outweigh the resource costs of the AIAD program.

VI. Conclusion

Incorporating more time for design is difficult with a full curriculum, but the AIAD program at USMA offers some solution. There are many beneficiaries of the AIADs. The sponsors or customers receive an enthusiastic cadet usually at the end of the cadet's junior year to do work, conduct tests, and be part of a design team. Even though the project sponsor spends time mentoring the cadet initially, the cadet provides the organization some degree of expertise and most sponsors are surprised at the zeal and commitment to the project they receive from the cadet. The cadets work on real world projects. Some of them are small, and some are larger, involving complex test equipment and computer codes that USMA does not have. Many of the design projects involve military vehicles and equipment that will be fielded in the Army in the next few years, so cadets are working on equipment that they will personally use in the future. Cadets have the opportunity to see real world engineering. Lastly, the department and the Academy benefit from this experience. Project sponsors provide feedback to us concerning the level of academic knowledge of the cadets, our curriculum, and our department objectives. This

feedback is valuable for our own internal assessment of the AIAD program and our mechanical engineering program and courses.

Bibliography

1. Petrino, Patrick, USMA AIAD Feedback Questionnaire, West Point, NY, 1999.
2. URL: http://cgi2.usma.edu/cgi-bin/ws.exe/websql/iad/indnewpr.hts; IAD Project Login
3. URL: http://cgi2.usma.edu/cgi-bin/ws.exe/websql/iad/ppview.hts?IADNBR=6216; IAD Project 6216
4. Ullman, David G., The Mechanical Design Process, McGraw-Hill, New York, 1997.
5. URL: http://www.abet.org/downloads/2000-01_Engineering_Criteria.pdf; page 32

ROBERT RABB

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JOHN KLEGKA

COL John Klegka is an Associate Professor and the ME Division Director in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point. He received a B.S. from USMA in 1973, a M.S. degree from the University of Michigan in 1982, and a PhD from Texas A&M University in 1989. He has enjoyed many assignments within the U.S. Army during his more than 27 years of active duty service.

Appendix A: New Project Web Site

IAD Project - New Project Entry Form

Please fill out the following form for the project that your agency is sponsoring. All information is required unless otherwise noted. When you have completed the form, please submit your information in order for the project to be entered into our database. **Note:** If your IAD project's duration is more than three weeks, please notify the IAD POC prior to submitting your project.

Project Funding

If your agency is funding this project differently than you initially specified, please adjust the percentage.

% Funding by Agency: 100

Project Info

Project Name:

Cadets : **Min #** **Max #** **Faculty :** **Min #**

Project Type: **BOTH - CADET/FACULTY**

Duration: **3 weeks**

Type of Security Clearance required: None

Category: Department of Mechanical Engineering

Facility/Area Access required: None

Related Category:

- None
- Army Acquisition
- Department of Behavioral Sciences and Leadership
- Department of Chemistry
- Department of Civil Engineering

(Select all that apply. Do not re-select the main category for this project. If this does not apply, select "None". Help available.)

Project description:

Background required:

Project Location Info

(If the location of the project is different than the agency location, please update the following.)

City: **State:** MD - MARYLAND

Point Of Contact Info

Name: **E-mail:**

Fax #:

Submit Clear

Return to IAD Project Agency Home Page

Appendix B: Sample Project

Cadet IAD/Faculty Research Projects - Dept POC View Individual Project

Listed below is the information for the project selected. You have the capability to Edit, Approve (if project not already approved), and Delete by selecting the corresponding buttons at the bottom of the screen.

Agency Information

MACOM: AMC/ Non-ARL
Name: Tank Automotive and Armaments Command - Tank Automotive and Armaments Research and Dev Center
Address: AMSTA-TR, Warren, MI, 48397-5000
WWW URL: http://www.tacom.army.mil/

Project Information

IAD #: 6216
Title: Electric Drive Technology Development
Approval Date: 11/23/1999

Project location: Warren, MI
Project for credit? No

Project Description:
Project include MATLAB and FORTRAN code writing. Attendance of ongoing project meetings. Report progress of contractor work. Depending on project schedule duties include control systems setup. Cadets are encouraged to attend research seminars and assist in presentations by the team which include ride/drive demonstrations of ED vehicles. Those showing interest in programming may assume project work in modeling and simulation.

Background Required:
1. Rudimentary knowledge in controls and thermodynamics. 2. Cadets are cautioned to bring clothing that may be stained and oiled. 3. Rudimentary knowledge in the use of handtools. 4. Potential candidates are urged to contact POC via email or phone for further discussion of the nature of the project.

Number of Cadets: 1 - 2
Number of Faculty: 0
Duration: 3 weeks

Category: Department of Mechanical Engineering
IAD POC: Major Rabb

Related Category:
Department of Electrical Engineering and Computer Science, POC: Dr Tappert

Security Clearance Required: None
Facility/Area Access Required: None

Cadet Sponsor Information

Name: Harold Pangilinan
Phone: (810)574-8532 **FAX:** 8105748532
DSN prefix: 786
E-Mail: pangilih@cc.tacom.army.mil

Edit Delete

Return to IAD Project - Dept POC Project View Menu

Appendix C: 1999 AIAD Projects

Project	**Agency / Location**
Constructive, Virtual, and Live Simulation & Modeling of Current/Future Army Helicopters	NASA Ames / Moffett Field, CA
Tilt-Rotor Design for Next-generation Rotorcraft	NASA Ames / Moffett Field, CA
Rotorcraft Design Studies for the Army's Future Joint Transport Aircraft (JTR)	NASA Ames / Moffett Field, CA
Aeroperformance Analysis of a Future Army Helicopter	NASA Langley / Hampton, VA
Wall-crawling Robot Concepts	ARL / Aberdeen, MD
Electric Drive Refurbishment / Demo / Maintenance / Modeling	Tank Automotive Command / Warren, MI
Flight Test Instrumentation Rack	AMC / Fort Rucker, AL
Munitions Research Assistant	U.S. Army / McAlester, OK
Combat Vehicle Design Tool Development	UT @ Austin / Austin, TX
Testing of Transparent Armor	UT @ Austin / Austin, TX
Fixed Wing Flight Training	Dept. C&ME / West Point, NY
Review, Test, and Evaluation of Space Flight Science and Crew Equipment	Johnson Space Center HoustonTX
Experimental Investigation of Parafoil Inflation	Natick Research / Natick, MA
Mechanical Systems Design	Mustang Engineering / Houston, TX
Military Academic Research Associate	Livermore National Lab Livermore CA
Airborne Systems Evaluation	USARDS Group / Boscombe Down UK
Artillery/Weapon Systems Studies	USARDS Group / Halstead UK
Wheel Systems Technology and Capabilities Studies	USARDS Group / Chertsey UK
Power Plant Project Engineer	Enron Engineering / Houston, TX
Foreign Military Equipment Eng. Data Exploitation	USAF / Wright-Patterson AFB, OH
Automotive Testing	U.S. Army Aberdeen Proving Ground / Aberdeen, MD

Appendix D: AIAD Sponsor Questionnaire

AIAD Feedback Summary 1999

Based on your knowledge of mechanical engineering and your experience and knowledge regarding the needs of the United States Military Academy and the Army, please answer the following questions regarding these enclosures:

(**Please Note**: If you do not feel qualified to address any particular question, please leave it blank.)

Please use the following scale:
5-strongly agree 4-agree 3-neutral 2-disagree 1-strongly disagree

1) The Mechanical Engineering Program Objectives are consistent with the mission of the United States Military Academy.

2) The curriculum outlined in the enclosed templates support the achievement of these Program Objectives.

Please provide any further narrative input on these questions:

Based on your contact with cadets and graduates of the USMA Mechanical Engineering Program, please answer the following questions regarding their achievement of the Program Objectives:

3) Cadets and graduates understand the philosophical basis for the practice of engineering as a social enterprise that uses design to solve problems.

4) Cadets and graduates develop an understanding of and an appreciation for the natural physical laws, particularly as they apply to mechanical engineering.

5) Cadets and graduates internalize the design process and demonstrate creativity in solving problems.

6) Cadets and graduates are provided the elements of engineering practice necessary for success as entry-level mechanical engineers or for admission into and success at top mechanical engineering graduate programs.

7) Cadets and graduates demonstrate a commitment to life-long learning.

Please provide any further narrative input on these questions: Please see above comment.

Based on your contact with cadets and graduates of the USMA Mechanical Engineering Program, please answer the following questions regarding their basic engineering abilities:

Cadets and graduates demonstrate:

8) an ability to apply knowledge of mathematics, science, and engineering.

9) an ability to design and conduct experiments, as well as to analyze and interpret data.

10) an ability to design a system, component, or process to meet desired needs.

11) an ability to function on multi-disciplinary teams.

12) an ability to identify, formulate, and solve engineering problems

13) an understanding of professional and ethical responsibility

14) an ability to communicate effectively

15) the broad education necessary to understand the impact of engineering solutions in a global and societal context.

16) a recognition of the need for, and an ability to engage in life-long learning

17) a knowledge of contemporary issues

18) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Please provide any further narrative input on these questions: