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Innovative Prototyping and Rigorous Experimentation (iP&rE): A One Week Course to Build Culture and a Cadre

Albert Sciarretta, Steven Ramberg, Joseph Lawrence III, Andrew Gravatt, Paulette Robinson, and Mitchell Armbruster

CENTER FOR TECHNOLOGY AND NATIONAL SECURITY POLICY

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About the Authors

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Mr. Andrew Gravatt

Andrew Gravatt joined CTNSP as a Senior Research Fellow, where his in-depth knowledge of information and communication technologies is being used to conduct research in the areas of social media, big data, the deep web, and simulations. He began his career at NASA's Goddard Space Flight Center as a systems engineer. He spent two years during the "dotcom boom" as a consultant managing and developing commercial web sites and applications. After serving as an Associate Professor at NDU's iCollege for one year, Mr. Gravatt was appointed as the Chair of the Systems and Technology Department where he was responsible for the IT Project Management, the Enterprise Architecture, and the Chief Technology Officer curriculum.

Dr. Joseph P. Lawrence III

Joseph P. Lawrence III, PhD, is a Distinguished Research Fellow at CTNSP on assignment from Pennsylvania State University via the InterGovernmental Personnel Act. At CTNSP, Dr. Lawrence occupies the Chief of Naval Research Chair and participates in advisory panels for the DOD, the DON, and the National Academies. Prior to his current position, he was a Federal Senior Executive and served as the Associate Technical Director and the Director of Transition at the Office of Naval Research from 2005 to 2011. He first joined ONR in 2001 as the Director of Surveillance, Communication, and Electronic Combat. The greater part of his career was spent at the Naval Research Laboratory where he was engaged in research and then management of a large number of classified projects.

Dr. Steven Ramberg

Steven Ramberg, PhD, is a Distinguished Research Fellow at CTNSP on assignment from Penn State University. At CTNSP, he provides analysis and advice on science and technology (S&T) topics and policies, primarily in areas of naval relevance. During his career, he served as a Fellow and as Vice President for Arete Associates during 2007 to 2010; as the Director of the NATO Undersea Research Centre (NURC) in LaSpezia, Italy from 2003 to 2007; and as Executive Director and Chief Scientist for ONR during 2001-2003 after joining ONR in 1988. Earlier, he worked at the Naval Research Laboratory where he published over 60 unclassified technical papers in the archival literature

Dr. Paulette Robinson

Paulette Robinson, PhD is a Senior Research Fellow at CTNSP. Before joining CTNSP in 2013, she served as the Associate Dean for Teaching and Learning and Technology for the iCollege at NDU. Dr. Robinson is the leader for the Federal Consortium for Virtual Worlds, a group of over 1,600 individuals from government, industry, and academia who are interested in the use of virtual worlds in government. She is co-leading a project with the U.S. Department of Agriculture to provide secure access to virtual worlds for government. Before joining the Federal Government, Dr. Robinson was the Assistant Director for Academic Support in the Office of Information Technology at the University of Maryland.

Mr. Albert Sciarretta

Albert A. Sciarretta (U.S. Army Lieutenant Colonel, retired) is a Senior Research Fellow at CTNSP, where he assesses Army S&T efforts; as well as broader DOD technology and analytical needs. Mr. Sciarretta is also president of CNS Technologies, Inc., for which he supports DOD efforts related to assessing advanced military technologies, developing S&T investment strategies, and designing and executing tactical through operational demonstrations and experiment. His military service included operational assignments, instructing at the U.S. Military Academy, acting as a technology officer on armored vehicle task forces, and serving as Assistant to the Chief Scientist, U.S. Army Materiel Command.

Acknowledgments

We were pleased to be able to contribute to the effort sponsored by the Rapid Reaction Technology Office (RRTO) of the Deputy Assistant Secretary of Defense for Emerging Capability and Prototyping (DASD[EC&P]) and were grateful for their intellectual and financial support from inception through fielding of the pilot courses. In testimony to the initial foresight and dedication of DASD(EC&P) and RRTO leadership, we offer a few selected quotes from student evaluations:

> "Top down is good, but culture change, as you know, will be hard."
>
> "The real usefulness of the Capstone Project was the interaction between the members [students] and getting a better understanding of different organizational cultures."
>
> "Application of any concept into practice is the key. S&T (6.3) transition pressure is real. Lack of [an acceptable] failure culture is alive and 'not well'."
>
> "The course and Capstone Project provided a repeatable framework for conceiving, designing and executing experiments. I thought I knew how to do that going into the course, but didn't. I feel much more able to do this now."

The authors are especially indebted to the Case Study presenters who gave of their own time and effort to substantially enrich the course. Their biographies are given in Appendix H. We owe a special thanks to Mr. Alan Brown whose Case Study was given in all three iterations of the pilot course with his unique knowledge and style to the acclaim of the students.

Finally, we also gratefully acknowledge and thank the Chief of Naval Research for providing and supporting two of the Center for Technology and National Security Policy (CTNSP) principals (Dr. Joseph Lawrence III and Dr. Steven Ramberg) in this effort.

Executive Summary

This DTP contains all of the course planning and curriculum content provided in the Final Report delivered to the sponsor of a pilot, one week course developed at NDU for the Rapid Reaction Technology Office (RRTO) in the Office of the Deputy Assistant Secretary of Defense for Emerging Capability and Prototyping (DASD[EC&P]). The purpose for publishing this Defense and Technology Paper (DTP) is to make the material readily available to others who may benefit from our experience and wish to utilize the materials developed.

The RRTO sponsored the Prototyping and Experimentation to Improve Acquisition (PEIA) course development as part of its efforts to model a more agile technology organization and meet the goals of the Defense Department's Better Buying Power 3.0 (BBP 3.0) initiative. The pilot course focused on these ends:

(1) Experimentation with a variety of prototypes as a means to explore new capabilities in a learning mode to inform future acquisition, but without necessarily leading to an acquisition program of record in all instances;

(2) Achieve agile and affordable acquisition, based on the use of experimentation with prototypes, to define more robust requirements and to achieve greater technological maturity at the outset of formal procurement;

(3) Develop a cadre of midgrade officers and civilians familiar with prototyping, experimentation, and critical thinking in these areas before arrival in positions of relevant responsibility within the Department; and

(4) A growing and networked community of former students with online resources to support their future prototyping and experimentation efforts.

This CTNSP DTP has been prepared primarily with the intent to enable future implementations of a short course on Innovative Prototyping and Rigorous Experimentation (iP&rE). The DTP provides an overview of the course, with a discussion of the educational approach, the outline for a one week presentation, an outline of each of the sessions in the course, and a discussion of student assessments. It also includes a proposed plan for the transition of the course and for its future offerings. The appendices include detailed information of the specific course materials as well as short biographies for the speakers.

CONTENTS

I. BACKGROUND OF THE PEIA EFFORT

Mr. Benjamin P. Riley, former Principal Deputy for the Deputy Assistant Secretary of Defense for Emerging Capability and Prototyping (DASD[EC&P]), envisioned a course to help build a cadre of DOD military and civilian leaders familiar with the roles of innovative prototyping and rigorous experimentation to properly equip and prepare the U.S. military for an uncertain future. He began a dialog with faculty and staff of the Center for Technology and National Security Policy (CTNSP) at the National Defense University (NDU) to explore ways to offer a pilot course to these ends:

- Experimentation with a variety of prototypes as a means to explore new capabilities in a learning mode to inform future acquisition, but without necessarily leading to an acquisition program of record in all instances.
- Achieve agile and affordable acquisition based on more robust requirements and greater technological maturity at the outset of formal procurement.
- Develop a cadre of midgrade officers and civilians familiar with prototyping and experimentation processes and critical thinking before arrival in positions of relevant responsibility within the Department.
- A growing and networked community of former students with online resources to support their future prototyping and experimentation efforts.

Through this effort, the NDU/CTNSP staff fielded three iterations of a one-week pilot course while also searching for a permanent home for this educational offering and creating a prototype of an online Community of Interest (COI).

The NDU/CTNSP staff, drawing upon diverse experiences in education, science and technology (S&T), acquisition, and testing, developed a pilot, one-week course in 2015 and iterated on the course in three offerings during 2015: February, June, and September. To exemplify teaching points, guest speakers were invited to discuss relevant DOD prototyping and experiment case studies. Their biographies can be found in Appendix H. This report summarizes the outcomes of the effort and provides documentation of the final course content.

II. PEIA COURSE OVERVIEW

A. <u>Overall Instructional Approach and Learning Outcomes</u>

The overall instructional approach was problem-based, using case studies to model approaches to prototyping and experimentation for the students. Thus, it was both pedagogical (i.e., lectures with presentations) and andragogical (i.e., case studies, student projects, and discussions) whenever we could make it so. This approach also gave the students vicarious experience through the experiences of others. The central curriculum focus of the one week course was on the Design of Experiments (DOE) using a variety of prototypes ranging from conceptual elements to operational elements across a range of experimental venues or types. The students were required to do an experimental design project (Capstone) within several small teams. Their findings and recommendations were briefed on the last day of the course to a board of senior DOD officials who would ostensibly be making programmatic decisions based upon the team's output. This allowed the students to directly apply what they learned in the course to solving a problem. To illustrate the variety of prototypes and the ranges of experimental venues, a simple 3x3 matrix was developed as a mnemonic for the students as depicted pictorially in Figure 1 and in more detail in Figure 4. It was referred to as the 3x3 PEIA matrix and its use was required in the students' briefings of their Capstone Project.

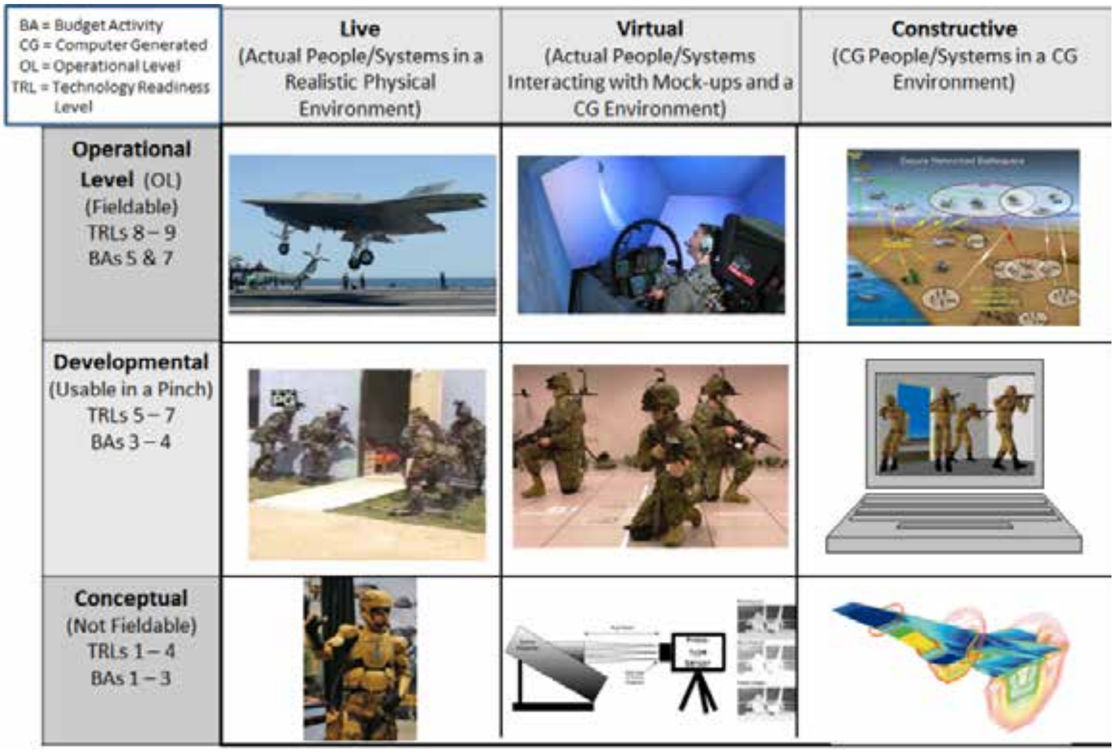


Figure 1. A pictorial representation of the 3x3 PEIA matrix in Figure 4

The five Learning Outcomes (goals) established for the course are identified below in Table 1.

Table 1. Desired Student Learning Outcomes

Students will demonstrate an understanding of the:
1) Strategic importance of prototyping and of experimentation for: a) Exploring potential new capabilities b) Refining requirements c) Maturing technologies
2) Approaches to conceive, design, conduct, and evaluate experiments
3) Value of appropriate risks in the various levels of prototyping and experimentation
4) Value of negative results (e.g., prototype failure) as an acceptable outcome of experimentation
5) Critical importance within any acquisition Program of Record of stable requirements and adequately matured technologies

The pre-course survey also provided information about the students' backgrounds, so better role assignments for the Capstone Project teams could be made. As part of the Capstone Project setup, the following key roles were defined as critical in any successful experimentation program. The roles were described to the students as:

Military User – You are the person who might use the new capability to solve your problem or to create an advantage.

System Buyer - You are the person who will manage the system integration and procurement of any new capability to meet stated requirements within cost and schedule.

R&D Supplier (researcher/technologist) – You are the person who assembled the technology and are its expert and (possibly naive?) advocate.

Requirements Setter – You will set the military requirements for the potential new system(s) to meet in procurement.

Tester and Evaluator – You will be asked to validate the results of any assessments against the stated requirements.

For the student Capstone projects, we assigned the students within each team to assume the role of one of the above expected participants in an acquisition program. Although not achieved for the pilot courses, Figure 2 provides notional goals for the demographics of the student target audience.

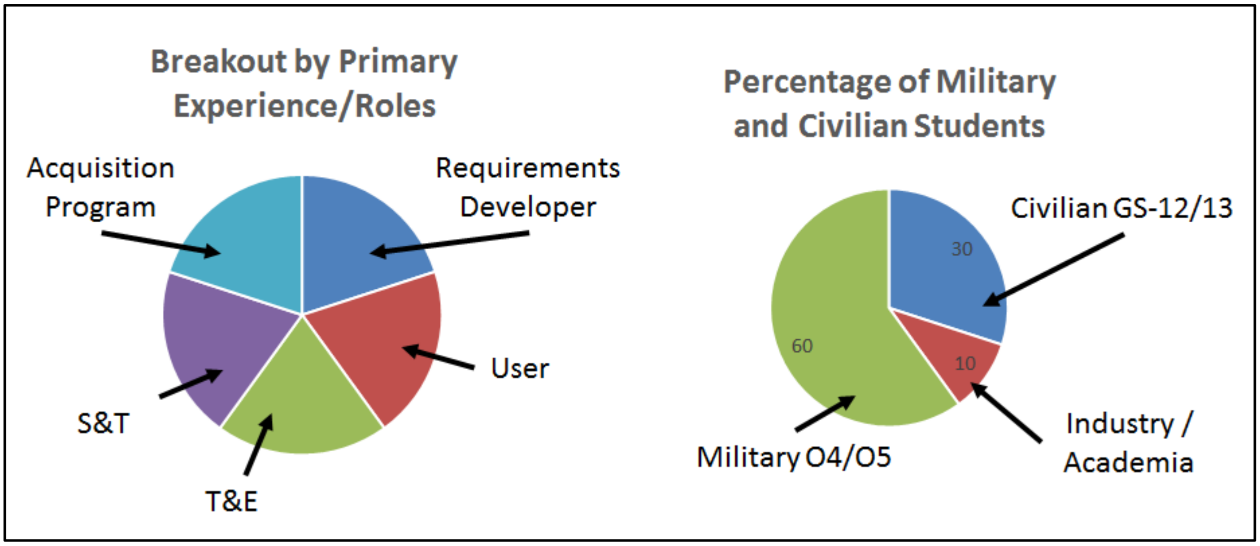


Figure 2. Notional demographics of student target audience

This breakout in Figure 2 includes a preference of somewhere between 20% and 50% of the student body with any acquisition training or experience. We did not enroll the desired fraction of Military O4/O5 students and had a larger civilian and higher military rank enrollment. More details for all of the above course information are provided in the following sections of the report and the appendices.

To support the assessment of the pilot courses, pre- and post-course questionnaires were developed and provided to the students. Additional discussion is in Section D, as well as Appendices C and D.

An example of a student Capstone Project presentation (outbrief) is in Appendix F.

B. Assembling the Main Elements into a One Week Course

It was a challenge to strike an effective balance between the need to provide the students with sufficient background information, tools, and multiple case studies with the practical student need for time to work as a team on their Capstone project. To mitigate this challenge, we used one case study (Smart Sensor Web) as a means to also illustrate principles of experimental design by a knowledgeable instructor and we chose case studies that had some synergy with the content of the Capstone Project. The resulting efficiencies seemed critical for all three pilot classes. With these critical efficiencies, the flow of the course became as follows:

Day 1	Welcome and Course Overview* Setting the Stage** Introduce Capstone Team Project*** Working Lunch (Teams Work on Capstone Project) Best Practices and Lessons Learned in Rapid Technology Development Definitions and Military Examples of Prototyping and Experimentation Design of Experiments with Case Study
Day 2	Short Review and Discussion of Day 1 Design of Experiments with Case Study (continued) Working Lunch (Teams Work on Capstone Project) Case Study 1
Day 3	Short Review and Discussion of Day 2 Case Study 2 Working Lunch (Teams Work on Capstone Project) Teams Work on Capstone Project
Day 4	Short Review and discussion of Day 3 Red Team Outbrief (optional) and Capstone Team Check-in Case Study 3 Working Lunch (Teams Work on Capstone Project) Case Study 4 Teams Work on Capstone Project
Day 5	Capstone Project Team Presentations and Feedback Course Wrap-Up Community of Interest Website Student Course Feedback (post-course survey completion)

* Including sponsor
** DOD acquisition terms, process and lessons
*** Description and tasking that begins with the working lunch that follows

Starting the second day, each morning began with a brief review of the previous day's program facilitated by a faculty member. It was very beneficial because it allowed the students to ask questions and offer their observations. It often set the stage for that day's materials. The published schedule for the third class can be found in Appendix E. Short descriptions of the main course elements are given in the next section.

C. Short Descriptions of the Main Course Elements

The full content for each course element is available online (see list in Appendix G). Here we provide a few sentences on the Objective, Approach, and any Observation(s) or Lesson(s) Learned for each main course element and offer a Recommendation(s) to improve, as appropriate.

1. "Setting the Stage"

Objective – Provide a common framework and terminology for students about the DOD technology development and acquisition processes. Let history and lessons-learned provide motivation for doing prototyping and experimentation properly and more often.

Approach – Defined DOD Budget Activities (BAs), Technology Readiness Levels (TRLs), and Technology Readiness Assessments (TRAs) in the context of DOD and Service stakeholders to evaluate the effects of oversight based on the maturity of requirements, concepts, and technologies. Summarized current acquisition practices; analyses of current performance, including data on Program Assessment and Root Cause Analysis (PARCA) of problems; and identify an alternative approach addressing the PARCA conclusions and based on extensive use of prototyping and experimentation.

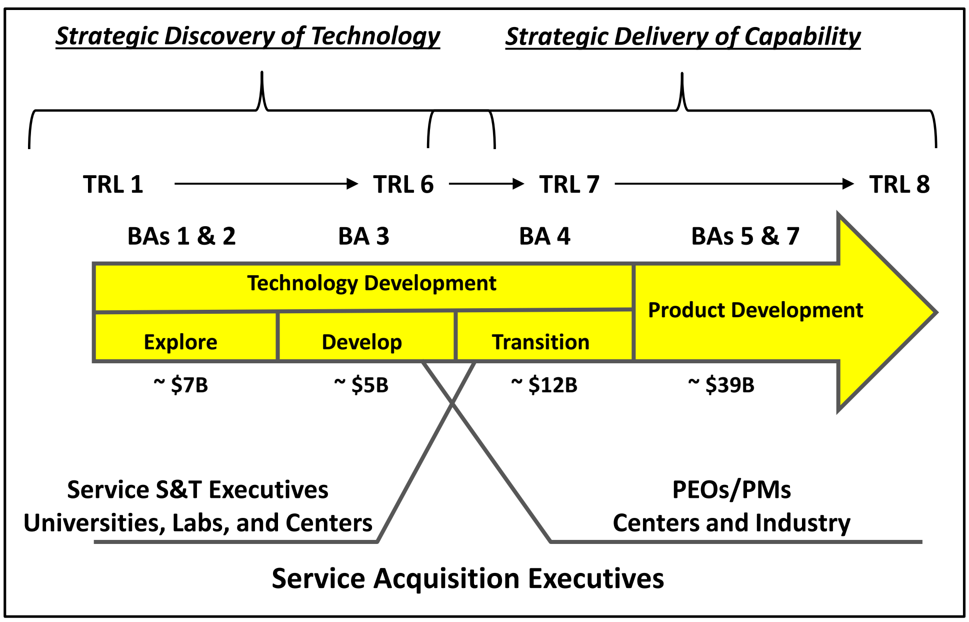


Figure 3. Relationship of Budget Activities (BAs) and Technology Readiness Levels (TRLs)

Key Observation(s)/Lesson(s) Learned – Students were not uniformly familiar with these terms or with the common practices or recent history of both successful and unsuccessful acquisition programs across DOD.

Recommendation(s) - As the student participation shifts to less senior military and civilian participants, the lack of common terminology and an overall framework is likely to grow and this unit of instruction becomes even more important. It is unclear if more read ahead material would be useful until there is some level of common terminology among the students.

2. Best Practices and Lessons Learned in Rapid Technology Development

Objective – Provide real world experiences of mostly military personnel who entered the prototyping and experimentation framework with limited background in the topic and the nature of prototyping and experimentation programs managed out of the Rapid Reaction Technology Office (RRTO).

Approach – Used first person experiences to engage the students. The discussion focused on personal experiences in confronting and dealing with bureaucratic, programmatic, and technical issues.

Key Observation(s)/Lesson(s) Learned – It is useful to orient students toward future career challenges.

Recommendation(s) - Spend more time linking prototyping and experimentation efforts to formal requirements and to U.S. Combatant Command (COCOM) needs.

3. Capstone Project

Objective - Provide students with a hands-on experimental design experience. It was important to include some flexibility in the choice of the problem to be solved and the available prototypes to use and/or create. The assessment was primarily a Design of Experiment (DoE) exercise to put those principles to work so the students could recognize a well-designed prototyping and experimentation program in the future.

Approach - Created teams of five to seven members assigned to the traditional five roles of successful prototyping and experimentation efforts (see Section II.A.). A short description of the Team Project was provided ahead of the course and supplementary materials were provided upon arrival. All three pilot courses used the assignment in the following text box.

> The Team Project: Focus on assessing benefits of pairing autonomous air and ground vehicles
>
> It is envisioned that the pairing will reduce the exposure of Warfighters in harm's way while enhancing the ability of a joint force to penetrate enemy controlled territory to:
>
> - Conduct reconnaissance or surveillance missions (e.g., establish observation point) to gather key intelligence information,
> - Provide targeting information for non-line-of-site weapons systems, or
> - Quickly resupply remote forces by a means other than using manned systems.
>
> Each team could choose any one of the above three "missions" or "problems" to address in their project. An example of one team out brief is included as Appendix F.

Key Observation(s)/Lesson(s) Learned - Commonality among Team Projects was critical for discussing and comparing results on the final day. Each team could see something in another brief that would have improved their own. The similarities with the Case Studies, particularly with the Smart Sensor Web, also seemed to make the teams more productive in the short time available. One of the more effective team briefs invented an overall framework ("campaign") for their project and recognized that some of the required Capstone outbrief content was not suitable for a brief to senior decision-makers. The team creatively developed a storyline ("limited deep dive") as part of their brief that was very effective while demonstrating they clearly understood their goal and their intended audience. As an example of a student Capstone Project presentation (outbrief), we have included this particular team's presentation in Appendix F.

Recommendation(s) – Develop a catalog of several Team Projects over time for re-use. Also, to avoid teams of more than six students, which reduces team effectiveness, we created a "Red Team" which was responsible for preparing the student teams on what to expect during their presentation to the Senior Board on the fifth day. The Red Team was required to brief its material to the other teams on the fourth day. The Red Team was tasked to act as staff to the members of the Senior Board and to provide background data and prospective questions to the Senior Board in advance of the next day presentations.

4. Definitions and Military Examples of Prototyping and Experimentation (P&E)

Objective – Provide the students definitions and examples of conceptual, developmental, and operational prototypes; as well as live, virtual, and constructive experiments. In addition, develop and provide the students a "take away" that would assist them in future prototyping and experiment efforts.

Approach – Developed a one-hour, 23-slide presentation which provided definitions and examples, as well as a brief discussion of the 3x3 matrix. There are many definitions for "prototypes" available in DOD. The goal was to have the students focus in on the three identified in RRTO and in the course -- conceptual, developmental, and operational prototypes. The instructor used examples from his extensive experience in experimentation to explain the differences among live, virtual, and constructive experiments.

Also, the "take away" was developed as a 3x3 matrix (see Figure 4) which conveys the relationships among the three prototype levels and three types of experiments.

Key Observation(s)/Lesson(s) Learned – Students often brought up the discussion of games. The instructor explained how games were like constructive simulations, but normally they are not "validated" or "accredited" sufficiently for use in constructive experiments of prototypes. They could be used in identifying emerging issues, but probably not more than that.

Recommendation(s) – Use the current presentation, and add a slide on games. Ensure that the instructor has experience in prototyping and experimentation. With time, some of the examples of prototypes will become outdated. They should be reviewed, and if needed, refreshed.

Types of Experiments

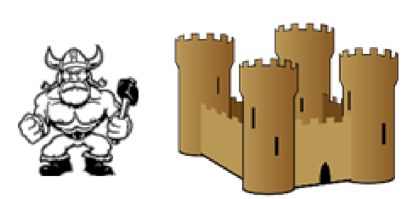
BA = Budget Activity CG = Computer Generated OL = Operational Level TRL = Technology Readiness Level	**Live** (Actual People/Systems in a Realistic Physical Environment)	**Virtual** (Actual People/Systems Interacting with Mock-ups and a CG Environment)	**Constructive** (CG People/Systems in a CG Environment)
Types of Prototypes: **Operational Level** (OL) (Fieldable) TRLs 8 – 9 BAs 5 & 7	**What:** Actual OL prototype **Why:** Most realism. Also, no technical, cost, safety, or environmental constraints **Warfighters:** If involved, trained on the OL prototype **Benefit:** Validate OL prototype benefits in an operational environment	**What:** Mock-up of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual OL prototype **Warfighters:** If involved, trained on the mock-up **Benefit:** Validate (to a lesser degree) benefits in an operational environment	**What:** CG representation (e.g., model) of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual or mock-up of OL prototype. **Warfighters:** If involved, trained on the CG version **Benefit:** Validate (to a lesser degree) benefits in an operational environment
Developmental (Usable in a Pinch) TRLs 5 – 7 BAs 3 – 4	**What:** Dev prototype might be augmented (to represent full capability) or totally represented as a surrogate system **Why:** OL prototype not available **Warfighters:** If involved, trained on augmented/surrogate system **Benefit:** Early user feedback; shape requirements	**What:** Mock-up of Dev prototype. As much as possible, it functions like OL **Why:** Technical, cost, environmental, safety, or other constraints prohibit use of actual Dev prototype. **Warfighters:** If involved, trained on the mock-up **Benefit:** Early user feedback; shape requirements	**What:** CG representation (e.g., model) of Dev prototype **Why:** Technical, cost, safety, environmental, or other constraints prohibit use of actual or mock-up of Dev prototype **Warfighters:** If involved, trained on the CG version **Benefit:** Early user feedback; shape requirements
Conceptual (Not Fieldable) TRLs 1 – 4 BAs 1 – 3	**What:** Conceptual prototype represented as a surrogate or as a "perceived" live system **Why:** Technically immature **Warfighters:** If involved, trained on surrogate/perceived system **Benefit:** User feedback on "needs"	**What:** Mock-up which represents the anticipated performance characteristics of the live system **Why:** Technically immature **Warfighters:** If involved, trained on the mock-up **Benefit:** User feedback on "needs"	**What:** CG representation (e.g., model) of Conceptual prototype **Why:** Technically immature **Warfighters:** If involved, trained on the CG version **Benefit:** User feedback on "needs"

Figure 4. The 3x3 Matrix of Types of Prototypes versus Three Types of Experiments

5. Design of Experiments

Objective - Using a systems engineering approach, discuss the experimental design process from identifying the problem down to developing metrics, a data collection plan, and a scenario. Combine these with available prototypes and resources to develop an experiment plan. Discuss the execution of the experiment plan, analysis of results, and development of recommendations.

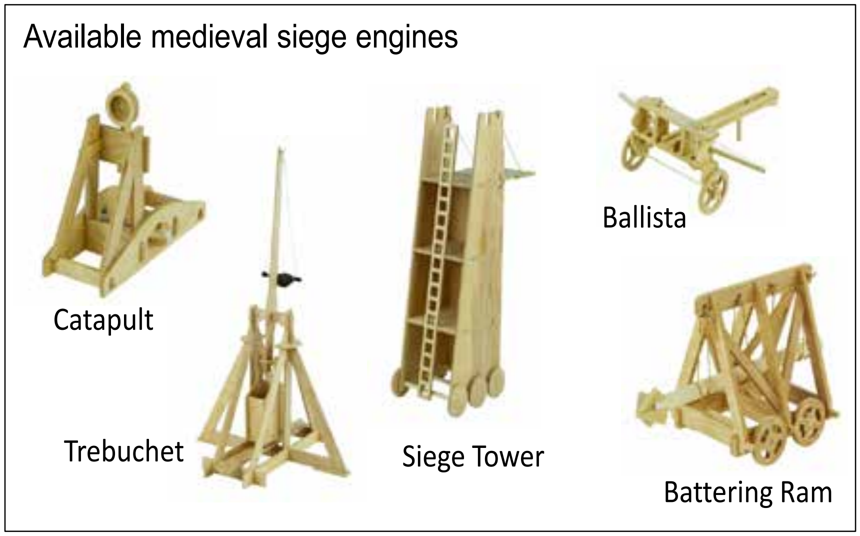
Approach - Used an entertaining, fictional, non-Service-centric example (e.g., Hagar the Horrible needs to breach castle walls with minimal loss of men) with props (e.g., wooden models of siege engines) to highlight points of the above objective.



Useful refrain: A good or bad experiment may be equally costly to run. The main difference is that the good experiment may have a beneficial return on investment.

Key Observation(s)/Lesson(s) Learned - The use of a simple, entertaining, non-Service-centric example with props was very useful in conveying a difficult, but essential, amount of material.

For the first pilot course, a more complex, highly technical and descriptive, example was used and the students became very confused. In addition, the first example was very much Army-centric, which was of interest to most of the Army personnel, but lacked the connection with personnel representing the other Services.



Recommendation(s) – Keep this topic in full, but always make certain that it "lives" for the students. Ensure the instructor has a background in both Design of Experiments and in executing live, virtual, and constructive experiments.

6. Case Studies

Objective – Provide the students with relevant examples of prototyping and experimentation efforts that were well executed and had impact on DOD even if it did not lead directly to an acquisition Program of Record.

Approach – Selected topics and speakers who could tell the storyline while pausing to engage students at certain junctures of the story to ask "What would you have done, if faced with these circumstances?" Also ensured that at least one Case Study was related to the Capstone Project, giving students at least one example that is relevant and similar to their assignment.

Key Observation(s)/Lesson(s) Learned – The synergies between selected Case Studies and the Capstone Project allowed the teams to build their projects further and deeper than would have been possible in a one week course.

Recommendation(s) – Keep some form of this synergy. The topics should include at least one Case Study similar to the Capstone Project.

Case Studies Used

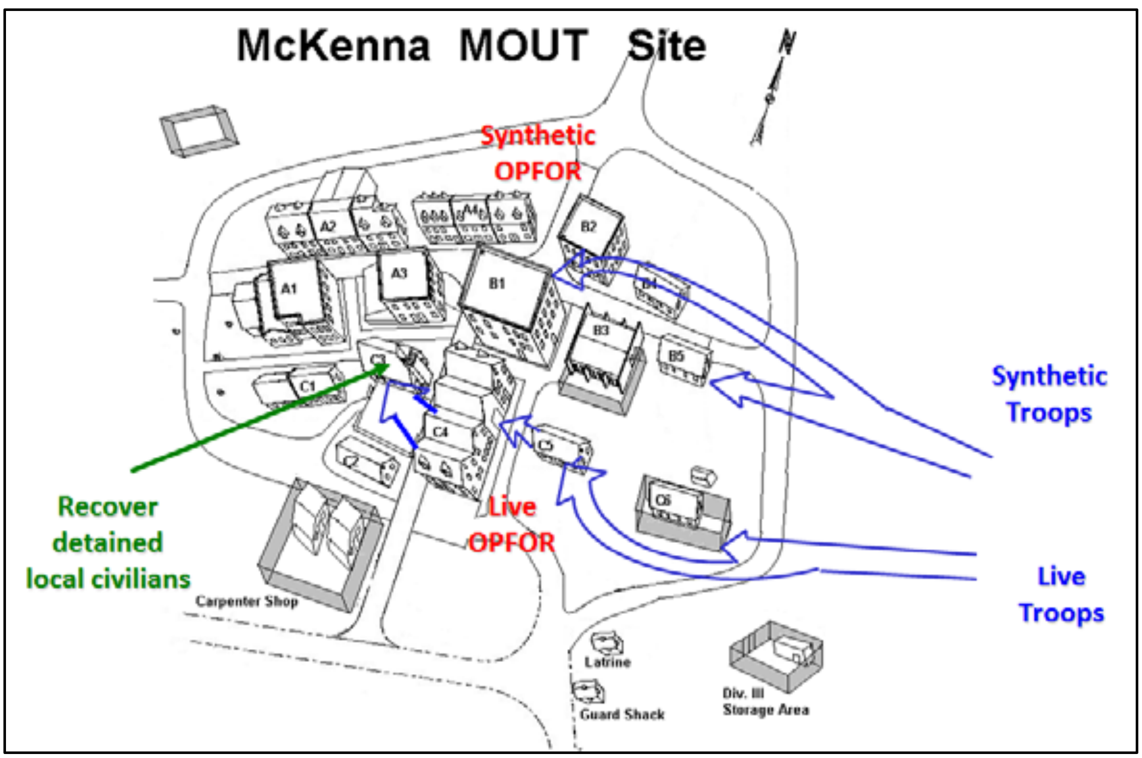
a) Smart Sensor Web (SSW)

Short Description – The SSW was a 2002 experiment that was conducted to assess the concept that an intelligent, web-centric, distribution, and fusion of sensor information, provided on demand, would greatly enhance the situational awareness of dismounted infantry at lower echelons. A brief depiction of one of the scenarios is depicted below.

Primary Attributes for the Course – Presented by the lecturer for Design of Experiments (DoE) who was also the Experiment Director for the SSW effort. Several synergies exist with the Capstone Project. This effort did not lead directly to a follow-on acquisition Program of Record, but shaped many follow-on developmental programs.

Key Observation(s)/Lesson(s) Learned – It was valuable to have this Case Study presented by the lecturer who was a key participant in the PEIA development effort and also the lecturer on principles of experimental design. The lecturer structured his narrative of the case around the material presented the first two days, especially: 1) Definitions and Examples, and 2) DoE.

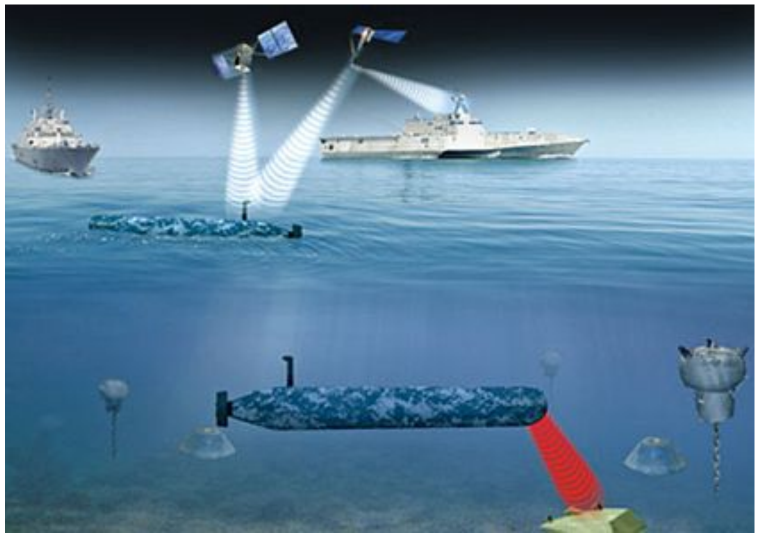
Recommendation(s) – If a single person cannot be found to do these three tasks (definitions, DoE, and SSW), then strong collaboration and thorough coordination among the tasks should be achieved by the lecturers.



b) *Unmanned Underwater Vehicles – Mine Countermeasures*

Short Description – The Unmanned Undersea Vehicle for Mine Countermeasures (UUV MCM) project has evolved from efforts starting in the 1990s. It provides unmanned mine countermeasure capabilities as a primary tool to keep critical sea lanes open.

Primary Attributes for the Course – This was a very good example of a team that adopted a long term "build-test-build" approach using prototyping and experimentation to incrementally field a revolutionary capability for a small warfare community within a small acquisition program context. Autonomy was an essential feature with low communication bandwidths in a cluttered environment.



Key Observation(s)/ Lesson(s) Learned – A very good maritime case study for autonomy.

Recommendation(s) – Keep it, or something similar, in the inventory as a good lead-in to the Capstone Project.

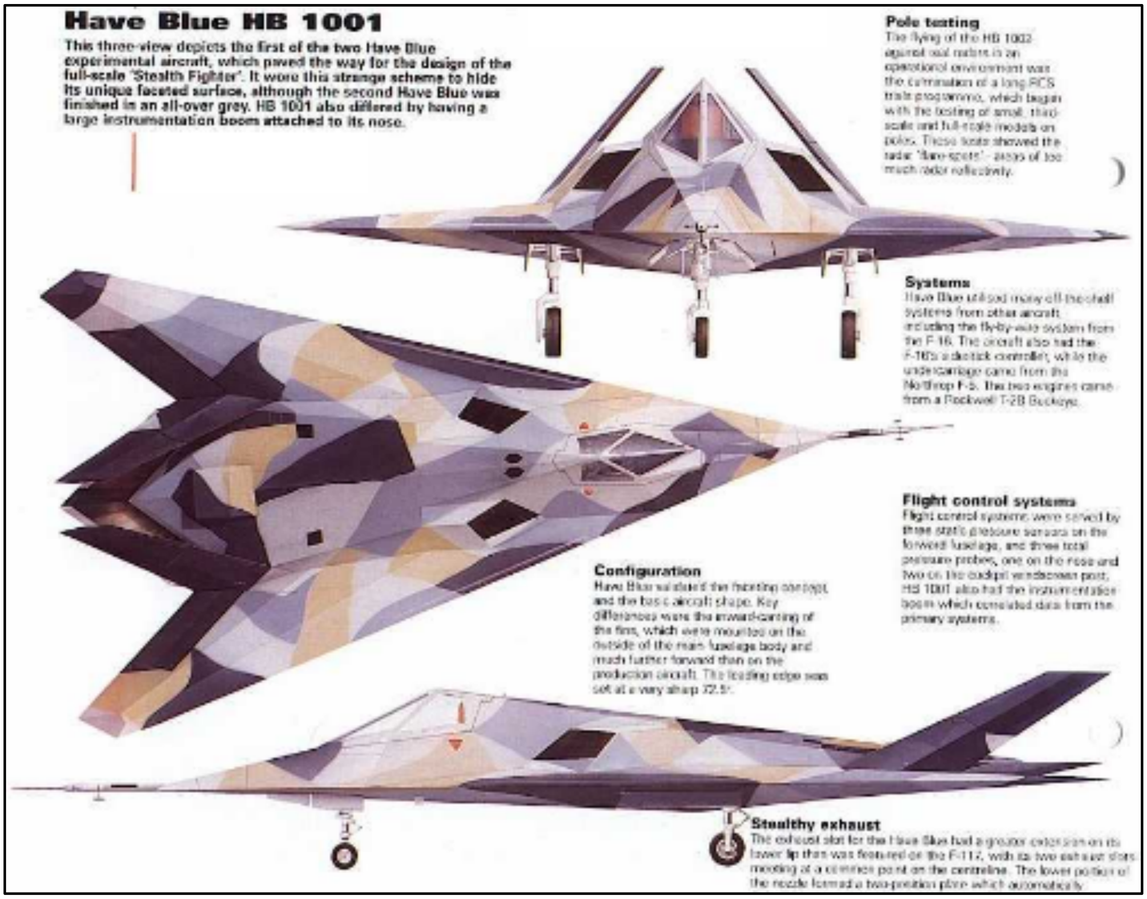
c) *Have* Blue

Short Description – Have Blue was the prototyping and experimentation effort directly leading to the U.S. Air Force (USAF) F-117 stealth attack aircraft.

Primary Attributes for the Course – Clearly a large, revolutionary prototyping and experimentation effort whose story can now be told for these purposes. After choosing this for the pilot course, the USAF highlighted it to USD(AT&L) as a prime example of how that Service would prefer to conduct prototyping and experimentation under Better Buying Power (BBP) 3.0.

Key Observation(s)/Lesson(s) Learned – The speaker, Mr. Alan Brown, was captivating for the students because he was the knowledgeable central technical figure for the program at the Lockheed "Skunk Works" (alias for Lockheed's Advanced Development Projects). Many of the program decisions were counter intuitive and may not have been possible in the glare of full disclosure.

Recommendation(s) – We have recorded two of Mr. Brown's presentations for future uses in class or within the online community. Have Blue is an ideal example of how prototyping and experimentation can enable introduction of new and unconventional technologies.



d) Wolf Pack

Short Description – Sponsored by the RRTO, Wolf Pack was a joint experimental project that sought to improve the combat effectiveness of small combat units. The project addressed several capability gaps which were identified in Iraq and Afghanistan. The overall Wolf Pack capability embraced a variety of mounted and dismounted technologies. Collectively, these technologies were assigned to one of the following capability elements:

- Situational Awareness Capability
- Communications Capability
- Electronic Warfare Capability
- Mobility Capability
- Protection Capability
- Direct Fire Capability
- Non-Lethal Capability
- Surveillance and Target Acquisition (STA) Capability
- Counter Improvised Explosive Device (CIED) Capability
- Biometric Capability

The Project's developmental approach was to assess the military utility of emerging but relatively mature military technologies through a program of theoretical war games and a series of practical, live experimentation events.

Primary Attributes for the Course – The original "testimonial" by a warfighter who was thrust into an experimental task by Vice Admiral (retired) Arthur K. Cebrowski at the Office of Force Transformation several years ago with little experience or preparation. His testimonial focused on how he dealt with bureaucratic issues to employ potentially game-changing capabilities.

Key Observation(s)/Lesson(s) Learned – The "testimonial" proved very effective and was continued as its own element of the course. However, as originally presented, there was little discussion of prototyping and experimentation.

Recommendation(s) – From a prototyping and experimentation perspective, this is not suitable as a prototyping and experimentation Case Study, per se. Some "inside the Pentagon" motivational discussion however appears warranted.

e) Ground Operation Robotics

Short Description – There were two presentations. One focused on basic research (BA 1) level efforts – i.e., conceptual prototypes. The second focused on applied research (BA 2) and advanced technology development (BA 3) level efforts – i.e., developmental prototypes. The presentations addressed: 1) multiple capabilities integrated onto testbed platforms and evaluated using structured experimentation in relevant environments; 2) natural language communication via speech, gesture, and text; and 3) autonomous search and grasp of an initially unseen object.

Primary Attributes for the Course – This is earlier in the developmental cycle than other Case Studies and offers the students a bit of an "over the technical horizon" view for their Capstone Project.

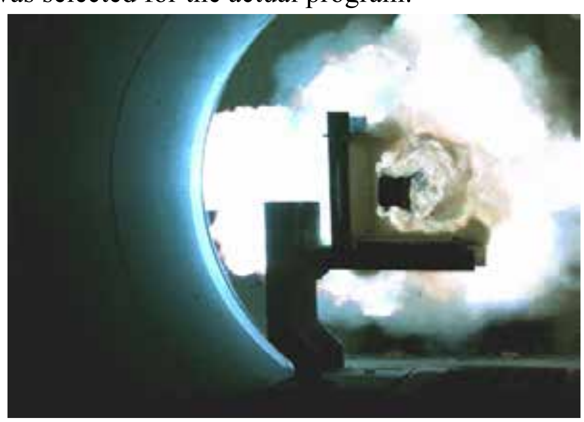
Key Observation(s)/Lesson(s) Learned – Both instructors provided excellent perspectives on S&T level efforts. The planning and executing of experiments for conceptual prototypes was very challenging. Student awareness of the value of experimentation with conceptual prototypes was made clearer with these paired case studies.

Recommendation(s) – This Case Study served to illustrate longer term S&T efforts leading to potential prototyping and experimentation efforts later in the S&T pipeline.

f) Electromagnetic Rail Gun

Short Description – This is a current example of a high payoff, near-term capability with large technical challenges being addressed over many years in S&T. It is now approaching a level of feasibility that prototyping and experimentation efforts are underway with operational (near-production) prototypes.

Primary Attributes for the Course – Illustrates a timely, careful, developmental approach toward an uncertain military capability having high payoff potential. The guest speaker stopped several times during the presentation to provoke student discussion at a decision point where there were multiple prospective paths for moving forward with the effort. The students enjoyed the discussion about selecting a way forward. After the discussion, the speaker would let the students know which was selected for the actual program.



Key Observation(s)/Lesson(s) Learned – This presentation included sensitive information (Distribution D) which could not be released for public dissemination. The paper could not be posted on the online COI site, and is not included in the publicly releasable DVD for this course.

Recommendation(s) – Include this as a Case Study.

7. Capstone Project Evaluation

Objective – To have the students identify in their own words a compelling argument for performance of prototyping and experimentation in advance of formal acquisition; and to give the students an experience briefing senior DOD decision-makers with their Capstone Project results.

Approach – Have a three to four person Senior Board of instructors and DOD executive-level decision makers be briefed by the students who are then attempting to gain buy-in from the leaders in the development of a prototyping and experimentation effort as a predecessor to initiation of formal acquisition program.

Key Observation(s)/Lesson(s) Learned - Difficult to obtain and hold a commitment of executive level decision makers for an entire half day.

Recommendation(s) - Schedule well in advance and use online meeting technology to enhance participation by these decision makers.

8. Online Community Portal

Objective - Provide a resource during and after the course for the students to retrieve materials and to establish contacts among themselves over their careers. Additional discussion can be found in Appendix I and various online screen shots (like the one immediately below).

Approach - Since this was not a major element of the PEIA funded effort and in the long term would not be housed at NDU, we opted for a simple Google site implementation as a means of at least identifying a prospective approach to a community portal.

Key Observation(s)/Lesson(s) Learned - Access could be problematic from government computers based on their firewall restrictions. Unless hosted on a secure, encrypted, network, only Distribution List A materials can be posted with the current approach.

Recommendation(s) – Improve access before, during, and after the course at a site that allows up to For Official Use Only (FOUO) and sensitive material.

D. Student Assessment

As mentioned earlier, the students completed a short pre-course survey and a more extensive post-course survey so that we could make better Capstone Project team assignments and also so that we could qualitatively measure progress against the established Learning Outcomes that we sought. In general, these surveys did not change for the three pilots, although we added a few items after the first pilot. The surveys are contained in Appendix C.

Students quickly learned that the instructional team was receptive to feedback to improve the course and many excellent suggestions were made and incorporated as we iterated on the course offerings. These student suggestions and observations for the last two pilot courses are summarized in Appendix D.

Appendix D (Student Survey Summary Reports [Courses #2 and #3]) also provides brief assessments of the survey and the student responses in terms of "Observations" and "Conclusions" made by the course instructors. For example, the first observation in Appendix D is:

- The responses are listed above in order of highest to lowest as determined in Class #2. The composition of the Student groups varied significantly from Class #1 to Classes #2 and #3 with more senior and more widely experienced students in Class #1 (a deliberate sponsor choice to iterate early on the course content and structure). Rank order of Class #2 and #3 experience is similar although Class #3 indicated higher levels across the board which may account for some of the later minor survey differences between Class #2 and #3 responses.

The corresponding conclusion immediately below this observation is:

- While useful data to monitor the class and to construct Capstone Project teams, the value of these survey questions is largely instructional for the students to think in terms of the five essential roles and the differing perspectives that are necessary for prototyping and experimentation success.

Additional observations and conclusions in Appendix D provide some great insights. They should all be considered in planning future courses. Here are a couple more examples of conclusions:

- The students gained a greater appreciation of the context and culture of DOD acquisition. The survey items are useful and the "before—after" comparisons are valuable, more so if they are available to the students and perhaps the Community-of-Interest over time.
- Generally high marks for the course and an essential question for a student survey including the opportunity to elaborate on both high and low inputs. These helped us tune materials between Class #2 and Class #3.

III. COURSE TRANSITION PLAN

At the outset, there was no expectation that a course of this character would become part of the curriculum anywhere at NDU. This evolved slightly with interest from the NDU iCollege and with the notion that some form of the course might be offered as an NDU elective should faculty and student interest warrant. The transition organizations that have been considered are the Defense Acquisition University (DAU), the Naval Postgraduate School (NPS), and perhaps the Air Force Institute of Technology (AFIT). We have pursued a collaboration with DAU by soliciting attendance by DAU faculty and staff in the last two pilot courses and by seeking feedback from the DAU attendees. This was helpful in the course development and iteration. Several meetings have been held subsequent to the last course offering in an attempt to better clarify a transition path from NDU to DAU. These discussions have involved DAU, NDU, and offices within the OUSD AT&L having responsibilities for prototype development and for the training requirements of the acquisition workforce within DOD. A representative of the NPS attended the first pilot course, but there has been no official interest in transitioning the course there.

As of the date of publication, the Office of the Deputy Assistant Secretary of the Navy – Research, Development, Test and Evaluation (ODASN RDT&E) had identified funding for a reprise of the course in a three-day format. The plan is to conduct three such classes for the Naval Science and Engineering workforce starting in FY16 and extending into early FY17.

In addition, the DAU has been converting the PEIA presentations into five to six presentation modules for an online course. The DAU point of contact for this effort is Dr. Martin Falk, Program Learning Director for Science and Technology Management.

IV. SUMMARY

In summary, we collect a number of the key observations and recommendations provided in the body of the report:

"Setting the Stage"

Key Observation(s)/Lesson(s) Learned – Students were not uniformly familiar with many terms or with the common practices or recent history of both successful and unsuccessful acquisition programs across DOD.

Recommendation(s) - As the student participation shifts to less senior military and civilian participants, the lack of common terminology and an overall framework is likely to grow and this unit of instruction becomes even more important. It is unclear if more read ahead material would be useful until there is some level of common terminology among the students.

Best Practices and Lessons Learned in Rapid Technology Development

Key Observation(s)/Lesson(s) Learned - Useful to orient students toward future career challenges.

Recommendation(s) - Spend more time linking prototyping and experimentation efforts to formal requirements and to COCOM needs.

Student Capstone Project

Key Observation(s)/Lesson(s) Learned - Commonality among Capstone Projects was critical for discussing and comparing results on the final day. Each Capstone Project team could see something in another brief that would have improved their own. Similarities with the Case Studies also seemed to make the teams more productive in the short time available. An example of a student Capstone Project presentation (outbrief) is given in Appendix F.

Recommendation(s) – Develop a catalog of several Capstone Projects over time for re-use. Also, to avoid teams of more than six students, which reduces team effectiveness, we created a "Red Team" which was responsible for preparing the student teams on what to expect during their presentation to the Senior Board on the fifth day. The Red Team was required to brief its material to the other teams on the fourth day. The Red Team was tasked to act as staff to the members of the Senior Board and to provide background data and prospective questions to the Senior Board in advance of the next day presentations.

Design of Experiments

Key Observation(s)/Lesson(s) Learned - The use of a simple, entertaining, non-Service-centric example with props was very useful in conveying a difficult, but essential, amount of material.

Recommendation(s) – Keep this topic in full, but always make certain that it "lives" for the students. Ensure the instructor has a background in both Design of Experiments and in executing live, virtual, and constructive experiments.

Case Studies

Key Observation(s)/Lesson(s) Learned – The synergies between selected Case Studies and the Capstone Project allowed the teams to build their projects further and deeper than would have been possible in a one week course.

Recommendation(s) – Keep some form of this synergy.

Observations, lessons-learned, and recommendations for the individual Case Studies are given in that section of the report.

Key "Take Away"

A key "take away" for the students was the following 3x3 matrix:

Types of Experiments

BA = Budget Activity CG = Computer Generated OL = Operational Level TRL = Technology Readiness Level	**Live** (Actual People/Systems in a Realistic Physical Environment)	**Virtual** (Actual People/Systems Interacting with Mock-ups and a CG Environment)	**Constructive** (CG People/Systems in a CG Environment)
Types of Prototypes — **Operational Level** (OL) (Fieldable) TRLs 8 – 9 BAs 5 & 7	**What:** Actual OL prototype **Why:** Most realism. Also, no technical, cost, safety, or environmental constraints **Warfighters:** If involved, trained on the OL prototype **Benefit:** Validate OL prototype benefits in an operational environment	**What:** Mock-up of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual OL prototype **Warfighters:** If involved, trained on the mock-up **Benefit:** Validate (to a lesser degree) benefits in an operational environment	**What:** CG representation (e.g., model) of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual or mock-up of OL prototype. **Warfighters:** If involved, trained on the CG version **Benefit:** Validate (to a lesser degree) benefits in an operational environment
Developmental (Usable in a Pinch) TRLs 5 – 7 BAs 3 – 4	**What:** Dev prototype might be augmented (to represent full capability) or totally represented as a surrogate system **Why:** OL prototype not available **Warfighters:** If involved, trained on augmented/surrogate system **Benefit:** Early user feedback; shape requirements	**What:** Mock-up of Dev prototype. As much as possible, it functions like OL **Why:** Technical, cost, environmental, safety, or other constraints prohibit use of actual Dev prototype. **Warfighters:** If involved, trained on the mock-up **Benefit:** Early user feedback; shape requirements	**What:** CG representation (e.g., model) of Dev prototype **Why:** Technical, cost, safety, environmental, or other constraints prohibit use of actual or mock-up of Dev prototype **Warfighters:** If involved, trained on the CG version **Benefit:** Early user feedback; shape requirements
Conceptual (Not Fieldable) TRLs 1 – 4 BAs 1 – 3	**What:** Conceptual prototype represented as a surrogate or as a "perceived" live system **Why:** Technically immature **Warfighters:** If involved, trained on surrogate/perceived system **Benefit:** User feedback on "needs"	**What:** Mock-up which represents the anticipated performance characteristics of the live system **Why:** Technically immature **Warfighters:** If involved, trained on the mock-up **Benefit:** User feedback on "needs"	**What:** CG representation (e.g., model) of Conceptual prototype **Why:** Technically immature **Warfighters:** If involved, trained on the CG version **Benefit:** User feedback on "needs"

This matrix was termed the "PEIA Matrix" and is in the curriculum materials available online. A pictorial version of it is in Figure 1 of this report.

Positive Student Assessment

To qualitatively measure progress against the five Learning Outcomes (goals) of Table 1, the students completed a short pre-course survey and a longer post-course survey. Based on those surveys, we have assessed that our success in meeting the goals was very good across the board; however, we forced our self-evaluation into a tertile ranking (by thirds, **T**op, **M**iddle, and **B**ottom) as shown in the second column in the Table below, with relevant student response items (identified in Appendix D) listed in the last column. We note again that student assessments were, on average, very good and our assessment of "**B**ottom" is therefore relative on the tertile scale and is provided to suggest areas that might be improved.

Table - Student Assessments of Learning Outcomes

Students will demonstrate an understanding of the:	Approximate Evaluations in Tertiles	Relevant Student Survey Items
1) Strategic importance of prototyping and of experimentation for:		
a) Exploring potential new capabilities,	**T**	Q2/7, Q6, Q13
b) Refining requirements,	**B**	Q6, Q13
c) Maturing technologies,	**M**	Q2/7, Q6, Q13
2) Approaches to conceive, design, conduct and evaluate experiments,	**T**	Q10, Q12
3) Value of appropriate risks in the various levels of prototyping and experimentation,	**M**	Q10, Q13
4) Value of negative results (e.g., prototype failure) as an acceptable outcome of experimentation, and	**B**	Q2/7, Q10
5) Critical importance within any acquisition Program of Record of stable requirements and adequately matured technologies.	**T**	Q4/8, Q10, Q11

V. APPENDICES

A. Course Management and Logistics

The NDU Project Manager (PM) for the Prototyping and Experimentation for Improved Acquisition (PEIA) course was Dr. Paulette Robinson. The management and curriculum contributions for the course was team-based and included Dr. Joseph Lawrence, Dr. Steven Ramberg, Mr. Albert Sciarretta, and Mr. Andrew Gravatt. Dr. Robinson produced and provided monthly reports to Ms. Paula Trimble, the PM at AT&L/RRTO. The project was concluded with delivery of this final report to Ms. Trimble in November 2015 along with a DVD of publicly releasable course materials and documents. The PEIA DVD was organized by Dr. Robinson with assistance from Mr. Sciarretta.

The project produced three one-week pilot courses in February 2015, June 2015, and September 2015. Curriculum was developed from June 2014 to August 2015. The overall instructional approach was problem-based, using case studies to model approaches to prototyping and experimentation for the students. Thus, it was both pedagogical (i.e., lectures with presentations) and andragogical (i.e., case studies, student projects, and discussions) whenever we could make it so. Case studies for the course were selected by the team. Three were used in pilot courses one and two. Four were used in the third pilot course. Changes in the curriculum occurred between the courses. Complete curriculum reviews were conducted two weeks before each of the pilot courses. All courses were held at NDU.

Outreach to potential students was shared by RRTO and the instructional team. Student registration and administration was managed by the PM, PEIA. Information collected on students included name, rank, organization, phone number, and email. Students were sent two emails. The first email was a verification of registration and the second was a logistics email that included logistical information and a map of NDU. Student classroom curriculum materials were organized by the PM, PEIA. The iCollege copied the materials and created the student binders.

Students completed a pre-course self-evaluation that assisted Dr. Ramberg in placing students into diverse teams. They also completed a post-course self-evaluation to provide feedback on the course. Data analysis was conducted by Dr. Ramberg.

The Community of Interest (COI) prototype was created by the NDU iCollege and Dr. Robinson. All materials were uploaded and organized by the Dr. Robinson. Included on the website was the curriculum background materials, student contact lists, maps, course schedule, case study slides, additional resources, and capstone materials. See additional discussion in Appendix I.

To assist the team in preparing course material; to support course execution, administration, and logistics; and to coordinate transition; course task lists were developed. The following is an example of the course task list for pilot course #3.

Task	Person	Backup	Due Date
Students (Sept 14-18 Course)			
Registration verification email			
Pre-course self-evaluation and logistical email			
Post-course self-evaluation forms			
Pre survey data to Steve			
Conduct post-course self-evaluation			
Post-course self-evaluation data input			

Task	Person	Backup	Due Date
Post-course self-evaluation data analysis			
Student list for sign in – U drive PEIA Course			
Student certificates of completion (file in U drive)			
Create list in order of curriculum materials			
Completed curriculum to iCollege			
Completed course binders (44-students and 6 faculty)			
Create Capstone Teams			
Print student presentation drafts			
COI review			
Red team project (team 5)			
Print IT user agreement forms			
Set Up (Sept 14-18 Course)			
Name placards			
Coffee, cups, creamer, sugar, tablecloths, trash can, etc.			
Set up room (LH 1108, 1106, 1105, 1104)			
Coffee pot (verify 9/11/15			
Bottled Water			
Coffee grounds (2 large)			
Make Coffee each morning of course			
PEIA Course/Sept Class Folder U Drive			
Graphic for PEIA Poster			
Sign graphic and request sent to graphics			
Signs completed			
Signs directing students to the classroom			
Technology (Sept 14-18 Course)			
Computers (5) for breakout room with Wi-Fi access			
Student List for network access (on U Drive)			
Student Wi-Fi___33 access list to Gravatt			
Student Wi-Fi___33 access			
Presentation computer and PPT slides loaded			
Presentation screens and set-up			
DVDs with student out brief template (4)			
Red Team Materials			
Curriculum Materials Placed into COI			
Students placed in COI			
COI ownership transfer to Joe			
August Monthly Report			
Final Report Draft			
Final Report			
THE PEIA REPORT			
What was needed and why			
Description of NDU/CTNSP Effort/Tasks			
Project Overview			

Task	Person	Backup	Due Date
Course Management			
Overall Pedagogical Approach and Learning Outcomes			
Curriculum Summary			
Setting the Stage			
Funding Projects and Lessons Learned (Ermer)			
Capstone Project			
Definitions and Military Examples			
Design of Experiments			
Case Studies			
Smart Sensor Web			
UUV			
Have Blue			
Wolfpack			
ARL Robotics			
Electromagnetic Rail Gun			
Student Assessment			
Project Evaluation			
Online Community Prototype			
Logistics			
Project Start and End Dates			
Deliverables			
Pilot Course Testing			
PROJECT TRANSITION PLAN			
BUDGET SUMMARY			
DIGITAL MATERIALS (DVD)			
Project Transition			
DAU			
Transition Follow-up			
Transition Briefings			
Earl Wyatt			
DAU Leadership			

B. Capstone Project materials provided to the students

Capstone Project Description - You are a member of a team that has been assigned to assess the benefits of technology components of a potential development acquisition program. You will be briefing a senior Flag/SES Board to gain approval for your prototyping and experimentation plan. The information generated by the execution of your plan will be used by senior decision makers in the future to better assess technology maturity, understand potential warfighting benefits, and determine a path forward. The potential program will pair unmanned air and ground systems that are fully coordinated and mostly autonomous. It is envisioned that the pairing will reduce putting warfighters in harm's way while enhancing the ability of a joint force to penetrate enemy controlled territory to:

- Conduct reconnaissance or surveillance (e.g., establish observation point) missions to gather key intelligence information,
- Provide targeting information for non-line-of-site weapons systems, or
- Quickly resupply remote forces by other means.

Individually, both unmanned systems may be able to perform these tasks. However, they each have limitations in accomplishing them. Terrain and enemy actions normally introduce limitations on the ground vehicle's situational awareness, movement, and line-of-sight surveillance/targeting capabilities. It is believed that the pairing will enable the ground component to have better situational awareness and to maneuver more rapidly on the battlefield, avoiding difficult terrain, obstacles, and even threat forces. For the unmanned air system, limited time-on-station and lack of stealth may be its primary limiting factors. It needs to be determined if the pairing's synergistic warfighting capabilities (e.g., shared situational awareness, enhanced ground maneuver) provide significantly greater military benefits (e.g., reconnaissance, surveillance, targeting, resupply) to the joint force than either one can provide individually.

The Team must select from the above desired capabilities to establish goals and objectives for the Prototyping and Experimentation (P&E) Plan.

The experimentation assets available for you to use (or not) are list in Table 1.

Table 1. Description of Available Assets

Assets Available for Prototyping and Experimentation	Short Description
UAV	Level 5 autonomy available now at TRL 9 (live, virtual, and computer-generated systems available now) Level 6 available in five years at TRL 6 (virtual and computer-generated systems available now)
UGV	Level 4 autonomy available now at TRL 9 (live, virtual, and computer-generated systems available now) Level 5 available in five years at TRL 6 (virtual and computer-generated systems available now) Level 6 available in ten years at TRL 3 (computer-generated systems available now)
UAV-UGV Pairing System	Pairing software is at TRL 5. Interaction communications between the UAV-UGV are at Level 4 autonomy –human intervention/direction is needed for the pairing system to operate as envisioned.

Assets Available for Prototyping and Experimentation	Short Description
Warfighter-System Interface	The Warfighter-System Interface (WSI) for the integrated UAV-UGV pair is currently at TRL 5 – mostly on a computer-based system, as opposed to common handheld controller. Envisioned UAV-UGV WSI cannot operate with a single human controller – independent sub-controllers are needed for the UAV and the UGV. All system controllers using the WSI must be in the same room to support verbal interactive communications among themselves while controlling the UAV-UGV pairing system, as envisioned. NOTE: Current levels of autonomy and TRLs require the pairing to function – as envisioned – with significant "human intervention" by warfighters and civilian engineers. With Level 6 autonomy, the paired system will require little to no human intervention and will respond appropriately to the "command and control" of warfighters.
Communications Links (General)	Technically available at various bandwidth rates, but may be constrained by potential interference with civilian and military systems
Live Force	Live personnel to play roles of C2 (including use of WSI), intelligence personnel, and limited number of operators of indirect fire systems (manned aircraft systems and other non-line-of-sight weapon systems)
Fielded systems which may be available as live, virtual, and computer generated systems	Non-line-of-sight weapons (tube/missile artillery and air-to-ground missiles with precision guided munitions) Manned aircraft systems (fixed wing and rotary) C4ISR systems [NOTE: safety and environmental constraints may limit use of live weapons and manned aircraft systems – ranges have limited bombing capabilities]

Capstone Team Tasks

The team will deliver to a Flag-level/SES Board a briefing to gain approval and funding for a prototyping and experimentation approach to assess the military benefits of the envisaged capability. The team needs to:

- Convince the Board that the approach will prove the value of the envisaged capability, refine requirements, and determine the next steps (e.g., disregard the technology and capability, shelve the technology for future consideration, pursue further development, or pursue a program of record).
- Convince the Board that they understand what needs to be done for prototyping and experimentation.
    - Address the alternative types of prototyping and make the case to the Board that this approach is the smart one.
    - Be ready to describe and discuss a representative portion of the experimentation planning to show the Board that the team understands the Design of Experiment process and what needs to be done.
- Show the Board that after the prototyping and experimentation is completed, the team should be in a position to take the next step (as described above).

- Show the Board that the team has developed a plan to address the risks that need to be addressed.

The briefing should address at least the following:

Capability Goals. Derived from the envisioned Capstone Project Description above.

Possible Prototyping and Experimentation (P&E) Program Development Approaches. Discuss options for moving forward – e.g., program using current technologies, program using more mature technologies, refining requirements. If the technologies are mature enough and the needs/requirements are settled then an acquisition program could be started with issuance of a request for proposal (RFP) to be funded with BA5 funds. If the technologies are not mature enough and/or the needs/requirements are not settled then a prototype and experimentation effort may be warranted using BA3-4 funds before "graduating" to a BA5-funded program. Technologies could also be merely assessed using prototyping and experimentation and then be put "on the shelf" until needed at a future date. Identify the development approach chosen and, presuming that an initial prototype and experimentation phase (BA3-4) is recommended, justify the potential additional time and costs as compared to a straightforward acquisition program award (BA5) to a prime contractor.

Prototyping based on Technology Readiness and Capability Requirements. Based on the readiness of the technology as well as the stability of the capability needs/requirements, discuss which prototypes would be considered for assessment.

Experiment Objectives Experimentation objectives should support Program Goals previously identified. (In the interest of time, two are provided. The Project Team should expand on these and develop at least one more.)

- Objective #1 – Determine if current levels of autonomy warrant moving forward with the development acquisition program.
- Objective #2 – Determine if pairing these platforms provides capabilities which are significantly more beneficial than operating them independently.
- Objective #3 – <<TBD>>
- Objective #4 – <<TBD>> (optional)

> For Instructor Use Only
>
> Examples of additional objectives:
>
> – Determine shortcomings in warfighting capabilities, including performance and effectiveness, of this pairing approach and identify potential mitigation strategies.
>
> – Determine warfighter-system integration needs
>
> – Determine gaps in needed technical capabilities and possible technical solutions

Take no more than two of the objectives and determine the following:

- Identify Sub-Objectives (optional) (if applicable, no more than four)

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Examples of sub-objectives:

- Determine impact of levels of autonomy on individual and collective tasks
- Determine when the UAV provides the UGV the most benefit in pairing
- Determine when the pairing has no benefit
- Determine when it is effective for the UAV to participate in the ISR, targeting, and logistics missions
- Determine what aspects of the UAV information cannot be replicated by the UGV or any other system
- Determine which system provides the best targeting information
- Determine if pairing should be more than one air and one ground component
- Determine minimum bandwidth rate for pairing links
- Determine shortcomings, if any, in communications links between unmanned systems and C2 and intelligence personnel

- Using the most critical objectives/sub-objectives, identify four Essential Elements of Analysis (EEA)s
- Using the most critical EEAs, identify four Hypotheses
- For two of the hypotheses, identify metrics for proving/disproving each one. Identify at least four measures of performance (MOPs) and two measures of effectiveness (MOEs) for each hypothesis.
- Determine two overall measures of value (MOVs) for assessing Operational Utility.
- Develop a Data Collection Plan
- Develop a Scenario which supports the Data Collection Plan
- Identify which live, virtual, and computer generated systems (especially operational, developmental, and/or conceptual prototypes) will be used in the scenario
- Identify potential constraints (e.g., availability of air space, safety issues, and environmental issues) for executing the experiment.

Risks. Discuss any risks which should be considered during the prototyping and experimentation process.

Appendix B, Annex A. Levels of Autonomy

Levels of Autonomy

Level	Name	Description
1	**Human Operated**	All activity in system is direct result of human-initiated control inputs. System has no autonomous control of its environment
2	**Human Assisted**	System can perform activity in parallel with human input, acting to augment the ability of the human to perform the desired activity, but has no ability to act without accompanying human input. E.g. anti-skid brakes.
3	**Human Delegated**	System can perform limited control activity on a delegated basis. The level encompasses automatic flight controls, engine controls, and other low-level automation that must be activated or deactivated by a human input and act in mutual exclusion with human operation.
4	**Human Supervised**	System can perform a wide variety of activities given top-level permissions or direction by a human. The system provides sufficient insight into its internal operations and behaviours that it can be easily understood by its human supervisor and appropriately redirected. The system does not have the capability to self-initiate behaviours that are not within the scope of its current directed tasks.
5	**Mixed Initiative**	Both the human and the system can initiate behaviours based on sensed data. The system can coordinate its behaviour both explicitly and implicitly. The human can understand the behaviours of the system in the same way that he understands his own behaviours. A variety of means are provided to regulate the authority of the system with respect to human operators.
6	**Fully Autonomous**	The system requires no human intervention to perform any of its designed activities across all planned ranges of environmental conditions.

6

Note: This slide (#6) is taken from open source presentation by Andy Williams, NATO Allied Command Transformation Operational Analysis Branch, at NATO sponsored Autonomous Systems 21-22 May 2014 Online Workshop. See:
http://innovationhub-act.org/drupal/node/533 and
http://innovationhub-act.org/drupal/sites/default/files/u4/AxS_Innovation_Hub_AutonomyBenefits.pdf

Appendix B, Annex B: Spec Sheets and related references for the assets available in Table 1

If you are looking for more details on future capabilities for your prototyping and experimentation systems, you may chose exemplars of such systems as you fill out the table of options from your Capstone Project Description.   Here are some links that you may also find useful to these ends:

http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf

http://en.wikipedia.org/wiki/Unmanned_aerial_vehicle

http://en.wikipedia.org/wiki/Unmanned_ground_vehicle

http://www.militaryaerospace.com/articles/print/volume-25/issue-12/unmanned-vehicles/canadian-military-chooses-irobot-ugvs-to-detect-chemical-agents-explosives-and-radiation.html http://www.militaryaerospace.com/articles/2011/08/qinetiq-develops-tracked.html

http://aviationweek.com/military-government/unmanned-k-max-operates-unmanned-ground-vehicle

http://www.fas.org/irp/program/collect/uav_roadmap2005.pdf

http://nextbigfuture.com/2015/01/us-army-future-vertical-lift-helicopter.html?m=1

Appendix B, Annex C: Outbrief Requirements and Formats

A list of the “minimum required” slides were developed for each team to use as a starting point.

C. Pre- and Post-Course Student Survey Questions – PEIA Course

Pre-Course Self Evaluation:

1) On a scale of 1-5, please indicate your experience or knowledge as of today about the following: (1=None, 2=A Little, 3=Some Familiarity, 4=Working Knowledge, 5=Held a Related Assignment)
   a) ___Setting requirements for new military systems or capabilities
   b) ___Technology Readiness Levels (TRLs)
   c) ___Science and Technology or R&D activities
   d) ___Program management for system acquisition
   e) ___System demonstration or validation testing
   f) ___Experimentation using prototypes
2) Please indicate if the following are true ("T") or false ("F") statements in your view today:
   a) ___Unanticipated outcomes of a demonstration are usually unwelcome
   b) ___System requirements should not change once a system acquisition is underway
   c) ___The only possible failure for an experiment is a result of a poor experimental design
   d) ___Most DOD acquisition programs do not conduct prototype development and experimentation
   e) ___Most major DOD acquisition programs of the last 2 decades have exceeded significant (Nunn/McCurdy) limits for cost/schedule growth set by Congress

As a member of a course Capstone Project team, you will be required to outline approaches using experimentation with prototypes. This could lead to a new acquisition program with unmanned air/ground components that are fully coordinated and mostly autonomous for the military user(s). The desired capability is coordinated operations that improve situational awareness for ground forces and perhaps also provide capabilities for targeting information to remote weapons systems and ISR for others.

3) How do you see your role(s) in such a team project? [mark with an "X" all that might apply for you]:
   a) ___Setting requirements
   b) ___Determining system utility for operating units (i.e., military user)
   c) ___Developing prototypes (i.e., R&D supplier)
   d) ___Acquisition Program Management (i.e., system buyer)
   e) ___Designing a demonstration/test/experimentation program for a prototype (i.e., evaluator/tester)
   f) Of the above 5 roles, which one best summarizes your overall expertise? ______________.
4) Which of the following do you expect might be the top 4 primary risk areas to the successful delivery of a proposed new capability within cost and schedule? [Select only 4 areas]
   a) ___Immature technologies
   b) ___Unstable requirements
   c) ___Lack of user feedback
   d) ___Budget uncertainty
   e) ___Congressional actions
   f) ___Overselling by vendor(s)
   g) ___Other (please explain) ____
5) In anticipation of the actual course, what are your overall goals and expectations for the course? [Short description].

Post-Course Evaluation:

6) Please indicate by a check, the areas below where you gained significant and useful knowledge or insight from the Course:
   a) ___Setting requirements for new military systems or capabilities
   b) ___Technology Readiness Levels (TRLs)
   c) ___Science and technology (S&T) or research and development (R&D) activities
   d) ___Program management for system acquisition
   e) ___System demonstration or validation testing
   f) ___Experimentation using prototypes often of widely varying types/maturity
   g) ___Importance of diverse expertise and experience in teams

7) Please indicate if the following are true ("T") or false ("F") statements (Yes, you did this before the course):
   a) ___Unanticipated outcomes of a demonstration are usually unwelcome
   b) ___System requirements should not change once a system acquisition is underway
   c) ___The only possible failure for an experiment is a result of a poor experiment design
   d) ___Most DOD acquisition programs do not conduct prototype development and experimentation
   e) ___Most major DOD acquisition programs of the last 2 decades have exceeded limits for cost/schedule growth set by Congress

8) Which of the following do you expect might be the top 4 primary risk areas to the successful delivery of the new capability from your Capstone Project? [Select only 4 areas, mark with an "X"]
   a) ___Immature technologies
   b) ___Unstable requirements
   c) ___Lack of user feedback
   d) ___Budget uncertainty
   e) ___Congressional actions
   f) ___Overselling by vendor(s)
   g) ___Other (please explain)____

9) Please indicate on a scale of 1-5 (5=High) how well the course achieved the following items and how important each item was to you (two scores for each item):

Item	Achieved (1-5)	Importance (1-5)
a) Met your personal goals and expectations going into the course		
b) The extent to which the stated course objectives were clear		
c) The extent to which the stated course objectives were accomplished		
d) The utility of text/presentation material and study notes		
e) The quality of the interactions among students		
f) The quality of the interactions between the students and the instructors		

g) The quality and topics of classroom instruction and activities		
h) The quality and utility of the online portal for the course		

i) Please elaborate immediately below on very high or very low numbers above (additional space is provided at the end of this survey):

9) Please rate on a scale of 1-5 (5=High) the following course attributes:
   a) ____ Depth of material presented
   b) ____ Usefulness of the case studies
   c) ____ Usefulness of the Capstone Project
   d) ____ Pace of the course
   e) ____ Relevance of the course to real world problems
   f) ____ Value of this course to you
   g) ____ Your overall rating of the course
   h) ____ Other (please write out your criterion):___________________________________
   i) Please elaborate immediately below on very high or very low numbers (additional space is provided at the end of this survey):

10) Please indicate on a scale of 1-5 (5=High) how well the Capstone Project has provided you with an appreciation of the need, prior to initiation of an acquisition Program of Record, for:
   a) ___ Stable requirements
   b) ___ Mature technologies
   c) ___ User buy-in
   d) ___ Prior prototyping and experimentation
   e) Please elaborate immediately below on very high or very low numbers (additional space is provided at the end of this survey):

11) Please indicate on a scale of 1-5 (5=High) how well the Capstone Project has provided you with approaches to:
   a) ___ Conceive an experiment
   b) ___ Design an experiment
   c) ___ Conduct an experiment
   d) ___ Evaluate results from experiments
   e) Please elaborate immediately below on very high or very low numbers (additional space is provided at the end of this survey):

12) Please indicate on a scale of 1-5 (5=High) how well the course demonstrated the strategic importance of prototyping and of experimentation for:
   a) ___ Exploring potential new capabilities
   b) ___ Refining requirements
   c) ___ Maturing technologies
   d) ___ Appreciating the value in appropriate risk in prototypes and possible failure in experiments
   e) ___ Improved system acquisition

13) Please elaborate immediately below on very high or very low numbers (additional space is provided at the end of this survey):
14) Please share with us how you would improve the course in the space below.

D. Student Survey Summary Reports (Courses #2 and #3)

Class #1 = Students were given an incorrect post-Course survey, used limited pre-course data for **11**

Class #2 = **19** pre-Course responses and **20** post-Course responses, average of all 1-5 evaluations = **4.15**

Class #3 = **27** pre-Course responses and **26** post-Course responses, average of all 1-5 evaluations = **4.11**

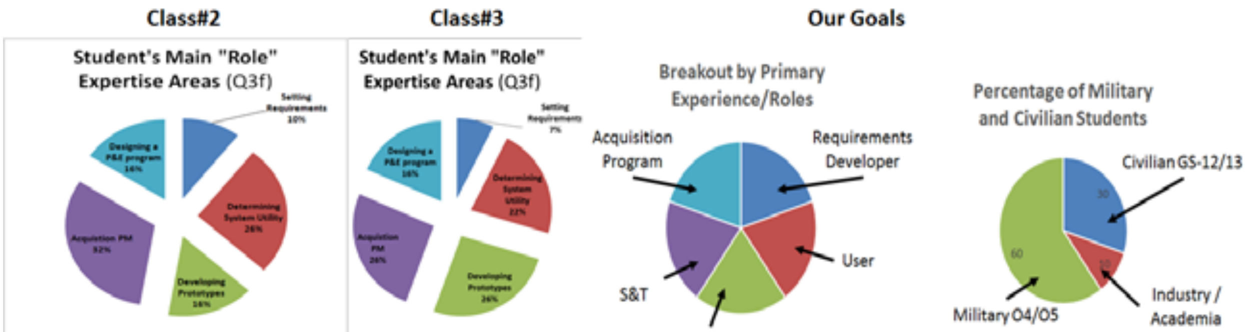
Q1- Student reported prior experience or knowledge (on a scale 1-5)	Class #1	Class #2	Class #3
S&T or R&D activities	3.36	3.68	4.11
Technology Readiness Levels	4.00	3.42	3.72
Program management for system acquisition	4.45	3.21	3.67
System demonstration or validation testing	3.73	3.21	3.78
Setting requirements for new systems/capabilities	4.00	3.05	3.33
Experimentation using prototypes	3.91	2.68	3.52

Q3-Student willingness to serve in 1 of 5 Team Roles (%)	Class #1	Class #2	Class #3
Designing a P&E program	100%	68%	52%
Determining System Utility	36%	58%	48%
Setting Requirements	45%	47%	59%
Developing Prototypes	73%	32%	56%
Acquisition PM	64%	32%	48%

Observation: The responses are listed above in order of highest to lowest as determined in Class #2. The composition of the Student groups varied significantly from Class #1 to Classes #2 and #3 with more senior and more widely experienced students in Class #1 (a deliberate sponsor choice to iterate early on the course content and structure). Rank order of Class #2 and #3 experience is similar, although Class #3 indicated higher levels across the board which may account for some of the later minor survey differences between Class #2 and #3 responses.

Conclusion: While useful data to monitor the class and to construct Capstone Project teams, the value of these survey questions is largely instructional for the students to think in terms of the five essential roles and the differing perspectives that are necessary for prototyping and experimentation success.

Student Mix:



<u>Observation:</u> We did not achieve the student mix that was our goal of balanced participation, although close.

<u>Conclusion:</u> This was <u>an essential survey question</u> for forming diverse Capstone Teams.

Student Expectations (Q5):

Class #1:
Gain additional knowledge of the PM field (techniques and processes) and certify myself as PM professional.
Applicability for the T&E professional.
Understanding how prototyping and experimentation work together, and fit inside the capability development cycle.
I hope to develop an understanding of how the use of prototyping can reduce risk in the acquisition process for military systems. I hope to learn how to define/build a successful prototype program.
I'd like to understand how prototyping can help transition technology into programs of record.
To provide feedback on the course content and structure
Use capstone project lessons learned for a current project.
Class #2:
To get better insight into the potential for rapid prototyping and experimentation to accelerate adoption of leading edge technologies in the DOD acquisition system, as well as the possible road blocks. I hope to provide a valuable operational perspective and leverage previous concept development work I have done regarding unmanned systems in A2/AD environments.
I hope to learn more about refining requirements for large acquisition programs and gain a better understanding of the importance of prototype evaluation.
From R&D supplier POV, DOD 5000 is too bureaucratic, requirements are locked 3-10 years before EMD/LRIP, and changing the requirement to accommodate threat
Gain a greater understanding of the Prototyping and Experimentation landscape in the fiscally constrained environment which DOD is under.
Acquire latest approaches to system acquisition in a fiscal constrained environment.
To learn more about the DOD acquisition program and processes for getting R&D projects turned into Service programs of record.
Understanding the role of prototyping in acquisition and how it can improve decisions
To explore experimentation in terms of the Code of Best Practice by Alberts and its role in improve acquisitions.

Through this exercise, I hope to **gain insight into the scope of an experimentation campaign**. As I am new to this area, I am interested to see how planning might be carried out, even in the classroom environment- the parties that are involved and their roles, the process that is followed and the issues that emerge during the course of the planning.
I am new to the process, so I would like to increase my knowledge base.
Understand how this course content can be applied to AF institutionalization of Experimentation Campaigns.
I hope to learn new methods and best practices from others' experiences.
Identification of interdependencies within the acquisition process. Impacts of experimentation, prototyping and modeling on programs.
Better understand how to show the value of using modern development methods (including using prototypes) and enterprise strategies to defense leadership.
Develop an understanding of the acquisition and requirement development process and how that is integrated with experimentation and prototyping.
Prototyping and acquisition will be necessary for completion of my project for the CNO's Rapid Innovation Cell (CRIC). I'd like to **expand my knowledge and get some real world experience in these areas**.
To gain an introduction by means of a practical application process with respect to Science and Technology or R&D activities. Also to **exercise an opportunity on Technology Readiness Levels (TRLs) evaluation and designation**. **Exposure to the concept of experimentation using prototypes in a scenario setting to enhance foundational learning**.
Class #3:
Understand how DoD will adapt and meet the rapid technology requirement coming from unconventional threat within short developmental cycle
Goals: To better understand how prototyping and experimentation can be used to lower the government's risk in developing/fielding new technologies and capabilities. To understand the intent of BBP 3.0 in pushing for a more informed buyer from the government's standpoint. Expectations: I expect to gain a better understanding of the various perspectives from my classmates, given they sit in different parts of the acquisition system. I expect the curriculum and instructor(s) to facilitate discussions that yield fruitful learning points that I can bring back to my daily activities. Learn more about Virtual Prototyping and its role in the future of DOD Acquisition.
1. Develop a deeper understanding and appreciation for prototyping and experimentation. 2. Have a better understanding of the role of prototyping and experimentation in system acquisition. 3. Learn from and get to know some fellow acquisition professionals. 4. Learn skills and methods that can assist me in my duties as a JCTD Manager.
To gain working knowledge of acquisitions in the technology space.
To become more familiar with the S&T and R &D process.
To gain additional insight regarding the path of DOD Acquisition process and perspectives of others in the DOD acquisition process.
Add to big picture knowledge across DON organizational domains of how prototyping and experimentation will successfully fit into the delivery of proposed new capability. Gaining better knowledge of those areas in which I am less experienced.
Learn more about how prototyping and experimentation can/should be implemented into the roadmap of a program. Gain some working knowledge to help bridge the gap between the Science and Technology, to include the Joint Concept Technology Demonstration community, and the Acquisition Community.
To gain a better understanding and working knowledge of how to utilize the development of prototypes to mature technology, get more out of testing and evaluation, reduce the risk to the program and ultimately deliver a better system to the fleet.

My goal is to become more effective in shepherding new technologies from commercial applications, through FFRDC performers into operational capabilities.
To learn practical skills in designing experimentation campaigns to include virtual and physical prototyping.
Learn new ways to accelerate technology development and delivery by using prototyping.
My goal is to gain insight into the prototype processes and to increase my understanding in the various phases. I believe that this understanding would enhance my abilities to support HQMC in their efforts to develop digital interoperability initiatives.
Apply knowledge gained to better plan and execute prototyping and experimentation strategies for advancing non-lethal technologies/capabilities to the end user.
A general review of items within my current job responsibilities.
Gain a better understanding of how other organizations operate.
Learn of DOD ""best practices".
Be exposed to ideas that could be implemented into my organization.
I hope to learn how to better promote prototyping and experimentation within acquisition program development.
To understand key constraints around effective rapid acquisition and build a working knowledge of rapid prototyping strategies.
A better understanding of how I may better coordinate my S&T efforts (BA-2/BA-3), with those of a technology transition team's (BA-4) follow-on efforts with the same technology as it transitions and evolves.
As an acquisition officer, I have held positions in every phase of DOD ACQ. I hope to interact with colleagues to streamline the acquisition of programs important to USPACOM.
Learn and understand the detailed process of the acquisition and development programs by means of prototyping and experimentation.
Bringing back teachable moments / methods to my command to enrich our collective knowledge in this arena.

Observation: Student goals and expectations were varied, but aligned well with the Course learning objectives and content.

Conclusion: The curriculum materials were aligned to the student's aims. This survey question is essential for course evaluation and to focus students on the course prior to the course.

The Course Outcomes (only Class #2 [green] and Class #3 [blue] had numerical responses)

Q2 and Q7 - Which of the following are True or False?	Before %="True"	After %="True"	Before %="True"	After %="True"
Most Major DOD Acquisitions had Nunn-McCurdy breeches	74	85	78	85
Most DOD Acquisition programs do not conduct P&E	53	80	52	35
Unanticipated demo outcomes are unwelcome	26	40	41	65
System requirements should not change in acquisition	26	40	59	46
Experiments only fail when designed poorly	26	40	22	35

Observation: Faculty believes that all of the above are "True" to some extent or another. The responses are listed above in order of highest to lowest as determined after Class #2. The average of the student responses in Class #2 all shifted toward "True" and probably reflect the likelihood of the statement being true across the board for any particular program, as they learned in both classes.

Conclusion: The students gained a greater appreciation of the context and culture of DOD acquisition. The survey items are useful and the "before-after" comparisons are valuable, more so if they are available to the students and perhaps the Community-of-Interest over time.

Q4 and Q8 - Choose four (4) primary risk areas to delivery of a proposed new capability within cost and schedule.	% Before	% After	% Before	% After
Immature technologies	84	90	78	88
Unstable requirements	79	80	85	80
Overselling by vendors	74	30	44	73
Budget uncertainty	63	55	74	54
Lack of user feedback	47	45	52	65
Congressional actions	37	30	55	12
Other	16	20	21	0

Observation: Of course, all items listed are a risk to success. The responses are listed above in order of highest to lowest as determined in Class #2 (Before). Student responses shifted slightly with a significant increase for "immature technologies" and a notable decrease in "overselling by vendors" in Class #2. Class #3 differed slightly but the overall ranking in both classes are generally consistent. Here are the "Other" risks provided by individual students:

- Risk adverse acquisition transition partners
- Changing threats
- Biting off too much at once
- Poor experimental result
- Under-informed Government program management teams
- Integrated management and alignment of technology, prototype, test and integration, and acquisition across organizational domains
- Poor program strategy and management

Conclusion: The students clearly rethought these as a result of the course and mostly consistent results emerged from the two classes. The survey items are useful, but could possibly incorporate language from the "other" items that students offered. The "before—after" comparisons are valuable, more so if they are available to the students and perhaps the Community-of-Interest over time.

Q6 - Areas where students reported significant and useful gains in knowledge or insight		Pre-Course Self-Assessment (1-5)		Pre-Course Self-Assessment (1-5)
Experimentation using prototypes (of varying types/maturity)	85%	2.68	77%	3.52
System demonstration or validation testing	70%	3.21	38%	3.78
S&T or R&D activities	55%	3.68	42%	4.11
Importance of diverse expertise and experience in teams	50%	N/A	50%	N/A
Technology Readiness Levels (TRLs)	45%	3.42	27%	3.74
Setting requirements for new military systems/capabilities	40%	3.05	23%	3.33
Program management for system acquisition	15%	3.21	35%	3.67

Observation: Significant reported gains in most areas with greatest gains in the areas that were self-reported as lower at the outset of the course and were the top desired learning outcomes for the course. Interesting that significant gain was reported for "S&T/R&D" although it was often cited as a top strength coming in to the course.

Conclusion: Good indication of course effectiveness. An essential question for the survey.

Q9 - Indicate (1-5) how well the course achieved these items and how important the item was to you	Achieved by the Course	Importance to the student	Achieved by the Course	Importanc e to the student
Quality of interaction between students and instructors	4.65	4.45	4.54	4.70
Quality of interaction between students	4.45	4.35	4.50	4.67
Extent the stated course objectives were accomplished	4.45	4.30	4.12	4.50
Met student's goals/expectations entering the course	4.30	4.55	4.00	4.50
Quality and topics of classroom instruction and activities	4.30	4.05	4.27	4.63
Extent the course objectives were clear	4.25	4.15	4.08	4.41
Utility of course material and study notes	4.25	4.05	4.08	4.33
Quality and utility of the online portal	2.50	2.83	3.87	3.40

Observation: Ranking is nearly the same for both Classes. Most evaluations are well above the average of all 1-5 ratings and appear significantly so. Generally achieved the most important items in the order of the importance to the students of both Classes with the exception of their "incoming goals/expectations" which could reflect a mismatch between what they were expecting and what we delivered. The online portal was not readily available nor explained until late in the week. Here are the elaborations provided for unusually high or low scores [lettering refers to the survey form item]:

- As a pilot course, the planning and organization of the instruction is near perfect for the intended objective.
- Great course, exceeded my expectations. In line w/ AF approach in that it is the level of detail needed to put together the campaign.
- Expected to learn new things, d) very well laid out and organized, e) open/informative and diverse, f) Alan Brown was great, g) Capstone provides hand-on + use of siege engines to illustrate, h) no issues w/ access (government laptop)
- Application of any concept into practice is the key. S&T (6.3) transition pressure is real. Lack of failure culture is alive and "not well". h) Would have been useful instead of burning CDs.
- The meeting interactions with my classmates/instructors was the most beneficial part of the course. I had very little acquisition/ prototyping/ experimentation experience, so I learned a lot.
- There was an online portal? [four other comments similar to this]
- c) Facilitated discussions (post review) of the case materials was most valuable. f) Sold the prototype concept well.
- The marks associated with stated course objectives relates to the information provided about the course prior to attending. I thought the course was going to focus on higher level prototyping push within OSD. The focus on experimentation and how to set it up was a welcome difference.
- I enjoyed the course and the content is especially valuable to my work.
- Options c-g above are all important
- Student contact is the best way to improve prototyping. Do more of it and less PPT.
- Expert instructors.
- I don't see the need for an online portal. Distro of the course attendees was very helpful. Case study (Rail Gun/Have Blue) very thought provoking and useful.
- The course re enforces the importance of experimentation across DOD.
- Tempo of the course kept it interesting and constantly moving. Outcomes were therefore understood and engaged by all members of the course. Highly recommend keeping this course going in light of the high visibility and need for P&E.
- Student-instructor interaction was great and Q&A session was very informative.
- There were too many case studies, focus on four cases and study it.
- "Clear objectives and good organization to meet them along with a great teach/presenter discussion.
- The presentation information was clear and helpful to succeed with the capstone as well as take to utilize in day to day tasking.
- Instructors were excellent and very engaging with relevant topics and interactions. "
- As stated in class, look to align with current DAU courses in management system testing. It is critical these three areas understand it. Define, Demo and experiment and prototypes in DAU glossary. Move detail on use of prototypes and experimentation up in Acquisition Framework

and phase of acquisition with details how to do that. More on pulling from 6.1-6.3 to get 6.4 and also how to align 6.1s-6.3 efforts to support 6.4.

- The greatest benefit of the class was learning from the other students and the encouragement and morning in which the instructors guided the conversation.
- The "5" marks are listed that way because I see them as vital to getting the most out of this course. I will be able to leverage a significant amount of what I learned in my efforts to support USMC efforts toward achieving digital inter ability.
- Didn't use online portal.
- Material was adequate, some death by MS PowerPoint on day 2. Good topic though. "
- I was not expecting a portal, but having one was great and made utilizing the material in the future easier.
- I was very impressed with the value, experience, and diversity of the class membership and instructors. "
- Text/Notes-->people can take with them and refer to later
  Topics-->Need to be timely and relevant
  ---->F117 very interesting/historical
  ---->Rail Gun Interesting/Happening NOW
  Online-->Too many different ""databases"" online I lose track. "
- I would have liked more material on the acquisitions piece - from acquisitions professionals in the DOD. Also maybe from logisticians, for a different perspective.
- Low-the portal is good for materials and short term interaction with classmates but is not essential to course success. High- interaction with instructors and classmates is essential (recommend one social event to allow the opportunity to interact with all classmates)

Conclusion: Generally high marks for the course and an essential question for a student survey including the opportunity to elaborate on both high and low inputs. These helped us tune materials between Class #2 and Class #3.

Q10 - Rate the following course attributes	Score 1-5	Score 1-5
Usefulness of the case studies	4.47	4.23
Usefulness of the Capstone Project	4.26	3.96
Depth of material presented	4.21	3.92
Relevance of the course to real world problems	4.21	4.38
Overall rating of the course	4.20	4.08
Pace of the course	4.11	3.96
Value of the course to you	4.11	4.08

Observation: Ranking is mostly the same for both Classes. Validation for the use of case studies and to a lesser extent the Capstone project, depth of material, and relevance. All good and consistent feedback. There was one "other" item offered for a course attribute:

- Willingness of faculty to take suggestions for improvement

Here are the elaborations provided for high or low scores [lettering refers to the survey form item]:

- Ratings are based upon current course curriculum; understanding that that will change over maturation of time and scope.
- Case studies, specifically Have Blue very useful.
- sufficient/adequate to meet needs, b) relevant, c) Seeing end results of other teams and experiencing the process within own team was very informative/insightful, f) will be able to leverage this experience to help inculcate experimentation/prototyping into Service workforce/culture, g) met all needs/expectations
- Case studies illustrated the parts very well. D) Probably too much time in Teams.
- The Alan Brown case study of real world examples helped reinforce the class themes.
- A/C/E/F/G- P&E are relatively new to me in my young acquisition career. Coming from a C4ISR -- particularly F22 background-- I get a different right picture for follow on acquisition assignments as well as understanding the current assignment at JIEDDO. How to write our new directives and acquisition policy.
- I have sig experience on the acquisition side of programs. Learning about the S&T side and the community at large will help me understand what happens before an activity becomes a program of record.
- The case studies, with the exception of Nextech were excellent. Evaluating a successful program, like Have Blue, against the course guidelines covered in the course was valuable. The constructed Hagar example was a great way of teaching the concepts. NexTech was a think tank exercise and the value was questionable.
- The real usefulness of the Capstone Project was the interaction between the members and getting a better understanding of different organizational cultures.
- Course in general is well done. Look at the order of the materials. Multiple (team) check-ins might have merit.
- I would like to see, if it exists, current efforts which encourage experimentation. JIFX comes to mind, but it does not go through the process outlined. Is there, current ongoing venues which encourage experimentation?
- I appreciate how the course was presented in the "K.I.S.S." fashion. As an end user, I was not familiar with the "process". The examples to expand on the material/subject taught was very effective.
- The case study brought significant context to the importance of prototyping/experimentation to avoid cost overages associated with unanticipated problems.
- A good portion of the course seemed to be focused on convincing us of the need for experimentation and prototyping. I think most of us already saw the need.
- Refining requirements--feedback loop to helping refine requirements was not discussed to a major degree, but acknowledged. For instance, if the Capstone project required us to do an iteration of feedback to refine a requirement, the feedback loop would be closed.
- Improved system acquisition--was not really emphasized to a great degree but maybe that is a follow-on course.

- I really believe that P&E needs to be an integral part of the future acquisition reform and the Defense Innovation Initiative when we attempt to leverage new tech and concepts.
  --more effort on the transition tools (experimentation and prototyping) and how they can be used to facilitate transitions.
  --case studies on ""transitioning"" with lessons learned as why it was successful or note.
  --try to focus the case studies on experiments"
- Appreciating the value (above)--managing risks and mitigation strategies to those risks is extremely valuable to better prepare a team when designing experiments and applying it to the structured process.
- Must haves for successful acquisitions.
- Help me understand the difference between prototypes and experiments.
- Most of this course was "preaching to the choir" effect for me.
- The course material did not get me to the importance but the discussions and case study and guest speakers did--especially Alan Brown.
- Definitely a key ingredient, but underutilized in the joint community.
- I had no idea how much effect P&E had on acquisition programs. This course helped to clarify that relationship as well.
- The course/capstone focused on designing experiments. The case studies on prototypes that enabled tech/capabilities to move forward. Suggest including some case studies that show failed acquisition due to no prototyping.
- Have Blue and Rail Gun were good but I don't think the lessons learned and good generalizations were pulled from them.
- Again, the acquisition and requirements piece could be expounded upon by DMEs, not researchers or PMs.
- If leveraged properly and used as defined, prototyping and experiments are low risk high payoff events in the acquisition process (help buy down risk to the wrong thing being produced/acquired).

Conclusion: An important type of question for the student survey to continually adjust the course content and approach.

Q13 - How well did the course demonstrate the strategic importance of P&E in the following areas	Score 1-5	Score 1-5
Appreciating value of appropriate risk and possible failure in P&E	4.55	4.38
Exploring potential new capabilities	4.45	4.27
Maturing technologies	4.40	4.08
Improved system acquisition	4.16	4.04
Refining requirements	4.15	3.92

Observation: Ranking is same for both Classes. Validation of most important elements but a bit surprising that the link to the last two items was less recognized. Here are the elaborations provided for high or low scores [lettering refers to the survey form item]:

- a) identified a gap in institutional knowledge what already exists and/or is already being worked on -"new" is relative so what's new to you/me is not necessarily new
- Top down is good, but culture change, as you know, will be hard
- There is a systemic and cultural issue g USCG and DOD and if not only understood before these items can become game-changers to DOD acquisition
- A great S&T program will increase the likelihood of having a successful program of record.
- The importance of experimentation in exploring and maturing new capabilities were covered in detail. How requirements are refined during experiments was not addressed as much. Does the user observe and go back to his COCOM and adjust his mission requirements?
- More time should be spent on what the improved acquisition system is and how that impacts prototyping and experimentation current structure.
- Maturing tech was well supported by the Have Blue discussion.
- I believe, as was brought up throughout the week, that the current culture of "risk aversion" needs to be addressed and maybe even quantified refocusing toward prototyping and experimentation.
- Thought this course was very well put together.
- Relevance--low depth, but I assume that is what you are going for.
- F117 Case Study--AWESOME.
- Capstone was a useful exercise and cemented lessons learned.
- Case studies were invaluable because I gained a deeper appreciation for program design/decision points/and usefulness of experimentation.
- The case studies re enforces the real-life examples as to the value of conducting well planned exercises and demonstrations.
- Strongly encourage making this a 2-day (no more than 3 day) class.
- While the case studies were interesting (especially the Lockheed Skunk Works and Electromagnetic RailGun), they did not help with the "hows" of prototyping and experimentation. Would have fewer cases
- The course could be shortened with amount of information presented or material could be presented more in-depth. Design of Experiments probably most important aspect. Would have been nice to have more depth in that.
- Overall topic was a real-world problem and solution.
- Case studies help solidify the course content and were very relevant to current climate.
- Group interaction could be enhanced with a little leadership to jump start forming and accelerate the process.
- Very valuable course topic and timing of course was great for me was data calls receiving for prototypes. I gave a few definitions and importance of the topic out of the course. Interactions were key but more detail on prototypes and experiments to different levels in the Acquisition Framework would be important. How to flow it through this and use system engineering process to maximize work is important as well as how PMs should use it.
- The case studies were outstanding. Having people who were actually government of the experiment/program were amazing. They were able to provide so much context and a way of approaching common acquisition and S&T problem that was invaluable,

- There are many aspects of this course that I will be able to leverage in my work. Very useful and informative.
- Would have liked to see more strategies for prototyping and experimentation for ACAT level programs. Most case studies were for S&T (early) vs post MSA type activities. No real discussion as how this informs MDA decisions.
- Case studies were excellent and extremely valuable. Capstone was great to illustrate approaches and learn from meeting the people and instructors and learning from each other in this course format was invaluable! I intend to work with people I met here in my future work.
- Case studies are very interesting to listen to and learn from.
- A more hands on use of/design of an experiment would help. I talked with Al and Ann (DAU rep) about capability of Ft Belvoir/CERDEC NVESD"
- Day 1 was a bore -- for anyone who has been in the community for any length of time
- DOE presentation and case study was simply wrong from an operating research point of view. They made EVERY mistake in the book. If you provided a proper intro to this, your definition would be much easier. i.e., a demonstration is one test where all FACTORS are held constant. A DOE term. "
- Would have liked more integration across case studies-BLUFS0 what was TRL line to be conveyed thru each case study.
- The case studies provided good examples and the capstone project drove home the points of the course.

<u>Conclusion</u>: An important type of question for the student survey to continually adjust the course content and approach.

Q11 - How well did Capstone Project provide appreciation for the following prior to formal acquisition:	Score 1-5	Score 1-5
Prior prototyping and experimentation	4.35	4.15
User buy-in	4.10	3.81
Mature technologies	4.00	3.65
Stable requirements	3.68	3.54

<u>Observation:</u> Ranking is same for both Classes. Fair reflection of the Capstone focus on conceiving and mostly designing the experiment. Here are the elaborations provided for high or low scores [lettering refers to the survey form item]:

- Not sure these are the right questions to focus on. Acquisition program. Capstone questions: why experiment, methodology, DOE. Not sure of the value of this question or my feedback.
- c) Critical validation of experimentation/prototyping for both expected and unexpected outcomes
- Would have been better if instructor stayed with the team

- F22 taught me while assigned there and watching the F35, KC Tanker program, FCS, etc. We as the SOS struggle with A-E and are too constrained in thinking to change quickly enough to really leverage commercial industry packages.
- These topics all contribute directly to the success a program
- Points C and D were central to the course and received much attention. Point A was not covered as thoroughly.
- Since the project had just one input, there was no change. B) and c) Lack of real "play"
- Integration of the user experience into the pre-development prototyping will shape requirements stability. The running of prototype experiments also can wring out technology maturity issues.
- The course homed in on the importance of making inexpensive mistakes in the realm of prototyping/experimentation versus costly premature production oversights.
- Stable requirements--this one is tricky. There is a push towards agile acquisition to include agile software development which requires stable requirements but allows for flexibility as well. So depending on the strategy (acquisition), "stable" requirements are relative. In fact, building on agility would be really programming.
- Prior prototyping and experimentation is extremely important to do this early on from a proof of concept all the way towards the operational/live environment. The 3x3 table provided would be greatly useful for the S&T RDT&E community. Shout be part of the AT&L community.
- Did not impact my opinion of these. Prior to the session, I believed all of these to be important.
- Historically acquisition programs that start really should wait until technologies are more mature. P&E is a much needed part of the acquisition process that has been appropriately addressed for years. This course helps bring it from none use to a valuable part of the process.
- Help me understand how project moves forward.
- Capstone had minimal effect on this appreciation.
- The benefit is class. The business use for "non-revolutionary" capabilities needs more emphasis.
- The course helped to highlight in greater detail the benefits of P&E prior to little "a".
- The capstone project really clarified the importance of user buy-in.
- Didn't increase my appreciation any more than existing DAU courses or real-life experiences.
- The value of the Capstone was great because it made you run through an experimental design right after learning about it (and with examples such as case studies). Having to run through a design in association with the didactic instruction made it much more retainable and drastically increased learning/retention.
- The capstone took a lot of time that perhaps was not well thought out. Teach DOE. Problem--mission decomposition, requirements (data collection points, analysis of data), results (did the results answer the problem.
- Not very clear on the requirements piece--would like to hear from requirements professionals themselves.
- Prototyping of experiments are key to fleshing out requirements, TTPs, and actual TRLs.
- Stable requirements and mature technologies are essential for the testing of systems but should/can be ""flexible"" to lessons learned from prototyping and experiments.

Conclusion: An important type of question for the student survey to continually adjust the course content and approach.

Q12 - How well did Capstone Project provide you with approaches to:	Score 1-5	Score 1-5
Design an experiment	4.3	3.88
Conceive an experiment	4.1	3.77
Conduct an experiment	3.9	3.62
Evaluate results from an experiment	3.9	3.5

Observation: Ranking is same for both Classes. Fair reflection of the Capstone focus on conceiving and mostly designing the experiment. Here are the elaborations provided for high or low scores [lettering refers to the survey form item]:

- Simply put, this is the how to play book.
- Great exercise.
- no previous formal experience, b) no previous experience in this context, c) exercised critical thinking and provided springboard points to further explore (i.e., process)
- d) Did not think deep analysis was the point of the class
- d) not too much time was spent on this
- a) Conceiving an experiment is new to me and not as intuitive as it may be to others who work in depth with P&E and have an S&T background. As a TM, I am more in the system acquisition phase(s) and spend more time in T&E, LRIP, etc. This earlier phase is what I need to understand at the concept and pre-system acquisition dev stages.
- Points b and c) were explained in detail through the Hagar example and the example sensor web
- Experimentation Capstone Project should be more closely associated with current environment to improve acquisition. Maybe a building block approach rather than one overall Capstone Project.
- c) and d) Experiment (project) ended at planning. Lack of data and "what's next".
- A greater review of the data collection plan and results, how they can be evaluated and where the pitfalls lie would be welcome.
- The course and Capstone Project provided a repeatable framework for conceiving, designing and executing experiments. I thought I knew how to do that going into the course, but didn't. I feel much more able to do this now.

Conclusion: An important type of question for the student survey to continually adjust the course content and approach.

Student feedback on ways to improve the course (Q14):

Continual assessment of resources and process: input/transformation/output. Excellent start-up as a pilot; little course correction required.
Refine the Capstone project "Problem Statement." We spent a bit of time upfront defining the problem before diving into the scenario, objectives, hypotheses, metrics, etc. -- Day #1 is a lot of MS PowerPoint. Great content and presentations (but long). Can you make it more interactive in the afternoon? Work in groups, don't give us all of the answers up front. -- "policy" experimentation -- Garth's comment during the week.

Some of these are duplicate of comments I made in class on Friday and some are new. 1) Consider breaking up into 2-hr blocks of teaching (1-way) followed by 2-hr blocks of team work to wrestle with the concepts just delivered. 2) Human Centered Design classes do this (Josh Marcuse@ DSD Policy and Adrianne Miller @OPM. 3) Col Ermer brief/case study veered between case study and an advertisement for RRTO. Recommend stick to case study portion. 4) Big picture--this course reinforces the notion of capital-P and big $. Prototyping force capital-P PEO. Would like to see something (maybe separate course?) that addresses continuous lower-level prototyping @ all levels. Less hierarchically driven more continuous creation.
Spend a little more time on the strategic planning and need for develop planning to deliver capabilities
Bring back 1 to 2 participants from the previous class to share how they implemented the learning points from the course. Create a cohort for data and revisit the survey to get ROI for the course. For example, are you collaborating with new organizations, etc.? Provide the results from cohort to new participants to drive cultural change. More "jointness." Identify live exercise opportunities to plug into for the experimentation and prototyping implementation.
1) 6.3 pressure to transition. 2) Failure not embraced. 3) How can higher HQs (e.g., RDECOM/CERDEC) get educated/buy-in to lower level folks can experiments/fail more?
Great Course! Even as a non-acquisition professional, I had no problem following the material. That said, challenge us more! There is definitely more time for additional case studies as well as more background and reference materials. Thanks!
Please make sure to list an alternate POC on the info/logistics emails that came out in the weeks prior to the calls. I understood Dr. Robinson had a medical emergency, but there was no one else listed as a secondary POC. The class gave me --- as a person with very little P&E experience-- a very good understanding of the property
Talking about experimental campaigns as they relate to developmental planning.
Perhaps develop a small CBT for additional foundation building prior to the course. I hope this becomes a full DAU course or part of STM Acquisition certification levels.
Replace case study 3 RRTO with a real actual experiment, put the RRTO command brief into another slot in the schedule, add a section on organization culture and organization change
While the overview of RRTO was important. The NexTech cast study were not good examples of experimentation and could be eliminated. Overall, I felt that the course could be condensed into 4 days. Note: In the interest of conserving resources, all materials, including surveys should be printed on both sides of the page. I am not sure how important it is for this course, but you may want to talk about past attempts to implement experimentation culture (e.g., Gen Slay at USAF/AFSC in the 1970s. WHY DID THEY NOT TAKE HOLD?
Have the RRTO brief by Col Ermer moved up to right after setting the stage brief. This will set expectations and goals for the course (up front) and makes the sequence of later briefs more understandable. Not sure I understand how the Capstone Project fits in line with the goals of the PEIA intent from the BATO study. *Overall: Great course to maintain to bring multiple organizations together to explain the future of prototyping and experimentation
"Rearranging order of the lessons. Col Ermer's would have been better up front. More discussion n in cases vice just making them monologues.
Multiple project check-ins or have 2 parts. Second part would be ""what's next?"". Students would get some ""results"" based on their approach. Fewer slides (about 30/hr.). Make short breaks (2 hr. blocks are too long, all we do is sit). Re-think set-up for the Capstone brief (need a ""judging panel', even if it is just faculty). IDEA: Make the Capstone a request for funds from RRTO. The Hagar case was good but should involve more student work. The answers to Al's questions were in the book! Clarify 100% the difference between a manufacturing prototype and an experimental prototype."
Experimentation and Prototyping integration within the acquisition process is critical for the future of DOD. The course could improve by getting representatives from the service acquisition community to

participate in the presentation of the course material. That would allow them to see and hear the level of understanding within the acquisition community. We had reps form the labs who had conducted experiments so the level of acceptance was high, but I feel the Program Management and PEO level attendance was less than it should be in order to build the momentum of acceptance as an acquisition practice.
Providing slides for a read ahead, Prove (or create) "dummy cards" of available assets that can be used or at least consider, government venue or funded experiment. Acquisition personnel participate in the overall course.
The first module addressed the acquisition lifecycle. Some example programs might have helped.
I was not entirely sure of the utility of the course for military operators. Early on, references were made to TRLs, 6.3 vs 6.4 funding and to a novice the interchangeable terms like "demo" "proof of concept" and "prototype." Operators are not exposed to nuances of acquisition are placed in an awkward position in becoming functional in the vernacular in a one week course. The course is successful in communicating the importance of P&E to an operator. But what is expected they do with that as they return to tactical units where the focus are METL tasks and combat readiness today; not two years from now? "Failing early and failing often" is not an axiom commonly shared in operations. However, this is critical in the world of acquisition, testing/evaluation, and probably where the course should select its audience.
More focus on the how of prototyping and experimentation instead of the why.
I will provide chapter by chapter comments via email.
Better guidance for the Red Team.
1) Fewer case studies--provide a comparison that matches AC's DoE practices. 2) Better background on BBP 3.0 and Acquisition cycle. 3) Have the slides for Case Studies in advance (for notes purposes). 4) Discuss the level of autonomy (1-6) scale and its future application for policy.
The Setting the Stage brief used non-standard definition and was somewhat confusing. For example, the "R" in RDT&E typically is the S&T vice how it was described as development.
More time on group discussion.
Course was great from a general perspective. --There are many different types of experiments. Done for all levels of DOD--not just services--nice to include those in future iterations.
If you tell us to bring over laptops, please have something for us to do on it. It would be better to have the binder information on disc instead of hard copy for those of us who flew in to the training.
1. More detail on the transition phase or "valley of death" navigation would be useful. A few examples of what works and what has not worked in transition efforts would help. 2. Add an OV1 slide to the template. 3. Add a risk cube to the template. 4. Provide a listing of S&T websites of contact info for DOD efforts that would be very useful as a quick reference.
Great course! Time well spent. Thanks for the opportunity to attend.
Tie the topic to strategic BBP 3.0 more. Higher level view of topic and less tactical view
Better define Red team assignment.
Include negative case studies.
Hands-on conducting/observing/analyzing a mini experiment. Could be accomplished in an afternoon at CERDEC/VVESP.
Bring in acquisitions and logistics to the course.
Felt that the course was presented from a somewhat narrow perspective -- e.g., the RRTO way which is only one piece of the long and wide spectrum of the Research to Acquisitions perspective with the time frame (i week) this is probably all that is possible, but if given more time and to make this course more comprehensive. I would bring in the services, SMEs, requirements guys, folks in acquisition, and PEOs.
I left wanting to see how what we learned here fits into the larger process of technology acquisitions from the folks that are actual decision-makers (on the acquisitions, requirements, etc.).

Appreciated having the COL and LtCol's perspectives to tie everything into the warfighters perspective. Overall, great course. Learned a lot and hope more people take it or receive this knowledge in some fashion.
1) Provide example(s) of successful prototyping venues (w/characteristics); possible guest lecture from program like TSOA. 2) Matrix of characteristics of prototyping and experimentation, test, and demo to help visualize which event is executing. Person provided a chart on his evaluation.

Observation: Students took this question very seriously and provided invaluable, detailed comments that were used between Class #2 and #3 to upgrade the materials as well as the schedule.

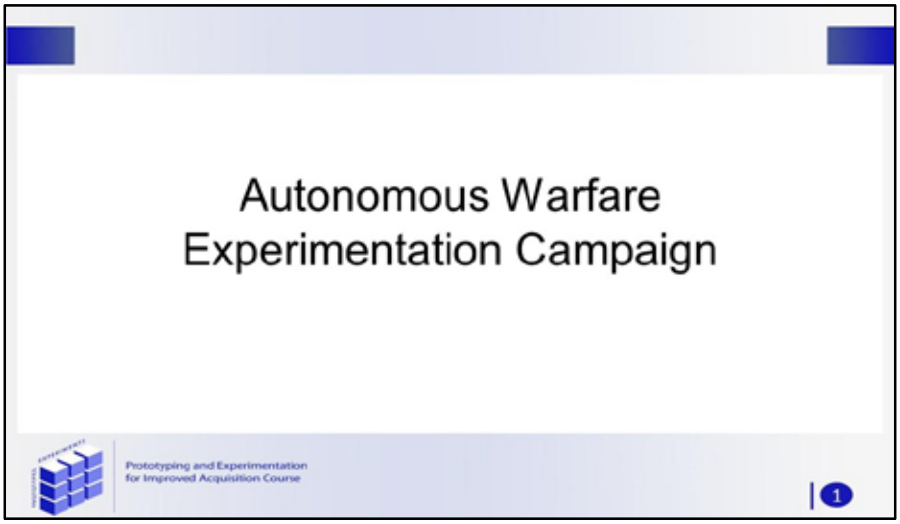
Conclusion: An essential question for the student survey in order to continually adjust the course content and approach.

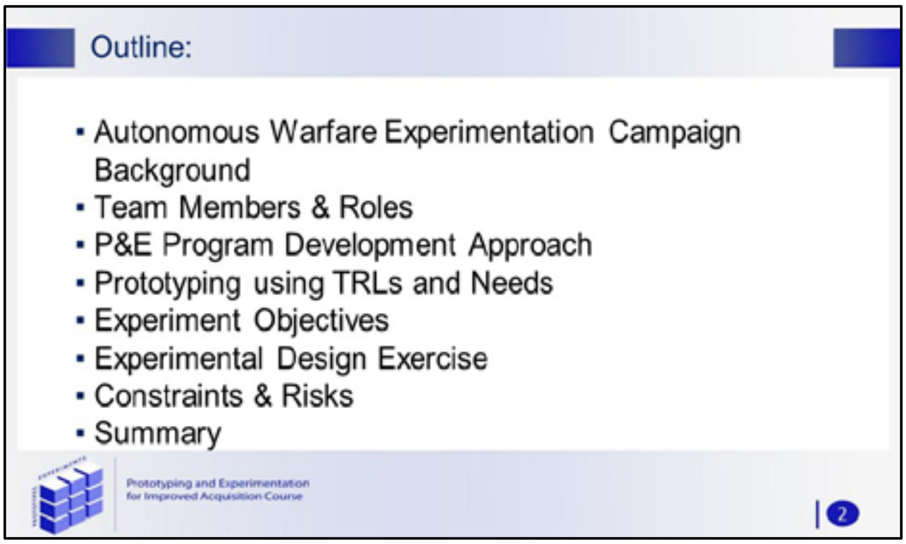
E. **Pilot Course 3 Schedule**

TIME	TOPIC	INSTRUCTOR
DAY 1		
MORNING		
8:00-9:00	Course Management and Orientation a. Ben Riley Welcome b. Logistics c. Course Overview d. Student Expectations	Robinson
9:00-10:00	Setting the Stage Definitions and terms will be introduced and a short discussion of the DOD acquisition process to provide context.	Lawrence
10:00-10:15	**BREAK**	
10:15-11:15	Setting the Stage (cont)	Lawrence
11:15-12:15	Introduce Capstone Project	Ramberg
12:15-1:00	Working Lunch—Teams Organize for Capstone Project	
1:00-2:30	Best Practices and Lessons Learned in Rapid Technology Development	Ermer
2:30-3:30	Definitions and Military Examples of Prototyping and Experimentation	Sciarretta
3:30-3:45	**BREAK**	
3:45-5:00	Design of Experiments (DOE) with Case Study	Sciarretta
DAY 2		
8:00-8:30	Brief Review of Day 1	Ramberg
8:30- 10:00	DOE with Case Study (cont)	Sciarretta
10:00-10:15	**BREAK**	
10:15-12:00	DOE with Case Study (cont)	Sciarretta
12:00-1:00	Working Lunch – Groups Discuss their Capstone Project	
1:00-2:15	DOE with Case Study (cont)	Sciarretta
2:15-2:30	**BREAK**	
2:30-5:00	Case Study 1:Smart Sensor Web SSW concept (2000-2002) was an intelligent, web-centric distribution and fusion of sensor information to enhance local situational awareness, on demand, to warfighters (dismounted infantry platoons and squads).	Sciarretta
DAY 3		
8:00-8:30	Review of Day 2	Ramberg
8:30-10:00	Case Study 2 – Have Blue Have Blue was the prototyping and experimentation efforts for the USAF F-117 stealth attack aircraft Guest Speaker: Alan Brown	Gravatt (facilitator)
10:00-10:15	**BREAK**	

10:15-11:30	Case Study 2 (continued)	Gravatt (facilitator)
11:30-1:00	Working Lunch – Capstone Project	
1:00-5:00	Work on Capstone Project	Team
DAY 4		
8:00-8:30	Review Day 3	Lawrence
8:30-9:00	Red Team Presentation	Sciarretta
9:00-9:15	Red Team Feedback and Discussion	
9:15-9:30	**BREAK**	
9:30-11:30	Case Study 3 – Robotics (ARL) Guest Speakers: Brett Piekarski and Marshal Childers	Sciarretta(facilitator)
11:30-12:30	Working Lunch – Capstone Project	
12:30-2:30	Case Study 4: Rail Gun Guest Speaker: Roger Ellis	Lawrence (facilitator)
2:30-4:30	Work on Capstone Project/Presentation	Team
DAY 5		
8:00-8:30	Presentation Group 1	Lawrence
8:30-8:45	Feedback Group 1	
8:45-8:55	Break and Set-up for Group 2	
8:55-9:25	Presentation Group 2	Ramberg
9:25-9:40	Feedback Group 2	
9:40-9:50	Break and Set-up for Group 3	
9:50-10:20	Presentation Group 3	Robinson
10:20-10:35	Feedback Group 3	
10:35-10:45	Break and Set-up for Group 4	
10:45-11:15	Presentation Group 4	Gravatt
11:15-11:30	Feedback Group 4	
11:30-12:00	Overall feedback/discussion on presentations	
12:00-12:45	Course Wrap-Up	Lawrence (Team)
12:45-1:00	Community of Interest website	Robinson
1:00-1:30	Student Course Feedback Session	Robinson (Team)

F. Example of Student Capstone Project Outbrief





Objective:

Characterize utilities, potential opportunities and risks by pairing UAV/UGV

- It is envisioned that the pairing will reduce the exposure of warfighters in harm's way while enhancing the ability of a joint force to penetrate enemy controlled territory to:
- The potential acquisition development program will pair unmanned air and ground systems that are fully coordinated and mostly autonomous to provide targeting information for non-line-of-site weapons systems to reduce the exposure of warfighters and enhance the ability of a joint force to penetrate enemy controlled territory.

Factors to Consider:

- Innovative uses of existing systems and equipment
- Feasibility of new concepts and technologies
- Interdependencies
- CONOPs, TTPs, doctrine, ROEs
- DOTMLPF
- Changes in force structure

Prototyping and Experimentation for Improved Acquisition Course

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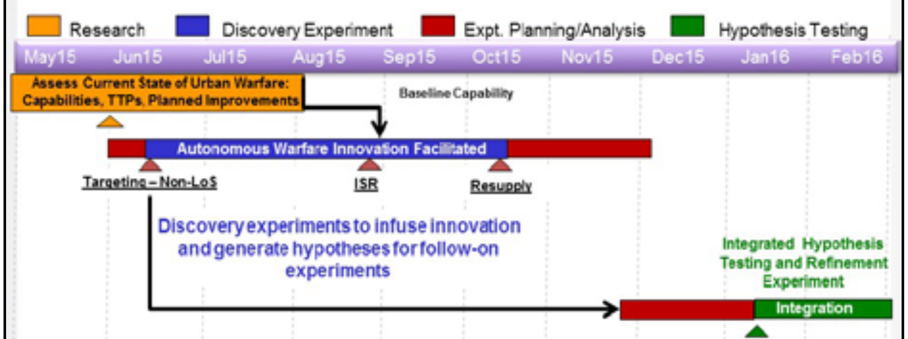
Autonomous Warfare Experimentation Campaign



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Team Members and Roles:

Team 1 Members	Role/Function
[redacted]	Military User
[redacted]	System Buyer
[redacted]	R&D Supplier (researcher)
[redacted]	Requirements Setter
[redacted]	Tester & Evaluator
Team Advisor	Joe Lawrence
Consultant	Al Sciarretta

NOTE: Names redacted for PPI reasons

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Experimentation Team

HAF
- SAF/AQR
- SAF/AQP
- SAF/AQX
- SAF/AQC
- AF/A2I
- AF/A3
- AF/A5R
- AF/TE

ACC
- A3/A3JC
- A3/A3JI
- A3/A3TO
- A3/A3TW
- A589/A5YG-TACP
- USAFWC/A3/5
- A589/A5/8X
- A589/A5-2
- GPA CFT
- NTTR/DOO

SOCOM
- 720th OSS

AFSOC
- A3/A3TW
- A5-8-9/A5KG
- AFSOAWC/A9
- AFSOAWC/A9T

Joint Staff
- J6
- JS J7

AFLCMC
- 21 IS
- WISN
- XZS
- XZSI

AFRL
- AFRL/ACC
- 711
- HPW/RHAS
- RISA
- RW
- RWWG
- RWPB

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P&E Program Development Approach:

Development Approach: Allow for innovation and early risk reduction; the objective is to provide data to leaders so they can make informed decisions.

Including:

- *The type(s) of prototypes chosen for your approach & why*
- *Any further prototype development likely after your plan is complete (TRLs?)*
- *Improved clarity and specificity of acquisition program requirements & specs*
- *Improved user buy-in*
- *A prospective path and simple timeline to a systems acquisition program (e.g., Milestone B – see Joe's Day 1 brief)*

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Approach - Prototyping using TRLs and Needs:

Types of Experiments

BA = Budget Activity CG = Computer Generated OL = Operational Level TRL = Technology Readiness Level	**Live** (Actual People/Systems in a Realistic Physical Environment)	**Virtual** (Actual People/Systems Interacting with Mock-ups and a CG Environment)	**Constructive** (CG People/Systems in a CG Environment)
Operational Level (OL) (Fieldable) TRLs 8 – 9 BAs 5 & 7	**What:** Actual OL prototype **Why:** Most realism. Also, no technical, cost, safety, or environmental constraints. **Warfighters:** If involved, trained on the OL prototype **Benefit:** Validate OL prototype benefits in an operational environment	**What:** Mock-up of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual OL prototype **Warfighters:** If involved, trained on the mock-up **Benefit:** Validate (to a lesser degree) benefits in an operational environment	**What:** CG representation (e.g., model) of OL prototype **Why:** Cost, environmental, safety, or other constraints prohibit use of actual or mock-up of OL prototype. **Warfighters:** If involved, trained on the CG version **Benefit:** Validate (to a lesser degree) benefits in an operational environment
Developmental (Usable in a Pinch) TRLs 5 – 7 BAs 3 – 4	**What:** Dev prototype might be augmented (to represent full capability) or totally represented as a surrogate system **Why:** OL prototype not available **Warfighters:** If involved, trained on augmented/surrogate system **Benefit:** Early user feedback; shape requirements	**What:** Mock-up of Dev prototype. As much as possible, it functions like OL **Why:** Technical, cost, environmental, safety, or other constraints prohibit use of actual Dev prototype. **Warfighters:** If involved, trained on the mock-up **Benefit:** Early user feedback; shape requirements	**What:** CG representation (e.g., model) of Dev prototype **Why:** Technical, cost, safety, environmental, or other constraints prohibit use of actual or mock-up of Dev prototype **Warfighters:** If involved, trained on the CG version **Benefit:** Early user feedback; shape requirements
Conceptual (Not Fieldable) TRLs 1 – 4 BAs 1 – 3	**What:** Conceptual prototype represented as a surrogate or as a "perceived" live system **Why:** Technically immature **Warfighters:** If involved, trained on surrogate/perceived system **Benefit:** User feedback on "needs"	**What:** Mock-up which represents the anticipated performance characteristics of the live system **Why:** Technically immature **Warfighters:** If involved, trained on the mock-up **Benefit:** User feedback on "needs"	**What:** CG representation (e.g., model) of Conceptual prototype **Why:** Technically immature **Warfighters:** If involved, trained on the CG version **Benefit:** User feedback on "needs"

Types of Prototypes

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Approach - Prototyping Using TRLs and Needs:

	Live	Virtual	Constructive
Operational Level TRL 8-9	UAV LV 5 UGV LV 4	UAV LV 6 UGV LV 5	UGV LV 6
Developmental TRL 5-7	UAV LV 6 UGV LV5	UAV LV 5 UAV LV 6 UGV LV 4 UGV LV 5 UGV LV 6 WSI COMM LINK	UAV LV 5 UAV LV 6 UGV LV 4 UGV LV 5 UGV LV 6 WSI COMM LINK
Conceptual TRL 3-4		UAV LV 5 UAV LV 6 UGV LV 4 UGV LV 5 UGV LV 6 WSI COMM	UAV LV 5 UAV LV 6 UGV LV 4 UGV LV 5 UGV LV 6 WSI COMM

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Experiment Objectives:

- **Experiment Objectives**
  - Objective #1 *Find* - Determine ability of UAVs/UGVs to acquire targets
  - Objective #2 *Target* - Assess improvements to paired UAV/UGV target designation
  - **Objective #3 *Engage* - Determine effectiveness of UAV/UGV as enablers for non-LoS munitions engagement**
  - Objective #4 *Assess* - Determine ability to accurately conduct BDA
- **SubObjective(s) For Engagement:** ***(1) Determine how much integration is required***, (2) Determine how much accuracy is enhanced and (3) Determine how unit effectiveness is enhanced

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Experimental Design - Issues/Hypothesis:

Critical Issues - Key questions to be resolved by the experimentation:

1. ***How does unmanned pairing improve situational awareness?***
2. How are TTPs impacted?
3. What are the environmental limits?
4. How is mission planning affected?

Hypotheses Regarding Situational Awareness:

1. Total Warfighter situational awareness is enhanced by the pairing of autonomous air and ground systems.
2. Unmanned pairing reduces the need for manned, ground reconnaissance.
3. Sufficient computer power is available to provide SA to higher echelons of command.

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Experimental Design - Metrics:

Hypothesis of Interest: Total Warfighter situational awareness is enhanced by the pairing of autonomous air and ground systems.

MOPs:

- Target collection score
- Target engagement score
- Time to identify target
- Accuracy of coordinates

MOEs:

- Impact of integration on C2
- Ability to facilitate calls for fire
- Benefits of linkage to higher HQ

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Experimental Design - Data Collection Plan:

Metric of Interest: *Time to ID Target*

- Independent Variable: UAV/UGV Integration
- Dependent Variable: Time to ID Target
- Baseline: UAV/UGV/Human, no integration
- Number of Runs: 10 Runs x 3 Targets with 2 Teams (Baseline/Integrated)
- Minimize Environmental Conditions

Other Factors to Consider:

- Quantitative Data
- Qualitative Data
- Aggregation of Data
- Data Storage
- Data Analytics
- Data Classification

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Time to ID Target Scenario:

This scenario uses static targets to measure the time to ID target.

- Future Experiments: Mobile targets

Potential Engagement Sequence:

- UAV arrives on station but is unable to locate target with acceptable certainty (fog, smoke, cover etc.) and cannot use its weapon.
- UGV arrives later due to travel speed but cannot get closer. UGV IDs target but cannot engage effectively.
- Working together, UGV provides target data to UAV. UAV engages target with more effective weapon.

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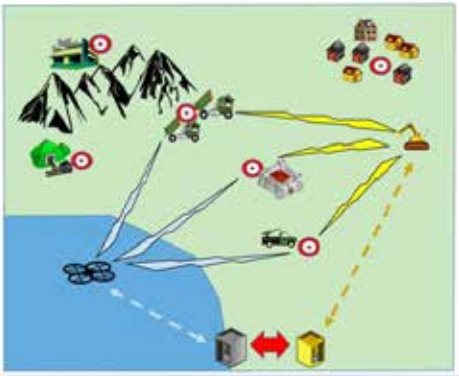
Experimental Design - Scenario Diagram:



Potential target locations
- Urban
- Forest
- Jungle
- Open

Potential targets
- Vehicles
- Personnel
- Storage areas
- Bunkers
- Fighting positions

Assumptions:
- 3 target locations would be used for each run.
- Targets would be varied between runs.

OV – 1 UAV/UGV/Human Integration:

Constraints & Risks:

Experimental Constraints:
- Cost - $100K/day
- Number of UAV/UGV
- Personnel/IRB/TDY
- Range Time

Experimental Risks:
- Weather
- Maintenance/Repair Parts

Summary:

- Autonomous Warfare Experimentation Campaign Background
- Team Members & Roles
- P&E Program Development Approach
- Prototyping using TRLs and Needs
- Experiment Objectives
- Experimental Design Exercise
- Constraints & Risks
- Summary

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Questions?

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G. **Description of Course Files available online at http://ctnsp.dodlive.mil/**

- Folder: Course Support, with following content:
  - PEIA poster

- Folder: Main Curriculum, with following content:
  - Orientation
  - RRTO (Wyatt) Briefing
  - Setting the Stage
  - Technology Development
  - Definitions and Military Examples
  - Design of Experiments
  - Schedule PEIA September Course

- Folder: Case Studies, with following content:
  - Smart Sensor Web Folder
  - UUV MMS Folder
  - Wolfpack Folder
  - Have Blue
  - Robotics Folder
  - Rail Gun (Student Handout)

- Folder: Student Capstone, with following content:
  - Read ahead
  - Case Study Description
  - Presentation which introduces the effort/task to the students
  - Student Project template

- Folder: COI Website

H. Speaker Biographies

Course Instructor and Case Study Speaker: Albert Sciarretta

Mr. Albert A. Sciarretta (U.S. Army Lieutenant Colonel, retired) is currently serving as a Senior Research Fellow in CTNSP. For more than 30 years, as a U.S. Army officer and civilian contractor, he has used his operational, research and development, and operations research experience to assess the military benefits of advanced technologies, develop S&T investment strategies, and design/execute tactical through operational wargames, experiments, and demonstrations. His current CTNSP effort is focused on developing a course of instruction addressing prototyping and experimentation. He has significant experience in designing and executing various DOD experiments and demonstrations utilizing combinations of live-virtual-constructive simulations of joint through tactical urban operations. His past CTNSP efforts include defining human dimension/performance issues and metrics for dismounted infantry, identifying operational and technical needs for command and control systems for small unit operations, and assessing advanced technologies for unmanned and autonomous systems and determining their use in military operations.

Mr. Sciarretta is President of CNS Technologies, Inc. In this position, he works primarily as an independent consultant, supporting various DOD organizations. Mr. Sciarretta is also a member of three high-visibility organizations: 1) the National Research Council (NRC) Board on Army Science and Technology (BAST), 2) a Chief of Staff of the Army Red Team to review U.S. Army Training and Doctrine Command (TRADOC) Army Capabilities Integration Center (ARCIC) Futures Concepts, and 3) an Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) Independent Review Team (IRT) for evaluating Army science and technology (S&T) and acquisition programs. He was selected for membership on the BAST for his expertise in research and development, operations research, experimentation, modeling and simulation, management, as well as his knowledge of human performance, small unit operations, and advanced information, sensor, and test technologies. He has served on many NRC BAST study committees, with the most recent being "Making the Soldier Decisive on Future Battlefields" for which, he served as deputy chair for squad operations and as a principal co-author for the final report.

Mr. Sciarretta is a certified Professional Engineer in the state of Virginia. He has two MS degrees – Operations Research and Mechanical Engineering – from Stanford University; a BS degree in General Engineering from the United States Military Academy; and a one-year, undergraduate credit in Design of Military Vehicles from the British Army's Royal Military College of Science.

Guest Speaker: Alan Brown (Have Blue)

Mr. Alan Brown retired in February, 1992, as Director of Engineering at Lockheed Corporate Headquarters. His two principal concerns there were the promulgation of Concurrent Engineering and Stealth Technology throughout the Corporation. He has given invited papers on both these subjects at national and international levels.

From 1975 to 1989 he was a member of the Lockheed Advanced Development Projects, colloquially known as the "Skunk Works". He served first as the deputy program manager for the Have Blue low-observable research aircraft. He then became program manager and chief engineer for the F-117A Stealth

Fighter from initial concept until the first production aircraft was built, 1978 to 1982, and from 1982 to 1989 was Director of Low Observable Technology.

He joined Lockheed in 1960, starting in the physics laboratory of the Lockheed Missiles and Space Company in Palo Alto. He moved to the aircraft company in Burbank in 1966, working on propulsion installation on the Supersonic Transport and the FX and VSX aircraft (which later became the F-15 and S-3A respectively), and was engineering manager for the Lockheed group at Rolls-Royce on the L-1011 commercial transport program.

He began his aeronautical career with an engineering apprenticeship at Blackburn Aircraft in England from 1945 to 1950. After obtaining a Diploma of the College of Aeronautics, Cranfield University, England, in 1952, he worked at Bristol Aeroplane Company as an aerodynamicist prior to going to the United States in 1956. He worked as a research associate and lecturer at the University of Southern California, and as a research associate at Wiancko Engineering Company before joining Lockheed.

Since retirement from Lockheed, he has taught short courses at Cranfield University, England; Linkoping University, Sweden; Georgia Institute of Technology; and the U.S. Navy Post-graduate School, Monterey, California. He has been active in the University of California Mathematics, Engineering and Science Achievement (MESA) program for middle and high schools since 1994.

Guest Speaker: Edwin Ebinger (Unmanned Underwater Vehicles)

Dr. Ed Ebinger is a retired Naval Commander and Master EOD Technician who has been supporting the Chief of Naval Operations staff at the conclusion of his 20-year active duty service in 2006. Ed was a qualified Surface Warfare Officer (SWO) and Special Operations Officer (EOD), as well as a designated Foreign Area Officer (FAO). Tours of duty included multiple overseas postings, combat deployments and Defense Agency staff billets. During his naval service, Ed received numerous campaign, service and unit commendation awards.

Since 2006, Ed has provided analysis in requirements and programming to the Chief of Naval Operations Staff within the Expeditionary Warfare Directorate. Within this directorate he has held positions that with responsibility for programs and funding in support of the Navy Expeditionary Combat Enterprise (NECE), and has recently been assigned responsibilities for the Navy's Mine Warfare (MIW) programming. His portfolio has included multiple Joint and Navy Rapid Acquisition Initiatives, ACAT I and JROC-Interest programs, and unmanned systems in the ground, air and maritime domain. Ed has extensive interface with both the S&T and Acquisition communities in the project formulation, prioritization, execution and transition to operations processes. Ed has been an active participant in multiple internal and external fora and has played an active role in shaping strategic visions and implementation pathways

Guest Speaker: Colonel Dan Ermer (Funding Projects and Lessons Learned)

Colonel Dan Ermer reported to his current position within the National Defense University (NDU) Dwight D. Eisenhower School for National Security and Resource Strategy on 10 July 2015. He was commissioned into the Marine Corps in December 1987 following graduation from Iowa State University under the Naval Reserve Officers Training Corps (NROTC) Program. For 27+ years he's served in the Marine Corps in various combat engineering and logistics billets, while assigned many diverse command, staff, special assignment, and joint tours of duty, both home and abroad. The highlights of his operational and combat tours consist of: Operation(s) Desert Shield and Storm, Operation Silent Assurance, Operation Resolute Response, and Operation(s) Iraqi Freedom 2-2 / 4-6 / 5-7. Prior to his recent assignment to the Eisenhower School, Colonel Ermer served as the Deputy Director and Chief Operations Officer, Rapid Reaction Technology Office for the Office of Under Secretary of Defense—Acquisitions, Technology and Logistics. While in this capacity, he worked to progress evolving, emerging technologies and deliver advanced prototypes in support of time-sensitive warfighter capability needs. Colonel Ermer holds a Master of Science degree in National Resource Strategy from NDU Eisenhower School, Washington, DC; a Master of Arts degree in Human Resources Development from Webster University, St. Louis, MO; and a Bachelor of Science degree in Agricultural Business from Iowa State University, Ames, IA.

Guest Speaker: Wade Hall (Wolf Pack)

Mr. Wade Hall (U.S. Marine Corps Colonel, retired) is a 1982 graduate of East Tennessee State University. Upon graduation he was commissioned a Second Lieutenant in the United States Marine Corps. He completed Marine Corps Officer Training at The Basic School, Quantico Marine Corps Base, followed by Naval Aviator flight training. He was designated a Naval Aviator in October of 1984.

He commanded at the squadron and regimental levels, served as the operations officer for the Marine Corps largest Marine Air Group, and the Navy's largest advanced jet training squadron. He conducted aircraft carrier operations aboard the USS Nimitz and USS Kennedy. His tours have taken him world-wide from Australia to Norway, the Middle East to the Far East.

He served a joint tour with the Office of the Secretary of Defense, working for the Deputy Secretary in the Office of Force Transformation with the late Vice Admiral Arthur Cebrowski.

He also served at Headquarters Marine Corps – Aviation Office as the director all Marine Corps Aviation platform weapons systems.

Colonel Hall participated in four (4) combat operations from Desert Storm, Allied Force, and Iraqi Freedom. He has over 3900 flight hours in six different type aircraft, with 2000 in the EA-6B Prowler and 330 hours in combat. He is qualified as a pilot, instructor pilot and mission commander in the EA-6B Prowler, the A-4 Skyhawk and aircraft commander in the KC-130 Hercules. His personal decorations include the Defense Superior Service Medal, Legion of Merit, Meritorious Service Medal with Gold Star, two Strike/Flight Air Medals with combat V, six Air Medals, and two Navy / Marine Corps Commendation Medals.

He is a graduate of the Joint Forces Staff College and Marine Corps War College. He holds a Bachelor's Degree in History and Political Science and a Master's Degree in Strategic Studies,

Colonel Hall retired from active duty in 2009 after 27 years of honorable service. Wade is currently the President and CEO of Corps Defense, a business development consulting company.

Guest Speaker: Rick Nagle (Unmanned Underwater Vehicles)

Mr. Rick Nagle is a retired Navy Officer and Master EOD Technician who has been supporting PMS-408 since his transition from twenty years of active duty service in 1997. During his Navy service, Rick was a qualified Surface Warfare Officer (SWO) with considerable shipboard experience in both the Navy EOD and surface warfare communities. He served as an EOD Officer in Charge on several tours of duty, and as a department head at Navy EOD Mobile Units, and in the latter half of his career served as Commanding Officer (CO) of EOD Mobile Unit SIX in Charleston, SC, and CO of EOD Mobile Unit EIGHT in Sigonella, Sicily. While in command of EOD Mobile Unit SIX, Rick deployed as the Task Unit Commander for Navy EOD MCM forces in Operation Desert Storm and led Navy EOD forces in several other campaigns and operations. His final assignment was as the EOD Program resource sponsor and requirement officer at the Pentagon. During his Navy service, Rick received numerous campaign, service, and unit commendation awards.

Since 1997, Rick has provided analysis and project management support to the Navy EOD Program Office, specializing primarily in technology transition and acquisition of maritime systems to address Navy validated requirements and future capability needs. Rick continues to play a contributing role, most significantly in the Navy's Shallow Water (SW), Very Shallow Water (VSW) and Expeditionary Mine Countermeasures and Maritime Homeland Defense counter-underwater improvised explosive device (UW/IED) investment portfolios in support of the Navy Expeditionary Combat Enterprise (NECE). Over his active duty and follow on career, he has authored numerous papers, presented at professional symposia, and has played an instrumental role in the development and staffing of investment strategies, strategic plans, and concepts of operations to gain stakeholder guidance and feedback and to sustainment support for material solution investment toward the acquisition of future naval capabilities.

Guest Speaker: Robert Simmons (Unmanned Underwater Vehicles)

Mr. Robert Simmons is the Assistant Program Manager (APM) for Underwater systems within PMS-408 Expeditionary Missions Program Office, a component of the Naval Sea Systems Command Acquisition and Commonality Directorate (NAVSEA 06). He also serves as the Assistant Technical Project Officer for NAVSEA involving Data Exchange Agreements between the United States and 17 allied and coalition partner nations involving Unmanned Underwater Vehicles acquisition and technology development. He has a Bachelor of Science in Aerospace and Ocean Engineering from Virginia Tech and a Master of Science in Public Administration from American University. He is certified by the United States Department of Defense in Level III Program Management and Systems Planning, Research, Development and Engineering. He has received the Joint Meritorious Unit Award for Support of Operation Iraqi Freedom, the Meritorious Civilian Service Award and the James D. Collie award for Sustained Outstanding performance in his duties as APM for the underwater system programs. Besides leading the fielding of next generation equipment to the Explosive Ordnance Disposal divers and Expeditionary Mine Countermeasures operators, he has worked with US, International and NATO Science and Technology activities, mainly through collaboration with the Office of Naval Research, for over 30 years with a focus on technology transition to the fleet.

Guest Speaker: Tom Swean (Unmanned Underwater Vehicles)

Dr. Tom Swean joined the Office of Naval Research in March 1993 as Science Officer for the Ocean Technology Program. In 1996, he became Team Leader for the Ocean Engineering and Marine Systems Team, and in 2005 he assumed the duties of Team Leader for the Maritime Mine Warfare Team and as such leads the Organic Mine Countermeasures Future Naval Capability Program. His work at ONR has focused on developing AUV systems and component technologies for applications to mine warfare, explosive ordnance disposal, naval special warfare, and ocean science research. Collateral duties at ONR include activities as National Leader to The Technical Cooperation Program, Technical Panel-13 (Mine

Warfare) , Head of U.S. Delegation to NATO Maritime Capability Group /3 (Mine Warfare and Port Security) and Member at Large to the NATO STO Systems, Concepts and Integration Panel. He received the Meritorious Civilian Service Award in 1999 and was named ONR Future Naval Capability Manager of the Year in 2009. In 2010, he was awarded the Arthur E. Bisson Prize for Naval Technology Achievement; and in 2014, he was awarded the Superior Civilian Service Award.

He started his career in 1976 as a Research Scientist for the STD Research Corporation, Arcadia, California addressing applications of magneto hydrodynamics to commercial and military power generation devices. While at STD he was a Principal Investigator on ONR contracts to develop pulsed power for space borne applications.

He joined federal service in 1981 as a Research Mechanical Engineer at the Naval Research Laboratory in Washington, DC. During his tenure at NRL he was Principal Investigator of the Fluid Dynamics Task Area, Head of the Fluid Physics Section of the Remote Sensing Division, and Head of the Center for Hydrodynamic Developments in the Laboratory for Computational Physics and Fluid Dynamics. During this time Dr. Swean led a group of 15 scientists and engineers in fundamental and applied studies of turbulent flow physics and modeling of free surface hydrodynamic signatures.

Dr. Swean attended Old Dominion University in Norfolk, Virginia, graduating with a Bachelor of Science degree in Thermal Engineering in 1970. He then entered Virginia Polytechnic Institute and State University, earning a Master of Science degree in Aerospace Engineering in 1972 and a PhD degree in Aerospace and Ocean Engineering in 1976. His graduate research at VPI was in the areas of hypersonic flows, spacecraft re-entry dynamics and turbulent wake physics. While at VPI he was named NSF Exchange Fellow and spent two years at the Institute for Fluid Dynamics in Bucharest, Romania. Dr. Swean is the author of 67 scientific and technical publications.

From 1963 to 1965, he was enlisted in the United States Marine Corps, and continued in the USMC Reserves from 1966 to 1970.

Guest Speaker: Brett H. Piekarski, PhD (Ground Operation Robotics)

Dr. Brett Piekarski is the Chief of the Micro and Nano Materials and Devices Branch within the Army Research Laboratory (ARL) and the Cooperative Agreement Manager for ARL's Micro Autonomous Systems Technology Collaborative Technology Alliance. While at ARL he has also served as the Manager of ARL's Specialty Electronic Materials and Sensors Cleanroom Research Facility (2002-2008), as a Microelectromechanical Systems (MEMS) Researcher in the Micro-Devices Branch (1997-2002), and as a Researcher in electronics manufacturing technologies (1988-1997).

He has a BS in Mechanical Engineering from North Dakota, a MS in Mechanical Engineering from Johns Hopkins University, and a PhD in Mechanical Engineering from the University of Maryland.

Guest Speaker: Marshal Childers (Ground Operation Robotics)

In the Autonomous Systems Division of the Army Research Laboratory (ARL), Mr. Marshal Childers is responsible for leading the Integration and Assessment Team which supports the integration, prototyping, and experimentation of autonomous robotics technologies. His current focus is on integrated performance and transition of technologies developed by the ARL Robotics Collaborative Technology Alliance. As a mechanical engineer, Marshal contributes to the research and development of ARL-funded unmanned systems technology and has oversight of the technicians that support the Division. He is the Technical

Manager for the U.S. Army Special Operations Command (USASOC)-sponsored Small Unit Support Improvised Explosive Device (IED) Defeat (SUSI) Program. Mr. Childers is a contracting officer's representative (COR) on a number of advanced development programs that integrate autonomy onto testbeds and evaluate the platform performance in relevant environments.

He has an MS in Mechanical Engineering from University of Maryland, Baltimore County (UMBC).

Guest Speaker: Roger Ellis (Railgun)

Mr. Ellis is the Program Manager for the Electromagnetic (EM) Railgun Program Office at the Office of Naval Research. EM Railgun, an Innovative Naval Prototype (INP), is a transformational multi-mission solution for ship self-defense, anti-surface warfare, naval surface fire support, and time-critical strike. The Railgun is designed to deliver lethal, hyper-velocity projectiles at ranges in excess of 100 nautical miles within six minutes. Mr. Ellis directs the development of the INP to mature the technology for transition to a formal ship acquisition program. Mr. Ellis has been involved in naval railgun technology development since 2000, and previously served as the Technical Director for the effort from 2005 to 2009.

Previous projects Mr. Ellis has been involved in include; an advanced propulsion system for a fire from enclosure shoulder launched weapon (co-authored patent), Tech Team 21 member for the navy’s new 155mm Advanced Gun System for the DDX ship with oversight over the gun barrel and oscillating assembly, conventional gun barrel technology efforts with focus on erosion mitigation, and systems engineering IPT coordinator for the Naval Surface Fire Support program.

He earned a B.S. in Mechanical Engineering from Utah State University in 1995 and an M.S. degree in Mechanical Engineering from Virginia Tech in 1996.

I. Online PEIA Community of Information Prototype

The prototype of the PEIA Community of Interest (COI) was made available to all of the students who attended the course. The purpose was to share content with the students and to provide collaborative tools for the students to share information and problems they are facing. All of the most current content is included in the COI. The COI was prototyped in a Google Site within a domain sponsored by the National Defense University. Should the course be adopted by another organization, they could continue using this site or they could design a community in another tool.

The online pages available to the students included:

- Home Page with Announcement Capability
- Course Schedule in Two Formats
- Downloadable Student Lists
- Student and Faculty Discussion Forums
- Case Study Slides
- Capstone Project—Student Assessment Documents
- Student Capstone Projects Arranged by Pilot Course
- All of the Materials Distributed in the Pilot Courses
- Resource Materials
- Pre- and Post-Course Self Evaluations

NATIONAL DEFENSE UNIVERSITY