Program Assessment and Alignment

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Abstract.

The Systems Engineering program at the United States Military Academy at West Point is quite a young program especially when compared to the other programs at this 206 year-old engineering university. As a young program we continue to evolve into the program necessary for our constituents - the Nation, the Army, the Academy and the West Point Community, the Faculty and the Staff and, finally, the Cadets themselves. To meet the needs of these constituents, we recently conducted a comprehensive self-evaluation. The results were a better alignment of our program objectives, our program outcomes, our courses and our lessons. To ensure our lessons and our courses sufficiently guide our cadets to achieve our program outcomes, we have developed and implemented a detailed and comprehensive outcome assessment methodology. Using a rubric-based assessment system, we will capture the performance of all our graduates to assess their learning and guide our future program development. Though this assessment methodology has only recently been implemented, it is already proven to be helpful in garnering insights into our program construction. It also has some drawbacks which we will work through and discuss in this paper.

Introduction

The United States Military Academy at West Point is built on tradition; the tradition of producing exceptional Army officers; the tradition of providing an outstanding engineering-based undergraduate education; and the tradition of developing leaders. Tradition can sometimes make it difficult to change. So much so that you may hear a cynical cadet utter that "West Point has 206 years of history unencumbered by progress!" Of course that is not true but the school does change, shall we say, deliberately. Deliberate change is not necessarily a bad thing and it is this type of change that we discuss in this paper.

Deliberate change is the result of assessment and reconsideration. In this paper, we discuss the process we followed to identify deliberate change needed in the Systems Engineering program at the United States Military Academy. ABET, which is the body that accredits engineering programs like our systems engineering program, identifies this deliberate review and change process as a "slow-loop". This is in contrast to a "fast-loop" process which identifies small changes to a program or course. These slow loop assessments are usually conducted every three to five years. More frequent changes do not allow the changes sufficient time to take effect and be evaluated. On the other hand, waiting too long to evaluate changes might allow the program to move too far astray.

In this paper, we discuss the process we followed and the results of our efforts to deliberately assess the systems engineering program and make changes as necessary. We discuss the effort to align the program, the ongoing assessment and evaluation plan we established to ensure we maintain alignment as we move forward and then we summarize with some lessons learned and conclude. We begin with a short background of the Department of Systems Engineering, the newest department at the United States Military Academy, and its namesake academic program.

Background

In 1989 the Department of Systems Engineering spun off from the former Department of Engineering (now the Department of Civil and Mechanical Engineering) to become the thirteenth, and still youngest, academic department at the school. The first Department Head, now retired Brigadier General James L. Kays, had quite a challenge ahead of him when he assumed that position. With very few undergraduate systems engineering programs in the country at that time to benchmark against, it was hard to know where to start. Kays, a former collegiate football player at Army, decided to focus on the fundamentals like most coaches do when trying to build and develop a young team. He designed the department with the focus on four overarching and enduring objectives that have persisted through three department heads: (Kays and McGinnis, 1995.)

- cadet education;
- faculty growth and development;
- remaining linked to the industry we serve - the Army; and
- integrating state-of-the-art computer and information technology into the education process.

With these objectives as the backdrop, Kays established the Systems Engineering program as a new academic major to be offered by the department. (Upon its establishment, the new department had assumed responsibility for the Engineering Management program which had been established some years before as part of the old Department of Engineering.) Most of the courses for the new Systems Engineering program had to be developed from whole cloth especially as there were less than a handful of similar undergraduate programs throughout the country. Through Kays' efforts and those of his staff and faculty, the Systems Engineering program received its first accreditation from ABET in 1997 and followed that up by being accredited again in 2003.

After making some important changes to the program following this latest accreditation in accordance with the few comments made by the evaluators, the program suffered from significant personnel turnover, especially at the Program Director position. In the five years following the 2003 accreditation, the program had five different program directors – each one changing out unexpectedly and leaving within a few weeks of announcing their departure. The courses in the program continued to be taught and directed by outstanding young innovators who ensured that their course was the best it could be for the topic area.

When the fifth program director assumed the position in the summer of 2006, he discovered a program that had not changed its program objectives or outcomes since the last accreditation but had significantly changed the course content for the courses that made up the program. This did not necessarily mean that the program was not properly aligned and all initial indications were that the program was in great shape. Still, it was time to conduct an in-depth analysis of the program – a "slow-loop" deliberate assessment - and it began immediately.

Assessment to Alignment

We began our process of deliberate program assessment by practicing what we preach (read: teach) – by taking a holistic systems approach using the Systems Decision Process (SDP). (Parnell, et al, 2008) The reader is referred to the recently released book, *Decision Making in Systems Engineering and Management"* by Parnell, et al, for a more detailed description of this process. For the purposes of description in this paper, we will limit our discussions to the first phase of this process, the Problem Definition phase, and most specifically, the first step, Stakeholder Analysis. In this step, the analyst

conducts detailed background information searches and conducts interviews with significant stakeholders to appropriately scope, bound and fully define the problem.

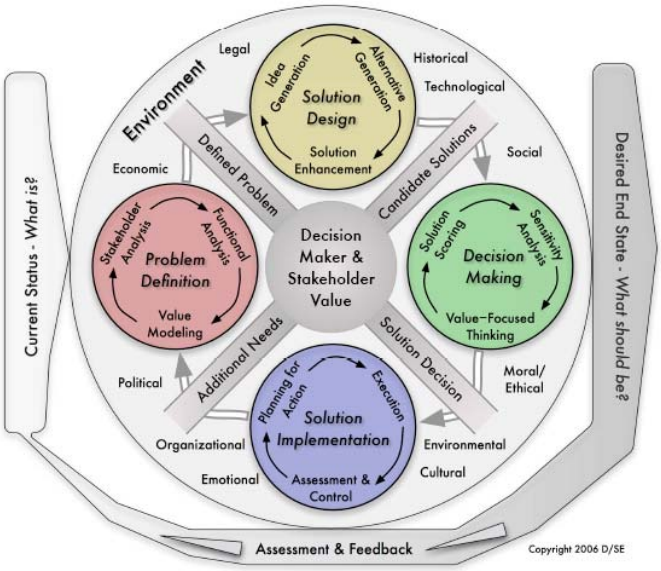

Figure 1. Systems Decision Process

In our deliberate review of our program, we started by reviewing our objectives and outcomes to ensure they were relevant and aligned with the needs of our various stakeholders. To determine if we were appropriately aligned as a program, we started by considering what lies at the very heart of what we are trying to accomplish – the mission of the United States Military Academy:

> *To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army.* (Educating, 2007)

We also derived insights from the educational goals of the Military Academy found in *Educating Future Army Officers for a Changing World*, published by the Office of the USMA Dean of the Academic Board. We considered the needs of our specific discipline area, systems engineering, by consulting the INCOSE (International Council on Systems Engineering) Handbook (Haskins, 2006). ABET was another sources Another significant input to our review process was ABET itself as the accrediting body for our program as ABET outlines a set of criteria that engineering programs should use to assess their students and the effectiveness of their programs.

Finally, we benchmarked our program objectives and outcomes against other undergraduate systems engineering programs around the country. We consulted the programs at George Mason University, the University of Pennsylvania, the University of Arizona, and the University of Virginia. One significant insight we discovered at the University of Arizona is how they structured their program objectives and outcomes. Essentially, after establishing their program objectives, they identified the outcomes that supported the achievement of those objectives. We followed this same approach in our program.

As a result of this deliberate review of our stakeholders, to guide the Systems Engineering program we revised the program objectives and subsequently defined program outcomes to support these new objectives. These objectives and outcomes are listed below:

Objective 1: Produce graduates who apply systems thinking, systems engineering and systems decision making throughout a career of professional excellence and service to the nation as an officer in the United States Army.

- Outcome 1.1: Define the problem, design solutions, make decisions, and implement the chosen engineering solution within a broad global and societal context.
- Outcome 1.2: Act professionally and ethically as a leader of character within each stage of the system lifecycle.

Objective 2: Produce graduates who effectively lead interdisciplinary teams in Joint, Combined, inter-agency, and multicultural environments.

- Outcome 2.1: Lead and work effectively as a contributing member of multidisciplinary systems engineering teams.
- Outcome 2.2: Employ up-to-date techniques, skills, and engineering tools necessary for Army officers and systems engineering practice.

Objective 3: Produce graduates who use an interdisciplinary approach to complex systems engineering problems in uncertain future environments by converting stakeholder needs, want and desires into system functions and requirements.

- Outcome 3.1: Identify and formulate a client's engineering problem and specify the client's actual needs using systems thinking, systems engineering and systems decision-making.
- Outcome 3.2: Apply knowledge of contemporary stakeholder issues to systems decision making.

Objective 4: Produce graduates who develop and evaluate innovative, value-focused solutions by defining system performance measures to guide solution design, systems decision-making, and systems implementation throughout the system life-cycle.

- Outcome 4.1: Define and measure system performance to guide solution design, systems decision-making and to validate that the design solution adds value and solves the defined problem.
- Outcome 4.2: Design or re-engineer a system or process in order to develop alternatives that meet the needs of a the client within realistic environmental constraints such as cultural, historical, legal, moral/ethical, economic, environmental, organizational, emotional, social, political, and technological.

Objective 5: Produce graduates who manage uncertainty by applying their knowledge of mathematics, science, technology and engineering to develop, quantitatively evaluate, and implement effective and efficient solutions.

- Outcome 5.1: Apply knowledge of mathematics, science, and engineering appropriate to Army officers and practicing systems engineers in order to develop, quantitatively evaluate, and implement effective and efficient solutions.
- Outcome 5.2: Design and conduct systems experiments, including collecting, analyzing and interpreting data.

Objective 6: Produce graduates who communicate engineering solutions convincingly both orally and in writing to technical and non-technical audiences.

- Outcome 6.1: Accurately, clearly, and concisely report findings, conclusions, and recommendations to the client in a manner that supports the client's decision.

Objective 7: Produce graduates who seek out and succeed in continued intellectual professional development in systems engineering and related fields.

Outcome 7.1: Demonstrate the skills necessary to support continued intellectual growth and learning for a career of professional excellence and service to the nation as an officer in the United States Army.

Before making a final commitment to these revised objectives and outcomes, we consulted our program constituents: the Nation, the Army, the Academy and the West Point community, the Faculty and Staff, and the Cadets. To represent them, we worked primarily through three main groups: the Faculty, the Alumni, and our Board of Advisors (BOA). Our BOA consists of representatives of other systems engineering undergraduate programs, the Army and leaders in the civilian community. With the concurrence of each of these groups, we felt comfortable that these program objective and outcomes could serve to guide our program alignment.

By aligning our objectives and our outcomes in this manner, we ensure that each of our objectives is being supported by one or more of our program outcomes. Consequently, we also know that we do not have program outcomes that do not support our program objectives. Given that we align our courses with the program outcomes, in this way we can ensure that we are not focusing our teaching efforts in courses and on topics within courses that we do not value as a program.

We continued this support approach to alignment of our program through our courses, our course objectives, our lessons and our lesson objectives. We recognized that we have a limited number of courses and lessons. In order to ensure that we are teaching the right topics (and teaching them well) to support our graduates and their attainment of the program outcomes and objectives, we had to make each lesson count and by that we mean, make sure that each lesson ultimately supports the achievement of our program objectives.

By aligning our courses and course objectives with program outcomes, we can first make sure we are providing sufficient instruction in the curriculum to support each program outcome and that we are not teaching topics which do not support the achievement of our outcomes. Similarly, we align lessons within each course and the corresponding lesson objectives with the courses objectives to ensure that we are not only supporting each course objective properly but also not teaching topics that do not support our course objectives.

This approach to alignment is best seen at Figure 2 below. This pyramid shows at the top of our curriculum is our program objectives and outcomes and that the courses , the course objectives, the lessons and eventually our foundation, the lesson objectives are properly aligned. We ensure this alignment through the review of our each course's Instructor Memorandum (IM) and syllabus and our instructor surveys. In our next section, we discuss how we assess from our alignment and achievement of our program outcomes through the assessment side of the pyramid.

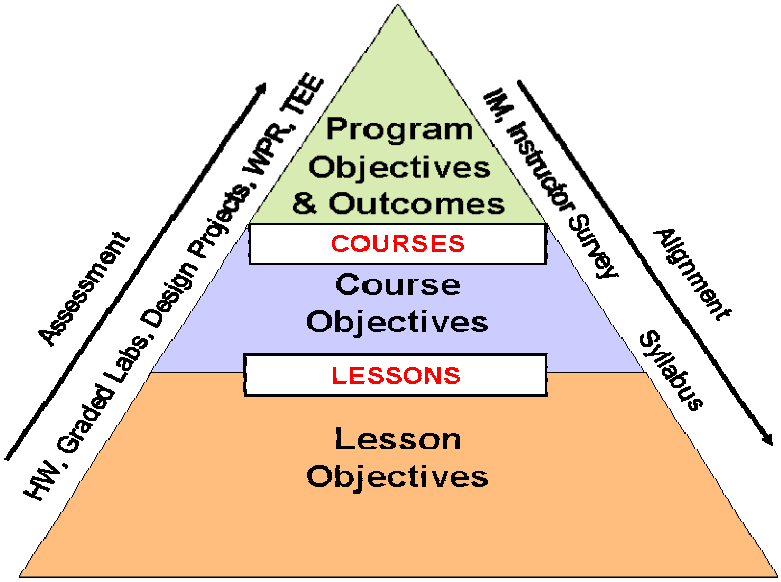

Figure 2. Program Alignment and Assessment Pyramid

Alignment to Assessment

Given the deliberate assessment and re-alignment of the Systems Engineering program as outlined above, it is important to assess the effectiveness of these changes. The assessment process is conducted at three distinct levels: direct assessment, course assessment and program assessment. Direct assessment is the means by which individual students are directly assessed to determine their ability to meet the stated outcome goals of the Systems Engineering program. Course assessments are completed by individual course directors at the conclusion of each academic term to assess the effectiveness of the course pedagogy and student learning in meeting the course objectives. Lastly, a program assessment is completed at the conclusion of each academic year by the program director as a means of assessing the effectiveness of the overall curriculum. Each of these levels of assessment will be discussed in more detail below.

Direct assessment is the means by which our program directly assesses our students to determine their ability to meet the stated outcome goals of the Systems Engineering program. There are two primary means for directly assessing our students' achievement of the program outcomes. The first method is the assessment of individual students against specified performance criteria that measure attainment of individual program outcomes. The second method is for each of the courses in the curriculum to design and administer graded events that assess student achievement of course objectives that align with the program outcomes. Both of these methods are routinely used and will be described in more detail below. The use of direct assessment is in keeping with an increased emphasis by ABET on the need for directly assessing student achievement of program outcomes. In order to stand up a program of direct assessment, we made a concerted effort to align our current assessment processes with this new area of emphasis of ABET.

The first of the two methods of direct assessment is to directly assess individual students and their ability to achieve the program outcomes. These direct assessments are completed for each Systems Engineering student across a number of courses on select events that measure the students' ability with respect to the program outcome goals which we expect they will be able to achieve prior to graduation from our program. The purpose of the direct assessment is not to "certify" individual students but rather to identify areas of strength and weakness in our program's curriculum in preparing our students to meet these outcome goals.

In order to implement this type of individual assessment we first needed to establish criteria by which we could measure our students' ability to meet each program outcome. For each of the twelve program outcomes we defined two or more performance criteria by which to measure an individual student's ability to attain all or part of the outcome. An example follows in Figure 3.

Program Outcome: Define and measure system performance to guide solution design, systems decision-making and to validate that the design solution adds value and solves the defined problem.
Performance Criteria: Develop a value model that identifies and defines performance measures for the objectives of each system function. Use defined system performance measures to guide the solution design ensuring that alternative solutions add value. Conduct trade-off analysis of multiple objectives using defined performance measures to assist in decision-making. Use modeling and simulation to assess and validate system performance against defined performance measures

Figure 3. Performance Criteria

In order to facilitate consistent assessment of our students, we further defined each of the performance criteria by establishing scoring rubrics that define various levels of student performance against the criteria. For each performance criteria we defined different levels of student performance. An example scoring rubric from the outcome above follows in Figure 4.

Performance Criteria: Develop a value model that identifies and defines performance measures for the objectives of each system function.			
Unsatisfactory	**Developing**	**Satisfactory**	**Exemplary**
No value model developed.	Value model includes performance measures identified for most system functions.	Credible performance measures defined for each system function and objective.	Performance measures are defined that are aligned with and directly measure each of the system functions and objectives.

Figure 4. Example Scoring Rubric

A complete list of the performance criteria that support each of the program outcomes as well as the scoring rubrics defined for each performance criteria are available from the authors.

The next challenge in establishing the direct assessment plan for individual students was to determine the course or courses where best to assess the students against the performance criteria we defined. Coupled with this challenge is the need to choose appropriate instruments by which to assess the students. In choosing appropriate courses and instruments to assess the students we maintained a philosophy of assessing the students: (1) where most appropriate with regard to the content in the curriculum, (2) using existing assessment instruments where possible, rather than creating new assessment requirements, and (3) as late as possible in the curriculum so as to get an assessment of the students' ability as close to the completion of the program as possible.

In terms of aligning the direct assessment of our students with the appropriate content in the curriculum, we wanted to make sure that the students had received sufficient instruction to date in their courses to meet the performance criteria being used to assess their abilities. Secondly, we wanted to make sure that the course provided sufficient opportunity to assess the students against the particular outcome. In essence, we wanted to ensure that this was the "right place" in the curriculum to do the assessment. For example, in support of assessing program outcome 5.1 "Design and conduct systems experiments, including collecting, analyzing and interpreting data, " one of the performance criteria we defined is "Use appropriate data analysis techniques including appropriate software data analysis tools to analyze the results of a systems experiment." Our assessment plan dictates that our students will be assessed against this criterion in the completion of a design project in the Statistics for Engineers course they take as part of the curriculum. Given that data analysis is a major topic in this course and the design project requires the students to do this type of analysis, this seemed like the "right place" to assess our students.

We made a concerted effort to align our direct assessment requirements with existing assessment instruments. In all but a handful of cases, we were able to use existing course requirements to assess each of the program outcomes and related performance criteria. For example, one of the performance criteria used to assess a program outcome related to lifelong learning asks about student participation in professional development activities such as professional societies and conferences. Clearly this is not an activity which the students are required to do nor is it assessed as a part of the curriculum. Therefore, in order to assess our students against this criterion we added a question related to their participation in these types of activities to the end of course survey for their senior capstone course.

In developing our direct assessment plan we tried to assess our students as late as possible in the program. In this manner, we hoped to get the truest assessment of their abilities as they approach the completion of

the academic program. Not only does this "late" assessment provide the students with the benefit of almost all of the instruction the academic program provides, but it also seems appropriate since we defined the program outcomes to be the set of knowledge, skills and attributes that our students should have upon graduation. One thing we have done with regard to assessing students as late as possible is that, where possible, we have coupled this assessment with a corresponding early assessment to gage the progress made by of our students' abilities over the course of the curriculum. We do this by assessing our students against many of the performance criteria in the introductory course we teach which is normally the first course our students take as part the program. This allows us to see the progress that our students make during the course of their time in the Systems Engineering program and again provides insights into the strengths and weaknesses of the curriculum.

In keeping with the philosophy of direct assessment outlined above, we were able to develop a direct assessment plan that allows us to assess our students against most of the performance criteria during the Capstone Design course that they take during their senior year. The basic design of this two-semester course requires students working in engineering design teams of 4 students or less to solve a problem for a real world client. A benefit of this year-long capstone experience is that the students are given numerous opportunities to demonstrate their ability to meet each of the program outcomes as they support their client. In doing so, these teams work closely with a senior faculty advisor throughout the year who is then able to effectively assess each student's abilities using the defined scoring rubrics for the performance criteria. As stated, there are numerous opportunities throughout the year for the faculty advisor to directly assess the students' abilities using almost all of the performance criteria without having to create additional assessment instruments. For example, the students regularly meet with their clients to provide interim progress reports of their work and each team is required to give a final briefing to their client and complete a written technical report of their work. These existing requirements are leveraged as a means for directly assessing the students' abilities.

Ultimately, this method of direct assessment calls for individual instructors to assess individual students using the scoring rubrics developed for each of the performance criteria identified to measure the achievement of the program outcomes. These assessments are done by instructors in select courses using select assessment instruments - exams, projects, client briefings, technical reports, etc. The results of these individual assessments are rolled up for each of the performance criteria and ultimately each program outcome as a means for assessing how well our students are attaining the program outcome goals. Descriptive statistics are compiled as part of this assessment process and compared against program outcome goals.

The second method of directly assessing the students is to have each of the courses in the curriculum design and administer graded events that assess student achievement of course objectives that align with the program outcomes. As stated in the previous section, each course is required to show the alignment of its course objectives with the program outcomes. Developing graded events that assess students' ability to meet the course objectives is a normal part of the course pedagogy. In terms of supporting the direct assessment plan, we require our course directors to develop these graded events with an eye not only toward assessing the course objectives but assessing the program outcome(s) with which their course objectives align. In doing so, they are able to use the performance criteria and related scoring rubrics for each of the program outcomes as a means for developing their course graded events.

As part of the process of developing their graded events, course directors are required to document the alignment of the content in the graded event (down to individual questions on exams) to both the course objectives and the program outcomes. This documentation is reviewed by the program director who ultimately is responsible for approving the content of the graded event. After the graded event is administered, course directors are required to assess the performance of the students against the course objectives and by extension the program outcomes. This assessment involves the reporting of the

statistical results of the exam including course averages, failures, as well as student performance on particular questions on the exam as they relate to course objectives and program outcomes. This assessment is also documented and reviewed by the program director who certifies the results of the graded event.

The results of these course-administered graded events are rolled up at the course level as they align with the program outcomes. For example, individual student performance is aggregated for a question or set of questions on a particular exam and reported against the program outcome that it supports. This is done for each course and for each of the major graded events in the course that test course objectives that support program outcomes. In this manner, the program director is able to monitor and assess the performance of students for each of the program outcomes across multiple graded events across multiple courses.

In addition to the direct assessment of students in individual courses as outlined above, course assessments are completed by individual course directors at the conclusion of each academic term. These course-level assessments are done to assess the effectiveness of the course pedagogy and overall student learning in meeting the stated course objectives and, by extension, the program outcomes. This assessment is less direct in that it involves the course director and the instructors in the course collectively assessing the achievement of their students in meeting the course objectives. This assessment is based on both the results of course graded events administered during the term and a subjective assessment by the instructors of their students' abilities. This course-level assessment also involves surveying the students at the end of each course and having them do a self-assessment of their own achievement of the course objectives. As a part of each end of course survey, we also ask each student to assess their own ability to meet the program outcomes.

This information from the course director and course instructors as well as the students is used to assess the effectiveness of the course pedagogy and support any changes to the course and/or curriculum that may be required. It is here that course directors are able to recommend changes to the course such as changes in the course objectives, course content, the balance of lessons spent on given course topics, etc. These course-level assessments are formally documented and provided to the program director to be used as part of the program-level assessment which will be discussed in more detail below.

At the conclusion of each academic year, the program director conducts an overall assessment of the program which he provides to the Department Head. This assessment generally includes program strengths and weaknesses, statistics on enrollment and grades, proposed program changes, and summary reports on individual courses. This is the program director's opportunity to propose changes to the Systems Engineering program as a whole. This assessment is formally documented and the annual report is also briefed by the Department Head to the Dean, as part of the latter's annual formal Review and Assessment (R&A) of the department.

Much of the information that feeds this program-level assessment is gained through the direct assessments and the course assessments described above. Through this assessment process, the program director is able to get a holistic view of the overall program. The program director is able to check the alignment of the program from top to bottom. He or she is able to assess the alignment of individual courses in the program with the program outcomes. He or she is able to assess the level of contribution of each of the program's courses in preparing students to achieve those outcomes. Lastly, the program director is able to assess the effectiveness of the assessment process itself. As a result of this program assessment, the program director is able to direct changes as necessary at the program or course level.

When combined with the formal and informal feedback we solicit from our faculty, our alumni and our Board of Advisors, the continual assessment process described above allows us to monitor, assess and

control the state of the Systems Engineering program to ensure that it remains internally aligned to ensure the successful achievement of our graduates.

Conclusions

As mentioned, there are two assessment cycles used for the Systems Engineering program. The long cycle which is done less frequently and looks at the high level program issues and the short cycle which his done more frequently and monitors the lower level program issues. The high level / long cycle assessment process was discussed in the first half of this paper. Most recently this "deliberate" assessment was done to check the alignment of the Systems Engineering program's objectives and outcomes with its stakeholders resulting in some significant changes. Additionally, it was used to ensure the alignment of the courses within the curriculum with these revised objectives and outcomes. The lower level / short cycle assessment process was discussed in the second half of the paper. It checks the alignment of course and objectives to the program outcomes and measures the performance of students in achieving those outcomes.

As described, this short cycle assessment is done at three levels: direct assessment, course assessment and program assessment. The course and program level assessment plans and procedures have been in place for quite some time. The direct assessment plan has been recently implemented and therefore will require close monitoring to assess its effectiveness. As we move forward with the direct assessment plan outlined above we will undoubtedly have to make adjustments to the performance criteria, the scoring rubrics, and/or the courses and instruments used to directly assess student performance.

One of the initiatives we are currently working on to support the alignment and assessment of the program is the development of a web-based program management system that will facilitate the collection and analysis of course and program-level data. This new capability will leverage an existing web-based, database-enabled course management system previously developed by our department and currently in use. Successful implementation of this program management system will allow for real-time data collection and continuous monitoring of the program.

Lastly, given the significant changes that have recently been made to the Systems Engineering program we are trying to minimize the number of changes implemented in the near future. By minimizing changes, we will allow the program to "settle in" and provide an opportunity to better assess and evaluate the effectiveness of the changes made.

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Lieutenant Colonel Michael J. Kwinn, Jr. (US Army) LTC Michael J. Kwinn, Jr., Ph.D. is an Associate Professor of Systems Engineering at the United States Military Academy at West Point where he currently directs the Systems Engineering and Operations Research programs.. Mike graduated from the United States Military Academy at West Point in 1984 and has Master of Science from the University of Arizona, a Master of Arts in National Security and Strategic Studies (with Distinction) from the Naval War College, and a PhD in Management Science from the University of Texas at Austin. He has worked on systems engineering projects for over 10 years and recently served as the Director of the Operations Research Center (ORCEN) at the United States Military Academy. Some of his recent work is in the areas of acquisition simulation analysis, military recruiting process management, condition-based maintenance implementation and assessment systems development for combat operations. He is President-elect for the Military Operations Research Society (MORS), is a member of the International Council on Systems Engineering (INCOSE), the Institute for Operations Research and Management Science (INFORMS) and has served as an advisory member for the Army Science Board.