Designing and Enhancing a Systems Engineering Training and Development Program

Philip N. Trudeau, Ph.D.
MITRE Institute
MITRE Corporation
Bedford, MA
trudeaup@mitre.org

***Abstract*— The MITRE Institute, the Training and Development (T&D) organization of the MITRE Corporation, is in the process of designing and enhancing its systems engineering (SE) T&D program. This long-term, strategic program is intended to complement an existing deep, self-selection, internal catalog program and an on-site Masters Degree program in systems engineering. The program direction and design are driven by a competency model that focuses on behaviors of successful SEs at MITRE. The program horizontally integrates and blends many T&D approaches at the same program level, including technical, non-technical, and e-Learning courses; student and manager assessments; customized on-the-job projects; group work and networking; a focused training resource database; student-manager commitment through an individual development plan (IDP); and a certification option. The program integrates concepts vertically by replication of content that is considered important on multiple, or all levels of the program, such as enterprise systems engineering, risk, team development, and persuasion and influence.**

The SE T&D program, called *SEworks*, will have three tiers, roughly in line with MITRE's technical career ladder, with the purpose of ensuring that SEs at certain levels in their career are armed with and capable of using various SE skills, methodologies, and techniques on the job, and also capable of tailoring them to their projects. Kirkpatrick level 1 and 2 measurement approaches will be used in various aspects of the instructor-led and e-Learning courses. Long-term, programmatic measurements on behavioral changes (Kirkpatrick Level 3) will focus on two approaches. One approach and goal is an 80% improvement of competencies that students focused on for their on-the-job projects, as determined through manager assessments. The other approach is a long-term trend analysis on our cross corporate assessments of students in the SEworks program.

With substantial senior manager input and support, The MITRE Institute has initiated a long-term, strategic internal SE T&D program, which is designed to complement existing deep SE catalog and onsite MS in SE degree programs. The main purpose is to enhance the SE behaviors and skills of MITRE staff, a core competency of the MITRE Corporation, and thereby allow the staff to deliver better products to our customers.

Keywords - systems enginering; training and development (T&D); education; competency model; measurement; training design

I. INTRODUCTION

A. MITRE Corporation & the MITRE Institute

The MITRE Corporation has approximately 7,000 employees in four separate Federally Funded Research and Development Centers (FFRDCs) supporting the Department of Defense (DOD), Federal Aviation Administration (FAA), the Internal Revenue Service (IRS)/Treasury/Veterans Affairs (VA), and the Department of Homeland Security (DHS). The company has two main facilities in Bedford, Massachusetts, and McLean, Virginia, near Washington DC. The company has approximately 65 domestic and 10 international sites, ranging in size from 5 to 180 staff. Delivering high-quality education and training to main campuses and remote sites has been highlighted previously [1].

The MITRE Institute is the Training and Development (T&D) organization supporting MITRE's technical staff and managers. The MITRE Institute has three main groups: Technical Group, Leadership & Management Group, and the Organizational Effectiveness Consultant Group. The first two groups are focused on individual staff development, while the Organizational Effectiveness Consultant Group focuses on group development, group change efforts, and/or group interventions. The Leadership & Management group has a three-tiered nomination program for first-, mid-, and senior-level managers. The Leadership & Management Program also manages new manager programs and coaching programs for mid- and senior-level managers.

The MITRE Institute Technical Group focuses on the training and educational needs of MITRE's Technical Staff. The Technical Group delivers three open enrollment catalog programs each year, with classes generally ranging from one-half of a day to three days in length, or occasionally longer. The main curricula areas are Systems, Software, and Domain Engineering; Advanced Operating Systems and Tools; Information Assurance; Networking and Communications; and Sensors. The Technical Group also manages a Business Applications Program, including licensed software tools and MITRE-built and MITRE-modified tools. The Technical Group manages an external vendor e-Learning program with many courses (3,200) and books (18,000) online. The Technical Group manages several university programs, including an Accelerated Graduate Degree Program, where

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staff study mostly for Ph.D. degrees and receive paid time off from their work programs. The Technical Group manages multiple on-site M.S. degree programs in Systems Engineering, and has other university affiliated programs.

For approximately seven years, the Technical Group has been planning a large nomination program in systems engineering, called ***SE****works*, which is described in this paper. [The naming process for the ***SE****works* program will be discussed later in this paper – the numbers used after the program names indicate the program level, with level 1 being the lowest.] One aspect of the early portion of this systems engineering program has been described elsewhere [2]. The full program design and the first year of implementation will be described in this paper.

B. MITRE as a Learning Organization

MITRE prides itself as being a learning organization. There are many avenues of learning and exchange at MITRE, among them the following:

- MITRE Institute (Technical, Leadership & Management, Organizational Effectiveness Consulting Groups – described above)
- University Programs: Basic Educational Assistance, Accelerated Graduate Degree Program, Johns Hopkins University M.S. in Systems Engineering degree programs, and other university affiliation programs
- Technical Exchange Meetings – usually one day in length on advanced technologies, occurring every week or two, and broadcasted throughout the main and site campuses
- Innovation Program Speaker Series, where CEOs and CTOs provide strategic technology talks
- The MITRE Innovation Program – MITRE's internal research and development program, which focuses on our sponsors' important problems and identifies portfolio areas where advanced and emerging technologies can dramatically improve the government's mission and business performance
- Organization or technical group technology seminars, delivered on a recurring basis by numerous groups within the company
- Vendor technology demonstrations and presentations, sponsored by numerous interest groups within the company.

C. Corporate Systems Engineering (SE) Technical Training Approach

While MITRE has many T&D approaches, as summarized in the previous section, systems engineering is a core competency of the corporation. As such, SE has always been an important part of our programs. Starting around the year 2001, we initiated programs to bring more focus to our SE T&D at MITRE. Presently, we have a three-pronged approach to T&D in SE:

- MITRE Institute open catalog programs are delivered three times per year and open to our technical staff and managers. These courses are commonly one- to three-days in length and cover processes, methodologies, models, tools, and related topics. Over a five-year period, we delivered 145 different SE courses – probably 75% by MITRE staff and 25% from outside vendors, consultants, and professors.
- MITRE began collaborating with JHU, and has started new cohorts in M.S. in SE degree programs almost every year since 2001. These cohorts take approximately two to two and one-half years to complete. JHU provides the main instructors and MITRE provides co-instructors and special lecturers.
- The ***SE****works* Program, as described in this paper, is a tiered nomination program, focused on different technical and career level combinations within the corporation.

As a three-pronged approach, the MS in SE degree programs provide deep, focused training in SE for staff members who want to earn an SE degree; the ***SE****works* program provides broad SE T&D and ensure that staff at all technical levels have the core SE knowledge that they need to complete their jobs; and the catalog program continues to provide the deep training in many SE topics that meet the immediate needs of MITRE's Technical Staff for their projects.

II. METHOLDOLOGY

A. Technical and Change Management Approach

We defined a high-level approach (Fig. 1) at the beginning of this program and conducted many special analyses and studies along the main path to clarify our design. From left to right in Fig. 1, at a high level, we defined a competency model for successful systems engineers at MITRE and used the model to conduct assessments with MITRE technical staff and managers to baseline the company and the new program. Subsequently, we created development solutions, first for the whole program and then eventually, by level. We considered change management activities throughout, such as senior management support and proper communications during rollout, but other change management considerations were dealt with before program rollout. Finally, during the fall 2009, we rolled out the first level of the program. These stages will be thoroughly covered in various sections of the paper.

Of special note was our alignment with senior management on this program. We first approached the CEO of the company about seven years ago to describe our intention to improve our internal T&D programs. He indicated that a corporate goal with several corporate officers, along with a cross-corporate committee, was forming to create a new goal – *Practice Systems Engineering*. We aligned ourselves with this group and the corporate goal at the very earliest stages of their formation. We used this group as a conduit for our ideas to be heard by senior management and also as a mechanism to obtain cross-corporate collaboration and feedback from senior technical staff. This cross corporate group collaboration was

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invaluable and helped to continually shape the program to be useful for our ultimate end users, the MITRE technical staff.

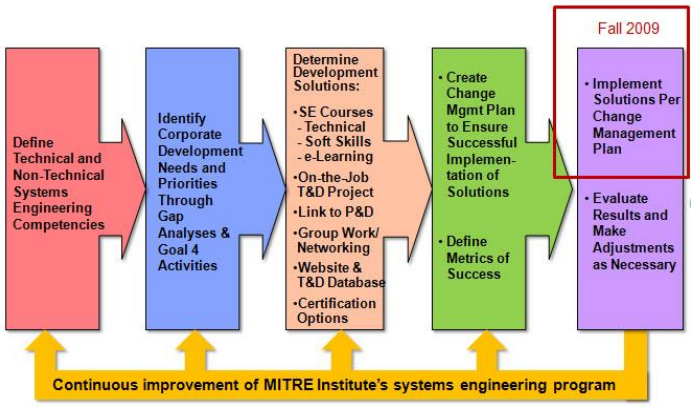

Figure 1. SEworks Program Methodology

B. Benchmarking with Best Practice Companies

As early studies and planning were initiated on this project, we decided to perform a benchmarking study to see how we compared to other top-tier training organizations in technical training, and specifically, in systems engineering training. The eight companies that we contacted ranged in size from slightly smaller than MITRE's 7,000 employees to over 300,000 employees. To increase the studies' objectivity, we hired an outside consultant to survey these eight technical companies, which had significant technical training and development functions. The eight companies included large high tech hardware, software, and service companies; large networking companies; medium and large aerospace companies; and a high tech educational consulting company.

We had two main goals with respect to learning best practices from these leading edge companies:

- How did they develop and reinforce technical learning programs?
- What Systems Engineering and Systems of Systems training were they doing to ensure their capabilities were leading edge in this technical area?

The benchmarking questions focused around eight areas of best practice, and included the following:

1. Competency Models
2. Certification Programs
3. Measures of Success
4. Needs Analysis
5. Balancing Overview and Deep Technical Content
6. Reinforcement of Learning outside the Classroom
7. Premier Technical Training Approaches
8. Lessons Learned

The study resulted in information about best practices and various trends for technical training. Participating organizations shared best practices for Systems Engineering training; however, they had little information for Systems of Systems Engineering training at that time, as they did not offer such programs.

Most participating organizations used competency models to drive training and development. Best practice companies used competency modeling techniques in limited and strategic ways. Several organizations had certification programs. Designers of these certification programs were able to describe several benefits of the program to customers, the organization and its employees.

Determining measures of success is a high priority for many of the companies. Like competency models and certification programs, metric programs can be quite costly. Therefore, best practice programs target large training programs only for metrics, for example, those which consume significant human and funding resources.

One overall best practice, regardless of the area of study, is to focus on strategic importance – invest resources in areas that will result in a competitive advantage. Several organizations that were studied use executive councils or cross-organization functional groups to ensure strategic relevance. As such, the important findings, especially the last two, can be summarized as follows:

- Best practice companies use competency models to drive training and development, but mostly on important programs in limited and strategic ways
- Measures of success are targeted toward strategic or large investment programs, due to the cost of metric programs
- Best practice companies perform needs analyses through formal methods, ranging from surveys to competency models with concurrent gap analyses
- Most of these best practice companies deliver content to geographically diverse employee populations, which require various distance learning methods, but one theme was consistent – content was "King"
- Most sophisticated T&D programs use multiple delivery methods of their content to address different learning styles
- "*Instilling common practices"* is one of the best practice outcomes from major T&D programs – these programs help to develop corporate culture
- "*High end, important T&D programs"* need both verbal and financial support from senior management.

We took every one of these results into consideration while we were designing our ***SE****works* program, as this paper will describe.

III. COMPETENCY MODEL

A. Building the Competency Model

The building and use of an SE competency model (CM) was an important part of this program (Fig. 2). The CM could help us analyze and define the training requirements, it would

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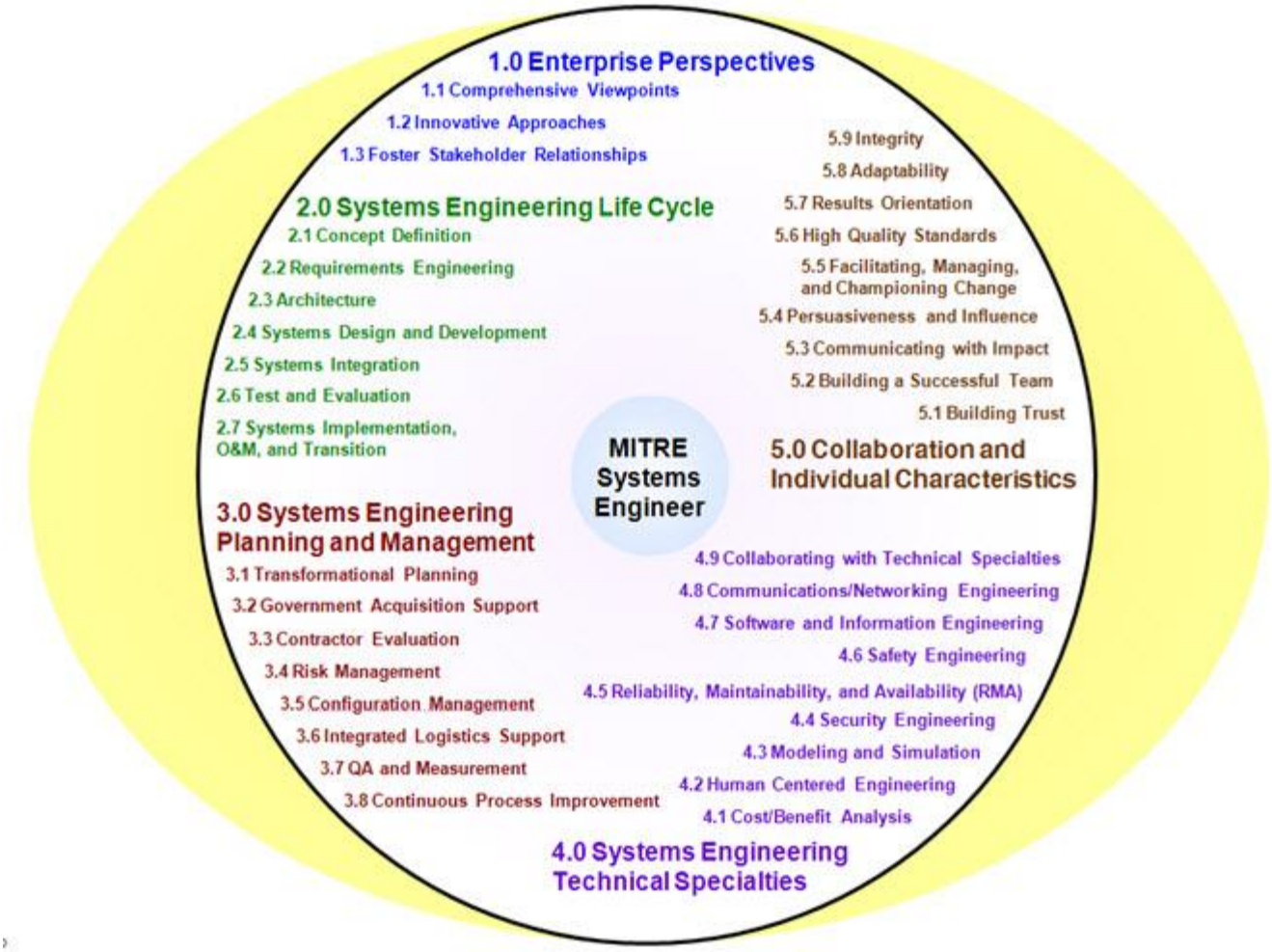

Figure 2. MITRE Systems Engineering Competency Model

be used for MITRE SE benchmarking, it would to be used for individual student and manager assessments, and it would be a major driver for curriculum development. With all these factors in mind, we spent considerable time and effort on developing a quality product. We hired a consultant to help and we spent one and one-half years on the task. The competency model development is described more fully elsewhere [2], but a brief description is included herein. We planned for a number of stages, including data gathering, information prioritization and analysis, information organization, information compression, final editing, and publishing of the model.

There are two general types of competency models:

- Success models, where a very small number of key competencies are described. These competencies describe a small number of essential competencies for staff to successfully perform a particular function.
- Comprehensive competency models, which describe the full range of competencies and behaviors to successfully performed in a large job family or function.

The MITRE Institute chose to develop a comprehensive SE CM, since its purpose was to drive a variety of SE training and development programs. The model needed both depth and breadth to support the T&D task, more than a success model would provide [3], [4], [5].

The MITRE Institute began the CM development task by collecting available SE competency, skill and knowledge information from industry, Government organizations, standards bodies, and MITRE Institute resources. The MITRE Institute staff wrote a draft CM, which attempted to describe how system engineering is performed at MITRE in accordance with our unique relationship with our Government customers.

Upon completion of the draft, the MITRE Institute scheduled 10, day-long focus groups in MITRE's Centers. There were two focus groups in each Center— the first set of five focus groups concentrated at the three lower technical staff levels, and the second set of five focus groups concentrated on the three higher levels of technical staff. Focus group members

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were asked to respond to the draft model, for example: What competencies should be added, dropped, and/or modified? Similarly, what behaviors in the competencies (usually 10-12 behaviors/competency) should be added, dropped, and/or modified? They were asked to prioritize all the competencies compared to their understanding of SE job tasks at MITRE. All the competencies were prioritized by each focus group, so that unimportant competencies could be removed from the model. The model included technical and non-technical competencies, as we felt that highly qualified, successful systems engineers require both skill sets.

After every two or three focus group sessions, the MITRE Institute staff re-wrote the whole model and then used it with the next set of focus groups. We used an iterative, SE spiral approach to produce the CM product. During development, the competency model varied in size from as small as 25 competencies to as high as 55 competencies. After many prioritization sessions and much editing, the model was finalized with 36 competencies — 27 technical and nine (9) non-technical competencies (Fig. 2). Each of the competencies had three proficiency levels – Foundational, Intermediate, and Expert. In summary, each competency has three proficiency levels, each proficiency level has three to four Key Actions (a grouping of similar competencies), and each Key Action has two to four behaviors.

The model was delivered to the cross-corporate SE team with which we were engaged and to the Officer Group. Another 35 senior technical staff and managers were asked to review and comment on the CM. Comments were analyzed and considered for inclusion by a group of Center representatives supporting the MITRE Institute. This was an important part of the process. Our team helped us sort out difficult changes to the model and provided some perspective that we were not able to supply from the education group. After editing of the final competency behaviors, the CM was published in September 2007.

B. Uses of the Competency Model

The first task after publishing the CM was to baseline the company against the CM. We wanted to understand how the technical staff felt they compared against the competency model and how capable the managers felt the staff needed to be in each competency to support our work programs in the next one to two years. We surveyed 600 technical staff and asked them to self-assess against the competency model, by asking, "How proficient were they compared to each competency – No Proficiency, Foundational, Intermediate, or Expert?" We asked the managers, "What percent (%) of the SEs who work for you need to be Foundational, Intermediate, or Expert for next year's work programs and projects?" We performed a gap analysis between the two surveys. It might be questioned as to whether a self-assessment with the technical staff was a good approach or whether the staff might indicate that they were more capable than they really were (as determined by what their managers might say). We decided to use the self- assessment approach, as we had considerable data from other programs in the MITRE Institute suggesting that when the staff assessed themselves, they were actually more severe on their ratings than when their managers assessed them [6].

The results showed a good correlation between what the managers needed for technical competencies on the work programs and what the staff said they were capable of delivering, when compared to the technical competencies. We had shortfalls on some of the non-technical competencies. While the survey was valid at a 95% confidence limit, we did see two data anomalies that we could not explain well from the result trends. One anomaly was in the number of staff who considered themselves experts in competencies as we increased in staff level (we expected an increase, but the percentage increase was relatively flat – possibly our more experienced staff have better self-assessment capability than our less-experienced staff – "you know what you do not know"). A second anomaly in the non-technical areas was that we similarly expected that the percentage of staff self assessing as "Expert" to increase, as we increased through our technical staff levels. It did not; it actually decreased. (Later we determined that the language "level cutters" between the proficiency levels for the non-technical competencies were insufficient to properly separate the levels and the data was biased in this area of the survey.)

To validate our first survey, and to try to sort out these two data anomalies, we conducted a second corporate survey in 2008. We redesigned the survey to take out possible biasing. We asked both questions of the managers, so they were providing the raw data on both sides of the gap analysis. We asked the managers the following questions:

1. For each competency, how proficient are your staff - Foundational, Intermediate, or Expert?

2. What percent (%) of the SEs who work for you need to be Foundational, Intermediate, or Expert for next year's work programs and projects?

As in the previous survey, we performed a Gap Analysis, and the results were similar to the first survey: a good correlation existed between what the managers needed for technical competencies on the work programs and what they thought the staff were capable of delivering for these technical competencies. We still had a few shortfalls for some of the non-technical competencies. However, at this point we felt we knew the basic capability of the staff at various technical staff levels with respect to the CM. We would continue to use the model in curriculum development, student-manager assessments, and on-the-job projects, and these aspects of competency model use will be discussed in later sections of this paper.

IV. PROGRAM DRIVERS

Many aspects of design need to be considered when designing a large, tiered program, for example, high-level program design, sub-level tier design, course design (instructor-led and e-Learning), special program segment designs, and logistical design. All aspects of the design will be discussed herein, but before we moved into the design phase, we wanted to confirm the drivers for the program design, so that we could use these drivers to shape the design and obtain feedback and affirmation from our senior management team.

The drivers came from our focus groups, the survey results, interaction with our cross-corporate SE team, previous problem

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areas we had seen in MITRE Institute programs, and discussions with our Corporate Officers.

The overarching driver or goal was to "*Provide a workforce that can skillfully apply MITRE's brand of systems engineering to meet our customers' needs."*..The program drivers, which originated from these various sources, could be summarized as follows:

- Provide baseline SE technical training and knowledge for various technical and/or career levels
- Close the non-technical, soft skills gaps
- Build consistency of SE practice through the training materials, but allow flexibility in examples and case studies to assist students in tailoring the material for their own projects
- Vertically integrate topics that should be taught at all levels, for example, risk, enterprise systems engineering, and certain non-technical skills

V. PROGRAM DESIGN

As we approached the design phase, we knew there were additional items to include in our thinking, for example, cost of programs, time students would be away from their project work, and cost and time involved in travel. We needed to work these practical considerations into the design, so that it would be palatable to the staff and supported by management. One of the keys was total training time. From experience, we felt we could deliver a quality program and obtain management support for a program that was 10-12 training days in length over a 10-month time period. With this constraint, we began to examine our options.

A. Use of Competency Model to Drive High-Level Design

We wanted the competency model to help drive the training and development activities, but there was more than one way we could complete the design. In general, we were considering a three-tiered program for two reasons – it mirrored our CM, which had three proficiency levels, and a three-tiered program would deliver a reasonable amount of content at each level to coincide with MITRE technical staff levels. For example, each program level would focus on two levels of MITRE's technical staff hierarchy.

The easiest design approach would have been to deliver the CM proficiency content on each program level for all 36 competencies. For example, in Fig. 3, the first program level would be represented by the red vertical slice through the CM, the second program level by the green vertical slice, and the third program level by the yellow vertical slice. The major drawback in this type of approach is that we would not have been able to obtain enough training time from senior management to deliver a quality program, or the content would have been superficial for many of the competencies. We did not think we could obtain more than 10-12 deliver days for the T&D program. As such, we only had about 72 delivery hours (e.g., 11 days X 6.5 delivery hours in an 8-hour day). Under the vertical scenario approach, we would only have about two (2) hours/competency on average to deliver content, if we covered all the competencies at each program level of the design. We could have potentially covered a few of these competencies in two hours of content, but in most cases, we would have needed considerable more time to provide proper coverage for the competency content, and sufficient time for the students to complete in-class examples and case studies, one hallmark of good learning principles [7].

Figure 3. CM Design Approach – Vertical Proficiency Approach

As such, we needed a different approach, where we could take into account the competency model, but other factors, such as which content we should deliver for different technical staff levels, the order of content delivery between levels, and the number of days to focus on specific content. With this in mind, we looked at the possibility of focusing on sections of the CM for different levels of the program. If we took this approach, we would simultaneously consider including some important topics at all or multiple program levels, as certain content was considered very important for successful systems engineers.

B. Three-Tier, High Level Design

At this point, we looked at training on specific areas of the competency model that were appropriate for different technical staff levels, for both technical and non-technical competencies. We also wanted to vertically integrate specific topics that were important to address on all levels of the program, for example, risk management and enterprise systems engineering.

We chose to focus our lowest level program ***SE****works1* on the technical aspects of systems engineering (Section 2 – Systems Engineering Life Cycle); we chose to focus the mid-level program ***SE****works2* on planning, management and process aspects of systems engineering (Section 3 – Systems Engineering Planning and Management); and we chose to focus our senior level program ***SE****works3* on enterprise systems engineering (Section 1 – Enterprise Perspectives). We decided to focus on the technical specialties (Section 4 – Systems Engineering Technical Specialties) through short e-Learning courses in both ***SE****works1* and ***SE****works2*. Our rationale on the technical specialties was that in many cases, we had deeper technology courses for Section 4 competencies in our open catalog program, and short e-Learning courses would introduce the knowledge area and make our SEs aware of the important issues. In the ***SE****works* program, we were trying to raise

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awareness of the technical specialty and some of the important SE issues in each technical specialty. The e-Learning courses were planned to be relatively short (e.g., 1-3 hours). The concept was that students would pick two or three of the eight technical specialties to study at each program level.

The approach for the non-technical, soft skill competencies would be to deliver them at the most appropriate level for the level of staff that would be in the program (Section 5 Collaboration and Individual Characteristics). With two of the non-technical competencies (e.g., 5.2 Building Successful Teams and 5.4 Persuasiveness and Influence), we decided that they were so important for the development of successful systems engineers, we would cover the competencies at two program levels, even though we would deliver different and customized content at the different levels. With those considerations in mind, Fig. 4 represents a mapping of our ***SE****works1* program against the CM.

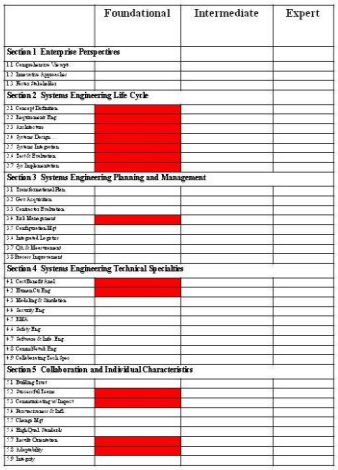

Figure 4. CM Design Approach – First Level Program

We were aware that in systems engineering training much of the content we had in our CM needed to be integrated with other systems engineering content in the CM. This meant that we would have to include concepts from other competencies to ensure a quality delivery, but we would not focus on those other competencies sections if they were not the focus of that particular level. For example, the details of configuration management would be presented in ***SE****works2*, but the need for configuration management and the general process of configuration control boards would be discussed along with SE models in ***SE****works1*.

Another design decision that we made for the first two levels of the program was that the content we decided to focus on should include knowledge and behaviors appropriate for both the Foundational and Intermediate CM proficiencies. Fig. 5 depicts this concept. We chose to do this because if we were only going to cover a specific level of the competency model at a specific program level, we should cover it as widely and as deeply as possible at the specified program level.

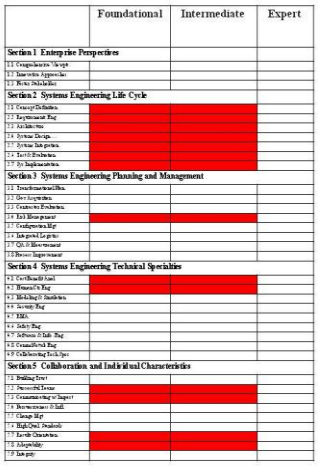

Figure 5. CM Design Approach – Final First Level Program

In summary, the final high-level design would focus on different sections of the CM at different program levels. Some competencies would be covered on multiple levels because they were important for successful system engineers. While it is difficult to show all these concepts in one figure, Fig. 6 depicts the CM Program Level mapping for the three-tiered approach, as follows: red color – ***SE****works1*, green color – ***SE****works2*, and yellow color – ***SE****works3*.

Figure 6. CM Design Approach – ThreeTiered ***SE****works* Program

Fig. 7 maps the previous more theoretical discussion of our approach to a more concrete listing of the topics that we planned to cover at the various program levels. The ***SE****works* program levels are shown as horizontal rows in the figure. In the vertical columns, the technical competencies are colored in blue; the non-technical competencies are colored in salmon; and the e-Learning and vertical integration topics are colored in yellow. The main technical and non-technical focus is shown next to the program level title for each level. For example, for ***SE****works1*, the focus is "Apply rigor to the SE Lifecycle activities and effectively communicate and collaborate." The specific competencies that would be covered are listed in the figure's cells.

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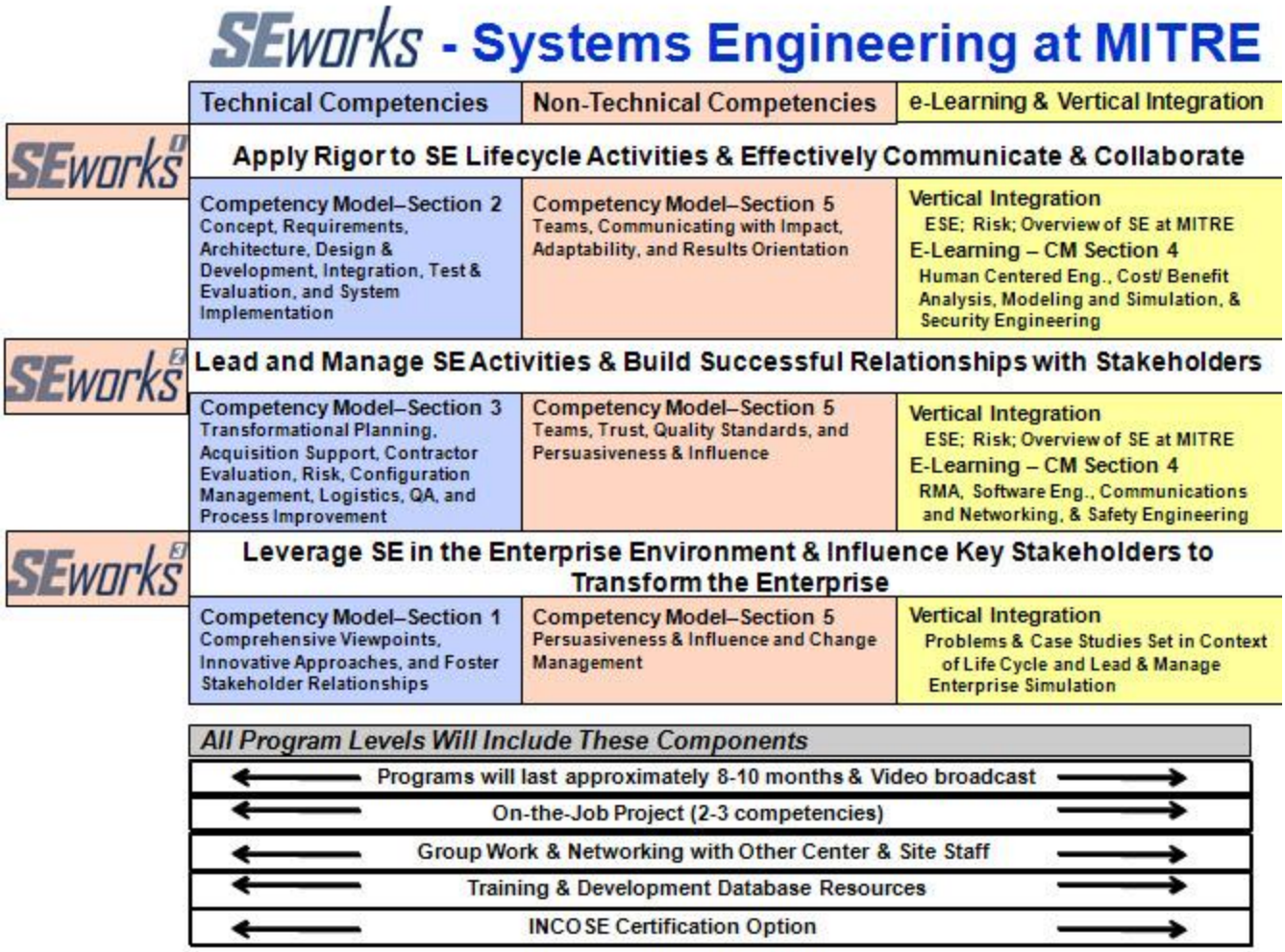

Figure 7. SEworks – Three-Tier, High Level Design

From a technical competency perspective, Section 2 of the competency model – Systems Engineering Life Cycles – would be covered in ***SE**works1*; Section 3 of the competency model – Systems Engineering Planning and Management – would be covered in ***SE**works2*; and Section 1 of the competency model – Enterprise Perspectives – would be covered in ***SE**works3*. Section 4 of the competency model – Systems Engineering Technical Specialties – would be covered in short e-Learning courses. The number of e-Learning courses to take would be dictated by the program, but which e-Learning courses to take would be customized by the students. Topics such as risk and enterprise systems engineering would be covered at all ***SE**works* levels. A number of extra design components are listed at the bottom of Fig. 7; they will be discussed later in this paper.

C. Technical Course Design

A main consideration in the design of the technical courses is whether we would design and develop them with resources from inside of the company or with external vendors, consultants, or professor partnerships. Each method has positive and negative considerations. On the positive side, when we work inside the company, it is much easier to customize the content. Our own employees know the inner workings of the company, and no matter how much we try to explain this to an external resource, it is never the same as having the course internally developed and delivered. On cost, the development of the content with internal resources would probably be about the same as with external resources, but the ongoing delivery would be less expensive. Negative aspects of using internal resources include the consideration that it is often difficult to obtain the resources needed at the time they are needed, and that although the presenters may have good platform skills, their skills are not honed as well as vendors, consultants, and professors who teach almost every week.

The positive side of using external development and delivery resources is the flip side of many of the negative aspects of using internal resources – for example, the instructors have considerable classroom platform skills, and they have taught in this topical area for years. Another positive

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aspect is that the materials are "road tested." While the exact configuration of the materials might not be the same as the outside vendor or consultant has used in other venues, the material has been used many times and has had the scrutiny of many students to improve the content and clarity over time. Another positive aspect of using external resources is that scheduling with consultants is usually easier than with internal technical staff. As long as we schedule early enough, we can obtain the vendor or consultant help we need, when we want it, because that is their business model. Conversely, internal resources have other project demands on their time. On the negative side, while the development costs might be similar between the two development approaches, the ongoing delivery costs are much more expensive with the use of external resources, and the customization to our own corporate environment is never as good as when we use internal developers and instructors.

Given some of these considerations, we decided to make the decision on internal vs. external development at the lowest level – the individual course. So, for example, program levels could be a mixture of internal and external developments and deliveries. In the ***SE**works1* level, five of the courses were developed and delivered by external vendors and consultants and one of the classes was developed and delivered with internal resources. With external vendors, we work with them to customize the content as much as possible for our environment. We worked with them to choose examples from their repertoire that would be appropriate in our environment, and we help develop examples and case studies that make the materials customized for our audience. More discussion about those decisions will be presented later in this paper.

D. Non-Technical, Soft Skills Courses

The make vs. buy decisions for the non-technical, soft skills courses are theoretically the same as they are for the technical skills in the previous section, with one significant difference: availability of subject matter experts and instructors for the non-technical competencies. Since our company is a technically oriented company, we do not have the non-technical personnel resources to develop and deliver from our own staff – especially with road tested content and instructors with considerable experience in this content domain. Given our situation, we decided we would use external vendors, consultants or professor resources to develop and deliver the non-technical courses. Again, we planned to work closely with external providers to customize the material as much as possible, including our own examples and/or case studies when possible.

E. e-Learning Courses

The decision to use e-Learning as a delivery mode has to be weighed against cost and the number of students who will use the training. While we have had considerable e-Learning resources from a vendor for many years (e.g., presently 3,200 courses and 18,000 books online), in the past, we could not justify the building of e-Learning content with internal resources, because the number of staff who would use "any individual" final product was not high enough. For example, we have significant numbers of vendor e-Learning courses that five or ten staff use during the course of a year. However, if only five or ten staff use the content during a year, it is much more cost effective to buy or lease the content than it is to develop the content. With the SEworks program, we felt that the number of staff who would use the content justified the investment.

While we had used e-Learning courses for years, we did not have any e-Learning development experience. As such, we hired a new staff member with considerable development experience. Our first choice focused on which development tool(s) to use. As long as we were to develop SCORM/AICC compliant e-Learning, the delivery platform should not make a big difference. The third tool set we examined was the one we selected. The tool selection process took about five months. In order to make the decision, we needed to bring in training, if we did not have experience with a specific tool set, and we needed to build prototypes to test the tool's capabilities for the type of content for which its use was planned.

Once the tool set was selected, our e-Learning designer developed a set of e-Learning development standards for our department. Since we had not previously developed any e-Learning content, our designer felt that we should have a set of design standards and principles to guide us. This was a good decision.

The final decision would be on which delivery platform to use. We had one option already available through a vendor relationship. However, we chose to implement a different internal vendor solution inside the company, as it would solve multiple problems at the same time. The solution we chose would allow the MITRE Institute to post and track our e-Learning content, broadcast and archive video deliveries of our instructor-led courses, and facilitate our group work and networking activities in ***SE**works1*. This confluence of requirements and a potential solution suggested to us that we deliver the e-Learning courses from this platform also.

We chose Section 4 of CM - the Systems Engineering Technical Specialties – as the content for the e-Learning developer focus. We have begun this development process. We found subject matter experts (SMEs) on our technical staff with whom our e-Learning developer could work. The e-Learning developer worked with the SMEs (usually one or two SMEs per course) to develop a high-level design and then followed that with the detailed design of each lesson within the course. Course objectives defined at the beginning of each module were used as the foci of test questions that were built for and delivered at the end of each lesson. While the SMEs know their content, and in some cases, teach detailed instructor-led courses for the MITRE Institute, there were situations where a "reality consultant" from the MITRE Institute and/or the SMEs staff needed to be brought into the process to determine if a topic really needed to be included, or if there might be a work around to some design impasse. The first two courses developed were *Human Computer Engineering* and *Cost-Benefit Analysis.*

Section 4 of the CM was written a little different than the other sections of the CM. SE can and does interface with dozens of technical specialties. We chose only eight for our competency model. The systems engineers need to understand some of the important technology considerations of these

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specialties, but there is no way they can be the master of all of these disciplines. As such, this part of the CM defined behaviors that were appropriate for the general systems engineers. The systems engineers have to know important aspects of the specialty, but more importantly, they have to know how to integrate the technical knowledge of the specialist into their project when the specialty work is complete. For example, when a specialist is brought in to help in some design aspect of a project or they are brought into conduct some special study or build a model, the general systems engineer needs to know how to orient the specialist to the project, including the history, the context, the environment, and the requirements. The systems engineer helps the technical specialist do a good job. The specialist knows how to build the model or conduct the specialty study, but the systems engineer helps them make it relevant for the particular project. The system engineer might help set parameters or limits on sensitivity analyses. Once specialists have completed their study or model, the systems engineer helps them integrate the specialty study results back onto the project and helps bring the results forward as part of the project's information and history. Our e-Learning courses will make our systems engineers cognizant of the technology in general, and aware of how those considerations need to be integrated with the main project.

F. Competency Model Assessment for Students & Managers

The next two sections of the paper on the CM assessment for students and managers and the On-the-Job project are closely aligned. The high level design of the ***SE****works* program included both defined curriculum sections and customized curriculum sections. The specific technical courses described earlier were part of the defined curriculum. The technical content of the e-Learning courses was defined, but the students only need to complete two to three of the eight e-Learning courses, so they can customize their programs in the e-Learning area. The largest area of students' customizations is on their on-the-job projects. We wanted them to take some of the learning back to their projects to increase the retention and usefulness.

To help them pick an on-the-job project with their manager, we set up an assessment and gap analysis process that would lead them to engaging and fruitful projects. We accomplished this through a student and manager combined assessment approach. Both the students and the managers were asked similar questions on an assessment in relation to our competency model, as follows:

1 Student

   a. Self-assess how proficient you feel you are with respect to the 36 competencies – No Proficiency (have never been exposed to this competency), Foundational, Intermediate, or Expert?

   b. What is your target proficiency, indicate how proficient you feel you need to be in this competency, taking into account your role and project work for the next one to two years?

2. Manager

   a. Indicate the proficiency level of your employee as it relates to each competency?

   b. Indicate how proficient you feel your employee needs to be in each competency, taking into account the employee's role and project work for the next one to two years?

The students and the managers completed these surveys (approximately 45-60 minutes apiece). Subsequently the student-manager pair examined a gap analysis report we developed for them, which compared the student and the manager's survey data. The report flagged competences where the student's existing and target proficiencies disagreed by one or more levels. The report flagged the same information for the manager. The report also displayed this information for both of them in a comparative manner, so they could see areas where they agreed and disagreed. The report highlighted competencies that might be important to work on – for example – those competencies that will be important on their job over the next one to two years, and at the same time, those competencies where the manager and/or the student staff member felt they are not at target levels proficiencies for these competencies.

G. On-the-Job Customized Learning Project

The next stage was for the manager and student to have a discussion revolving around the gap analysis report. This discussion allows the student to determine which competencies to focus on and then to configure an on-the-job project with the manager's assistance and concurrence. The idea of the on-the-job project is not to add much extra work for the students – they are already busy with their work programs – but to have them focus on some aspect of their project from a learning perspective. The project would require them to research the topic through our T&D resource database (described later), to seek out extra information around the company, and to talk to other MITRE staff members (develop their internal network). While the *learning* project would require some extra work, it should have been related to a task on which the students were already working, where the extra effort would hopefully help them deliver a better product.

We expect that this part of the overall ***SE****works* curriculum to be narrowly scoped on their project work, and we work to help the students keep this focus narrow. In this on-the-job project, we ask them to focus on competencies that have a high work priority over the next one to two years and those in which their target proficiencies are below the desired level. To keep the scope narrowly focused, we ask them to choose one or two technical competencies and one non-technical competency. The non-technical competency selection is a requirement, so that we can maintain a program level focus on both non-technical and technical development.

The students' managers will be asked to provide an assessment of the students' progress after the program has completed – probably three to six months after the program has completed. They will be asked whether the focus on the on-the-job project changed the behaviors of their staff member on the job. The MITRE Institute has a target metric of showing 80% improvement, as measured by their managers, on the

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competencies that the students focused on for their on-the-job projects.

H. Website and Training and Development Resources

We decided to develop a website for a variety of reasons, such as a central location for program descriptions, schedules, and nomination processes. We also wanted the website to be a long term history of the program, so it would include the students, mentors, instructors, alumni, and MITRE Institute points of contact. In addition, as part of our change management plan, we developed a communications plan that used the website as a focal point, with our advertisements continually sending our staff back to the website.

The most interesting part of the website was a co-indexed approach to presenting our competency model and T&D resources for each competency at each proficiency level. The competency model was implemented at multiple levels with descriptions of CM sections, competencies, key actions, and behaviors. While in any specific competency, the user can link to a set of training and development resources that are appropriate for that competency and that proficiency level within the competency. The T&D resources are broken into resource groups – instructor-led courses, e-Learning courses, books, papers/articles, and websites.

We collected resources throughout the MITRE Institute, across MITRE's websites and electronic libraries, and throughout our e-Learning vendor's course and book libraries. We loaded 600-700 resources into the database. Subsequently, to see if we chose good resources, we found two experts for each competency to review them. We asked the experts to tell us whether the resources were good ones to keep, whether we had suggested the correct proficiency level, and whether they had other good resources to include that were not listed from our analysis.

The CM and the T&D database will be used by the students in configuring their projects and in finding resources to complete their on the job projects.

I. Group Work and Networking

Group work and networking for the students in separate group sessions, during classes, and through other means helps the students in self-reflection (e.g., What have I learned and what do I need to learn?), it helps them internalize their learning (e.g., through class work reinforcement or discussions), and it helps them build a personal network (e.g., to find additional resources when they need a colleague with whom they can exchange ideas with or obtain feedback).

A number of group work and networking approaches were considered in the design of this large program. Each has positive and negative considerations and each has different costs. We considered a variety of approaches, for example, self-reflection through a journaling process. We considered pair wise grouping of students in various combinations, for example, a buddy system, a rotational buddy system, the student with a designated mentor, and the student with his/her manager as a mentor. Finally, we considered a variety of full group approaches, such as an electronic forum (e.g., a social networking community), live and/or remote groups (e.g., through video teleconferencing tools and or network enabled collaboration tools), self-monitoring groups, mentored groups, and coached groups.

In the first level, ***SE****works1* program, we chose a virtual, mentored group approach. Class cohorts of 25-26 students were sub-divided into three sub-cohorts of eight to nine students each. Each group has a facilitator from the MITRE Institute and a SE mentor from one of our corporate centers. The 15 sub-cohorts groups meet every two weeks for one hour for about nine months. A meeting collaboration tool is used. All the students' pictures are on screen in the tool, so they have a visualization of who is speaking. They have audio support through headphone sets we provided so that they can meet in the group sessions while they are in an office with a roommate, and not disturb the roommate. They can share files, make presentations and have discussions in the virtual meeting environment.

We requested SE mentors through senior management with the following systems engineering characteristics:

- One to two levels higher on the technical staff ladder than our students
- Recognized for their systems engineering talents
- 5-10+ years of MITRE experience
- Good communications skills
- Eagerness to share their knowledge

The first level ***SE****works1* has 19 planned sessions. The sessions are being used for pre-class work (e.g., read an article or a textbook chapter and be ready for a discussion), post class work (e.g., checking to see if the students need content clarification or if they need more resources), additional related content (e.g., adding related content that we did not have time to include in the curriculum – soft skill case studies and on-the-job examples), and project work. A good portion of the group work sessions are focused toward the students' on-the-job project work – understanding the student-manager assessment, using the gap analysis reports, configuring a project to work on, reporting on project milestones, and reporting out on final project results. The group work is also intended to build their personal network and get the students used to asking for help from others and providing help and feedback to others.

J. Staff-Manager Commitment through the Performance and Development Process and an Individual Development Plan

An important part of the development process in a corporate training program is making a student's manager aware of the various aspects of his/her staff member's development and making him/her part of this development. Part of this awareness comes through the nomination process when we ask the managers for nominations. At that time, we recommend the type of students we are looking for and this allows the managers to think about their staff from the perspective of the staff members' needs and whether this program would be a good match for them. We also involve them in the assessment and the on-the-job project activities. The students and their managers each complete an assessment on the student and then they have a discussion concerning the results – partly to come to agreement on where student's are in

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their development, but also, partly to define those competencies and a project to work on that will both help the students and their projects. One of the final avenues to solidify this partnership is for the students to complete an Individual Development Plan (IDP). IDPs are part of MITRE HR's annual Performance and Development process. Since the IDP is part of the development process, we decided to use this existing vehicle to help solidify the development process between students and managers.

The performance and development plan at MITRE defines the development goal & then has three components associated with it – a listing of the tasks and/or actions to be completed to reach the development goal, resources needed for the project or a measurement of completion of each activity, and a target date for completion of the task. Fig.8 depicts a mock up of this approach for our first year of ***SE**works1* students. The instructor-led classes, the e-Learning classes, the group work, and the project work are shown in Fig. 8. The section outlined with a red box delineates the project activities.

Development Goal: **SEworks1 – Learn & Apply SE Lifecycle Activities and Effectively Communicate and Work in Teams**		
Tasks/Actions	Outcomes/Measures or Resources	Schedule or Target Dates
Technical Courses 1) SEworks1 - Overview of SE @ MITRE 2) SEworks1 - SE Life Cycle Pre-Dev. Phase 4) SEworks1 – SE Life Cycle Dev. Phase 5) SEworks1 – SE Life Cycle Post Dev. Phase	Attendance 100% (or by Remote Verification – class #1 and #3 allowed)	Dates 1) November 2009 2) December 2009 4) March-April 2010 5) June 2010
Non-Technical, Soft Skills Courses 3) SEworks1 – Successful Teams & Results 6) SEworks1 - Effective Comm. & Adaptability	Attendance 100%	Dates 2) February 2010 6) June 2010
e-Learn Courses 1) Human Computer Engineering 2) Cost-Benefit Analysis	Learning Gateway Completion Records	Dates 1) Mar-Apr. 2010 2) June 2010
Group Work & Networking	Pre- & Post Class & Project Work	Bi-weekly – 8 Months
Project: Chose 2-3 Competencies (1-2 technical & one non-technical)	Student & Manager Take Survey; Use Gap Analysis Reports	Jan. 2010
Project Description Written & Sent to MITRE Institute	Project Description Completed, Including Objectives & Milestones	Jan. 2010
Project Milestone Update	Discuss with Facilitator, Mentor, & Group During Group Meetings	February– May 2010
Project Completion	1) Student presents final project to Manager and Class Group 2) Manager evaluates performance & behavioral changes	June 2010 Late 2010 or Early 2011

Figure 8. Example Student Individual Development Plan (IDP)

K. Optional Certification Program

While we were developing this program, we examined certification possibilities, even including a self-certification option. The costs to develop and maintain a self-certification testing program were prohibitive. Subsequently, we examined external certification options. The only program that met our needs was the International Council on Systems Engineering (INCOSE), which has several different certification options.

We decided to make the certification program optional to the ***SE**works* participants, and to make it part of our semester catalog programs for several reasons. We expect that certification might only be required by some of our employees and not all the participants of the ***SE**works* program. Students need the content from both ***SE**works1* and ***SE**works2* to have a better educational background to prepare for the test, and they may be enrolled in these programs with a five or more year time separation (in most cases, we do not expect that students would attend ***SE**works1* one year and then ***SE**works2* the following year).

To increase the percentage of students who complete the certification, we decided to add several types of events into our catalog program. While not completely configured at this point, the certification option will have some form of boot camp course focused on the certification process and the INCOSE handbook, and probably some form of mentored study group, with recurring meetings leading up to the test.

L. Graduation and Closure Activities

While our first graduation has not been planned, we find that graduation activities generally are good events for nomination programs that we offer. Graduations provide closure on the program. These programs allow us to thank the students and managers for their involvement. We summarize the program evaluation data, if it is available. We can recommend follow on or continuing learning opportunities. We may have an expert or motivational speaker.

Since ***SE**works* programs will generally have 20-30% remote staff, graduation and closure will most likely involve some type of multi-auditorium and distance broadcast format to reach all the students.

M. Operational Consideratons

One of the major drivers for operational considerations of corporate programs is cost. Cost for the development and delivery of the events is extremely important and should always be balanced with the quality of the program. A major cost factor is the cost for travel and the labor cost associated with time for travel for remote participants. Travel and its associated dollar and time costs were an important consideration for our first level, ***SE**works1* program, and will probably remain important in the future design of higher level programs. In ***SE**works1*, we modified two design features to accommodate the travel factor. We had six courses planned, but we only required three trips for remote staff. We did this with a combination of remote broadcasting and logistically juxtaposing two courses. We felt that the students should come together for as many courses as possible for networking purposes, but we knew management would be concerned with travel time and travel costs. We decided that if we had to broadcast some of the courses, we chose to broadcast the technical courses, as the examples and case studies in the non-technical courses are more difficult to work on remotely than those in the technical courses. With that in mind, we decided to broadcast two courses. We had one other opportunity to decrease the number of travel trips for training. The last two courses in ***SE**works1* were a one-day and a two-day course. By logistically juxtaposing these two courses, a one-day course, immediately followed by a two-day course, the remote students could travel once, but attend two courses. As such, the design had six courses, but due to broadcasting (two courses) and juxtaposing the last two courses, the ***SE**works1* program only required three trips for our remote students.

We chose a desktop broadcasting option that would allow us to stream to the desktop and archive the videos when we were done. The audio, video and materials were synchronized and in separate windows to increase their individual quality. We provided headphone/microphone headsets to all remote participants. This would allow them to sit in a two-person office, but not interfere with their officemate. The

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broadcasting could be accepted at remote offices, but also at home or while on travel, as long as students had an Internet connection. Our students were spread across the three U.S. continental time zones. The classes were initiated from the Eastern Time zone, so we made suggestions to western time zone students that they consider starting the broadcasted courses at home and then moving to work at the east coast lunchtime, or remaining at home for the day.

N. Naming and Branding a Training Program

Naming a program is important, and this section is included as a warning – save plenty of time for this process. We underestimated how long this process would take.

There were several purposes for naming the program, including:

- Name would become a corporate name or term that immediately should have recognition, a specified purpose, and a quality connotation.
- Branding this as a MITRE Institute product on our website, in our advertising, on our materials, and in other forms of communications.
- Logistically allows us to keep together information, files, materials, scheduling, and other course considerations as a separate set of information aside from all of our other activities.

We went through a three step process to brand the program: create the name, iconify the name, and color the icon. We specifically did these as separate activities and in this specified order. This simplifies the process, separates the decision points, and ensures that decisions on one item are not overshadowed by a different step in the process.

There were a number of considerations during the program naming process, such as:

- Quick and catchy name
- Easy to remember
- Demonstrate concept of "level" in the program name through words (e.g., first, mid, senior) or via number (1, 2, or 3), or color or some other symbol (e.g., gold, silver, platinum)
- Emphasize experience and practice aspects of the program
- Include the main level thrusts of the program in the various level names (e.g., technical, process, and enterprise thrusts)
- Consider our audience (i.e., for us – internal focus, mostly toward technical staff and managers)
- Consider the complexity of the names and their use – if too complex, some of its uses for websites, communications and materials might become difficult
- Consider if it works well with existing branding and logos we presently use within the MITRE Institute.

All of these factors were considered during the naming stage, but no name solved and/or optimized across all of these considerations. We came up with many names or name sets (i.e., three different names for the three different levels). Some name sets had different names for the different levels and other name sets had the level concept built into the name. We chose ***SE****works* for the program name and ***SE****works1*, ***SE****works2*, and ***SE****works3* for the levels within the program. We liked this name for a number of reasons, including that it was short, it was not complicated, it would be easily recognized, the main concept of the program (SE) was built into the name, the word "works" had an engineering connotation, and the program and the level names were the same, except for the appended number.

Iconifying the name required assistance from graphical artists. We wanted the name to stand out, but at the same time it had to be easily recognizable and readable in different formats – on the web, in printed communications, in email advertisements, and in materials. This part of the process took many iterations – we had to see it and we had to keep making modifications in size, font, font effects (e.g., bolding or slanting), and relationships of the letters and numbers to each other.

The final step, after agreement on the icons, was to color the icons. We considered the boldness of the colors, corporate colors, and MITRE Institute colors. Again, since the program icons would be used for a number of purposes, the color(s) had to be effective for all of these purposes. The final names, which were iconified and then colored, are shown in Fig. 9.

Figure 9. SEworks Program Icons

In summary, we underestimated the amount of time to complete this task. We thought it would take two to three weeks, while it actually took three to four months. The group size working on the naming project is important. When the group is too large, it is difficult to please everyone. A good process might be to open the group up early, just for ideas, and then close it down to a few select staff to make the critical decisions. You cannot optimize for all your considerations – it is a tradeoff – pick the important ones and realize you cannot design all possible considerations into the program name and icon.

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VI. Design of Level 1 Program – *SEworks1*

Previous sections of the paper have described the overall program design and some design aspects for ***SE****works1*. As this paper is being written, we are in the middle of our first year of program delivery of ***SE****works1*. The next two sections of the paper describe the design of ***SE****works1* at a more refined level.

A. Integration of Technical, Non-Technical, and e-Learning

In the course work area, we have integrated technical and non-technical content. Most of the content will be delivered live by instructors, or through desktop broadcasting. Content from Section 4 of the CM – SE Technical Specialties – will be delivered via e-Learning.

Fig. 10 depicts the technical courses with blue colored headers and the non-technical courses with salmon colored headers. These courses are being delivered to five cohorts of approximately 25 students each. We mix students from all MITRE Centers and from various MITRE sites, taking gender mix into consideration as well for each cohort, to develop a diverse cross-section of the company. This was a conscious part of the design as it will allow students to meet staff from many areas of the company and help them build their personnel networks.

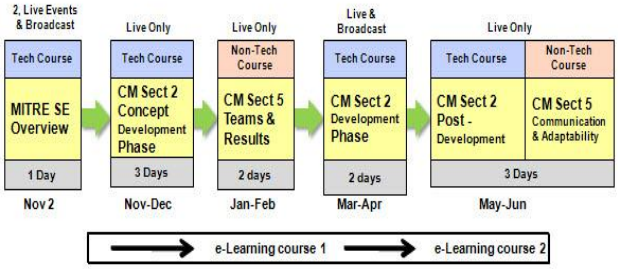

Figure 10. SEworks1 Curriculum Design

The first technical course was taught by two corporate vice presidents and five directors. We wanted to introduce the students to the program with senior management delivering the content and motivating them. Our instructors discussed several themes – some of these themes were part of our vertical content integration through multiple levels of the SEworks program, which was discussed earlier in this paper. The themes were enterprise systems engineering, quality, relationships, and organizations and resources that can help the student staff members on their jobs.

The three technical courses focus on Section 2 of the CM – SE Life Cycle, and the courses are designed to spend more time where MITRE spends more time, at the front end of the life cycle, as follows:

1. ***SE****works1* – SE Life Cycle Pre-Development Phase (3 days)
2. ***SE****works1* – SE Life Cycle Development Phase (2 days)
3. ***SE****work1s* – SE Life Cycle Post Development Phase (1 day)

MITRE went through a procurement that included professors, consultants, and education firms and chose a vendor to help develop and deliver these courses. We wrote a very detailed outline in the RFP, and we included about 70 SE artifacts that we wanted covered in the course materials. We had numerous meetings to go over the outline, we walked through the materials in detail, and we had specific meetings on examples and case studies. We wanted the examples to be relevant to the MITRE engineering population. The vendor supplied a number of good examples and we collaborated and supplied a number of examples and/or short case studies. These courses were all piloted before delivery to all the cohorts.

The non-technical courses cover the four non-technical competencies from Section 5 of the CM – Collaboration and Individual Characteristics – which we had planned to cover during the first level of this program. The two courses are defined as follows:

1. ***SE****works1* – SE Successful Teams and Results
2. ***SE****works1* – SE Effective Communications and Adaptability

In a similar manner to the technical courses, MITRE went through a procurement to obtain the needed resources. However, in this case, we used only consultants and educational firms. Again we wrote an outline for the courses and what we were looking for and we completed a standard procurement activity with oral presentations and best and final offers. Part of the vendors' oral presentations during the RFP process required them to present a 30-60 minute lesson on some aspect of the training and include an example. We worked with the chosen vendor to refine the outlines, walk through the materials, and spent extra time on the examples. The first course has four, short assessments embedded into the course dealing with teams and team experiences. These courses were also piloted before delivery to all the cohorts.

The e-Learning courses will eventually cover all the topics in Section 4 of the CM – SE Technical Specialties (Fig. 2). This part of the program will eventually allow the students to customize to a certain extent. During this year, we will only have two e-Learning courses built, so students will engage with the first two e-Learning classes, as follows:

1. Human Centered Engineering
2. Cost-Benefit Analysis

The e-Learning courses are being built to the specifications and considerations discussed earlier in the paper. We found SMEs in these areas, defined goals for the courses, detailed an outline and/or process for the courses, and built and tested each section. Each lesson has quiz questions built to test the objectives of that lesson. Upon completion of the development, we piloted the e-Learning classes to a small group of about five students, so we could make changes, and then we made the courses available to all the students. The first course on Human Centered Engineering is built and has a completion time of about three hours. The second course on Cost-Benefit Analysis is under development.

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B. Integration of Other Learning Activities

In addition to and integrated with the course work, we have group work and networking sessions and an on-the-job project. We divided the class cohorts of 25-26 students into three groups of about 8-9 students to provide a more collaborative setting for sharing and discussions. We brought in a more senior SE to help mentor each sub-cohort group. As such, the sub-cohort groups are comprised of about 8-9 students, a SE mentor from the Centers, and a facilitator from the MITRE Institute. We are using a group collaboration tool with two-way audio and full file and presentation sharing capabilities to run the meetings. Each group has its own meeting room and area in which to store materials or resources. 19 sessions have been scheduled for each of the 15 sub-cohort groups. The sessions involve pre-class work, for example reading a couple of articles, and having a discussion; post class work to ensure students understood the content; new content that is related but not included in the course work; and their on-the-job project work.

The on-the-job project activity started with the assessment described in an earlier section of this paper, where the students and their managers assessed the students' proficiencies against the competencies and also indicated which competencies were most important on their jobs in the next year or two. Gap reports helped the students and the managers to focus on a small set of competencies to work on, no more than three. At least one non-technical competency had to be included. The reports are being used and discussed as the students conceived their projects, along with their managers' assistance. Resources and other MITRE personnel that the students should engage with are discussed. The students will also be using the T&D database, which is linked to our CM to find resources for their projects. The resources are separated into open catalog and instructor-led courses, commercial e-Learning courses, books, articles and papers, and websites. As the projects progress, group sessions are dedicated to the project and the students discuss whether they are meeting their milestones and any problems they are having. In many cases, since these are less experienced technical staff, they are not as capable at providing feedback. We will be working with them to improve this skill.

We have taken considerable care to integrate technical and non-technical skills into this first level program – ***SE**works1*. We have non-technical skills in the instructor-led training (e.g., two, 2-day courses), in the group work sessions (e.g., about one-third of the meetings will be devoted to non-technical competencies) and in the on-the-job project (e.g., at least one non-technical competency is required as part of their project focus). We have integrated many learning methods and formats into the design, including instructor-led learning, e-Learning, group work, on-the-job project, and self-study through the T&D database and other resources. We are evaluating the students with pre- and post-tests on some courses, testing in the e-Learning modules, and a manager's assessment of their projects. We also ask for class-by-class evaluation by the students of the courses, looking for potential improvement areas.

VII. Design of *SEworks2* and *SEworks3*

The design for the second level program – ***SE**works2* has just begun. The design of ***SE**works3* is only conceived at the highest level of design at this point. The following two sections describe what is known about the program designs at the present time.

A. Design of *SEworks2*

The content areas for the second level program, ***SE**works2*, are again focused by the CM. The main emphasis for ***SE**works2* will be Section 3 of the CM – Systems Engineering Planning and Management (Fig. 2). The students will also be required to complete two or three (2-3) e-Learning courses from Section 4 of the CM – Systems Engineering Technical Specialties. The non-technical competencies that will be covered include the following: *Building Successful Teams, Trust, Quality Standards*, and *Persuasiveness and Influence*. Building Successful Teams was determined to be quite important so this competency is part of the ***SE**works1* and the ***SE**works2* design.

The decision on internal vs. external development and delivery of the instructor-led courses has not been made, but will probably be some combination of both approaches for the technical courses. The non-technical courses will be sourced from the outside again, due to the nature of the content versus the skill sets we can draw on from within the company. The e-Learning courses will continue to be developed with internal resources.

There will be a group work and networking activity and an on-the-job project. No decision has been made as to approach, but we might employ group instead of individual projects at this level. The group work will again be some combination of pre- and post-class activities, additional content not covered in classes, and project activity. No decision has been made on mentors or coaches or group structure. In essence, the overall structure and approach of ***SE**works2* will be similar to the first level program, but will focus on different areas of the competency model. Vertical integration topics, such as enterprise systems engineering, risk and some of the non-technical skills will be part of the design.

B. Design of *SEworks3*

The content focus areas of ***SE**works3* are known, but the design of the program is less well known and will probably differ from the first two program levels. The competency model content focus area will be Section 1 of the CM – Enterprise Perspectives (Fig. 2). The CM also has enterprise systems engineering behaviors in a number of the expert proficiency levels in other competencies, in addition to Section 1 of the CM, so these enterprise systems engineering behaviors will also be included in the design.

The design at the senior level will differ from the lower levels from a number of perspectives, but primarily driven by the fact that senior staff will not be able to set aside as much time for training as our lower and mid-level technical staff. Shorter, more focused seminars could be part of the design. Many could be designed as workshops to engage and bring the

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experience of our senior staff into the classroom to share with their colleagues. Approaches like a "technical simulation," similar to a business simulation used in leadership and management training, could be used. However, the simulation would simulate the technical and engineering decisions that need to be made on our projects, and not the business or management decisions normally seen in a leadership and management business simulation.

Some form of group work and networking activity, along with a project activity, will be part of the design. The design of these components is not known at this time.

VIII. Rollout and Nomination Process

A. Scoping Program Size – Job Family Analysis

In order to scope this program for MITRE's senior management team, we needed to estimate the maximum size of the technical staff population who might be interested in the program. We completed a job family analysis to determine the size, as the number of students would drive the cost estimate and allow senior management team to decide on the amount of funding they should allocate to the program.

MITRE has approximately 25 technical job families that are defined by Human Resources. We divided these job families into three groupings to determine the overall need. The first group included two job families, the two largest as measured by population – Multi-disciplined Systems Engineers and Information Systems Engineers. These two job families comprise about 40% of the technical staff population. The second grouping included four other job families, Information Security Engineers/Scientists, Defense/Space Systems Engineers, Domain Operational Analysts, and Software Systems Engineers. These four job families all have a job description that requires considerable systems engineering expertise, with some other skills layered on top of the base SE skills. Finally, we felt that the third grouping, the other remaining job families, might have some staff members who would be interested in this ***SE****works* program.

To estimate the overall maximum interest, we built a simple model that estimated the number of staff members who might be interested in this program by multiplying a percentage of interest times the number of staff in the job families at each staff level (Fig. 11). The output of this model allowed us to calculate a maximum population size for each level of the program. We made recommendations to senior management on how many staff would need to be trained at each level of the program, if the senior managers wanted to train the interested staff and move to a steady state in five to seven years. Availability of training funds and other corporate initiatives could affect the overall approach.

B. Three Year, Tiered Rollout Approach

Due to the size of these programs and the amount of new content and approaches that needed to be developed and implemented at a detailed level, we chose to roll the whole ***SE****works* program out over a three-year period, each year designing and rolling out a new level, while continuing to deliver the previous levels (Fig. 12). This is an aggressive schedule; time will determine whether we were able to maintain the schedule.

Job Families	Percent Coverage Factor
Main SE Job Families	
Multi-Discipline System Engineers	95%
Information System Engineers	95%
Related SE Job Families	
Information Security Engineers/Scientists	65%
Defense/Space System Engineers	65%
Domain Operational Analysts	65%
Software System Engineers	65%
Remaining Job Families (~20)	25%

Figure 11. Program Size Determined through a Job Family Analysis

SE*works* Level	Design Time Periods	Dates & Levels Delivered
1	Feb. – Oct. 2009 ***SE****works* Program Design, & ***SE****works1* Detailed Design	Oct. 2009 – June 2010 – ***SE****works1*
2	Feb. – Oct. 2010 ***SE****works2* Detailed Design	Oct. 2010 – June 2011 – ***SE****works1* Oct. 2010 – June 2011 – ***SE****works2*
3	Feb. – Oct. 2011 ***SE****works3* Detailed Design	Oct. 2011 – June 2012 – ***SE****works1* Oct. 2011 – June 2012 – ***SE****works2* Oct. 2011 – June 2012 – ***SE****works3*

Figure 12. ***SE****works* Program Rollout Over Three Years

IX. Measurement

A. General Measurement Considerations

The measurements that are built into this program use Kirkpatrick Levels 1, 2 and 3 [7], [8] on different aspects of the program. In addition, the survey and assessment data will give us a long-term understanding and benchmarking of the corporate SE capability.

B. Course Evaluations – Kirkpatrick Level 1

All the courses are evaluated by the students as they complete each course. The evaluations have 17 numerical questions, which focus on the instructor, the content, and the overall course value. Open-ended text questions allow the students to expand on their numeric assessments. Since the MITRE Institute has a long history of using this evaluation, we know what to expect in numerical values for high quality programs. Our staff members are not shy with their constructive criticisms. With their feedback, we will continually be able to improve the programs.

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C. Pre- and Post Testing for Some Courses – Kirkpatrick Level 2

Pre- and post-class tests will be used on the technical courses during the first year. No decision has been made as to whether this will be a long-term approach. The purpose of pre- and post-tests is often to use the results to examine the quality of the design of the courses. The test questions revolve around the objectives of the training. Comparison of the pre- and post-test results allows the course designers/developers to know if they have done a good job in presenting the content. The results should expose areas that could be treated in a different or improved manner. The pre-tests also "condition" the students for being ready to receive some of the concepts that will be presented in the lectures. The pre- and post-tests are of interest to some of the students from a general knowledge perspective and/or from a competitive perspective.

D. e-Learning Tests – Kirkpatrick Level 2

The e-Learning courses have been built with as much interactivity as the tools allow, with the goal of infusing interactivity into the courses to make them interesting for the students. However, there is no instructor to answer questions as they move through the content. As such, to measure and evaluate student progress, and to measure and evaluate parts of the design, quizzes have been built into each lesson of each course. The quiz questions are based on the objectives that were developed by the SMEs and the course designer for each lesson. Students need to receive a passing grade in each quiz to obtain a passing grade for the course.

It is also possible that an orthogonal look at the quiz results over time will allow us to determine whether the content or individual quiz questions need to be redesigned. For example, after 100 or 200 students have completed the course, we should be able to examine the quiz results by individual question. If quiz question 4 in lesson 5 of a specific course were completed incorrectly 70% of the time on the first attempt, then either the content is not clear or the quiz question is improperly designed.

E. Long-term Programmatic Measurement – Kirkpatrick Level 3

On a strategic level program, where the company is spending significant personnel and funding resources, we needed a long-term measurement of whether the ***SE**works* program is making a difference. One way we wanted to measure this was on the job, where it counts: Does it make a long term difference in the quality of products we are delivering to our customers? To estimate this measurement, we will engage with the managers of our student staff members. We will ask them to assess their staff members in relation to the competencies that the students chose to work on for their on-the-job project. The managers will be asked for their assessments of their students approximately three to six months after the students completed ***SE**works1* and their projects. They will be asked whether or not they saw an improvement in their student staff members' proficiencies. The managers will assess the students only in relation to the behaviors for the competencies on which they were focusing. We felt that the managers would have the best oversight of potential behavioral changes, the cornerstone of Kirkpatrick Level 3 measurements. The managers review the products that these student staff members deliver on the job, and therefore, the managers can provide the best assessment of any behavioral changes.

From a corporate perspective, the overall goal for the ***SE**works* program is to have an 80% improvement in the competencies that students focus on during their On-the-Job Project.

F. Long-Term Corporate Benchmarking with Assessment Data – Kirkpatrick Level 3

The MITRE Institute will be collecting and storing the assessment data for the various program levels over time. This data will allow us to examine and create a long-term view of the proficiency of the staff members, as viewed by themselves and their managers. Trend analysis will allow us to determine whether the program is making improvements at various staff levels on specific competencies over time.

X. CONCLUSIONS

A. Learning Organization and SE Enhancement Framework

MITRE is a learning organization. The MITRE Institute is one part of the learning activity and provides individual T&D support through the Technical Program and the Leadership and Management Program. The MITRE Institute provides group development and change management support through the Organizational Effectiveness Consulting Group.

The Technical Group has a wide and diverse catalog, which provides technical T&D courses each year in Systems Engineering, Software Engineering, Information Assurance, Communications, Networking and Sensors. Approximately nine years ago we started to modify our general catalog approach to enhance and improve SE T&D, a core competency for the company, by expanding to a three-pronged set of activities:

- Onsite MS in SE with Johns Hopkins University in two locations for staff seeking deep, degreed SE T&D (usually new cohort each year –20-22 students)
- ***SE**works* (described in this paper) – SE T&D driven by a competency model and appropriate for specific technical/career levels at MITRE (medium sized program; expected to grow to several hundred per year)
- Continuation of our previous SE catalog program; about 40% of catalog delivery in deeper SE T&D courses.(largest number of students choosing one or a small set of courses – 1,000-2,000 students/year)

This wide and deep approach to SE T&D should provide a long-term framework for continual improvement of the SE capability at the MITRE Corporation.

B. Conclusions Concerning the *SEworks* Program Deisgn

High level program design for the ***SE**works* program included development of a CM, benchmarking the company through assessments against the CM, program design, change management considerations, and program implementation. Feedback and measurement activities built into the program should improve the ***SE**works* program over time.

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The MITRE Institute's Technical Group funded a Best Practices Study with leading, high tech T&D organizations to examine the best practices for building strategic technical and/or SE T&D programs. Seven important findings were derived from the study and all were used in the design and development of the ***SE**works* program. Two findings were particularly important – large, strategic programs help to "*instill common practice*" in the company, and verbal and financial support from senior management is critical –early and often in the development.

A year and one-half effort was devoted to building the SE CM; we felt it would be the cornerstone to the program. We planned and have used the competency model for benchmarking the company, driving the curriculum development, and focusing the on-the-job projects through student-manager assessments. CM trend analysis will also give us a long-term view of the companies' relative competencies. The CM was developed using numerous focus groups, writing of four or five incrementally improved versions, competency prioritization and removal, and considerable corporate review and editing. The final CM has 27 technical and nine (9) non-technical competencies. The non-technical competencies were considered extremely important for a broad and deep view of T&D for successful SEs at MITRE. The results of benchmarking the company against the CM showed a good correlation between what the managers needed for technical competencies on the work programs and what the staff said they were capable of delivering. Although the results were somewhat suspect in the non-technical survey area, we had shortfalls on some of the non-technical competencies.

The ***SE**works* Program drivers came from our focus groups, the benchmark survey results, interaction with a cross-corporate SE team, definition through previous problem areas seen in other MITRE Institute programs, and discussions with our Corporate Officers. The drivers included providing baseline SE technical training and knowledge for various technical and/or career levels; closing the non-technical, soft skills gaps; building consistency of SE practice through our training materials; and vertically integrating topics that should be taught at multiple program levels.

The maximum program length of about 10-12 days in class, which we expected senior management to approve, provided a constraining function on the design. A vertical slice through the CM approach, where all program levels would be trained on all competencies, was determined not to be a workable solution. Under such a vertical design approach through the CM, on average students would only receive 2 hours per competency of training and that would not be enough time to provide sufficient time and exercises to meet their needs. This led us to a three-tiered program design where different sections of the CM were the focus of different program levels. Some competencies would be the focus of two program levels and a few competencies, for example, risk and enterprise systems engineering, would be the focus of all three levels.

There are two student customization areas in the program design. The first is the choice of their on-the-job project they choose to complete. The second is which e-Learning courses they choose to complete. For their on-the-job project, we ask them to focus on competencies that have a high work priority over the next one to two years and those in which their target proficiencies are below the desired level. To keep the scope narrowly focused, we ask them to choose one or two technical competencies and one non-technical competency. To guide their choice of the on-the-job project, we required that the students and managers complete an assessment of the student's proficiencies against our CM, coupled with which competencies are important on their work program over the next year or two. Gap analysis reports and templates help guide them toward project definition. While the project will require extra research of existing resources and people inside and outside of MITRE, the project is focused on a task they already have to complete on their jobs. The intention is to widen the students view and use of resources, to expand their networks in the company, and to improve the product quality delivered to our sponsors.

The second student customization is in the e-Learning area. The MITRE Institute has long been a user of vendor e-Learning products, but we had not considered our own e-Learning development in the past, as we could not justify the cost compared to the number of students who would use the end products. The ***SE**works* program changed this dynamic and we began an e-Learning development activity. After hiring a specialist, we selected a tool set, chose a delivery platform, and wrote a set of e-Learning development standards for our department. We plan to deliver Section 4 of the CM – SE Technical Specialties – through an e-Learning approach. Our approach has been to find one or two SMEs for each course topic, develop high level goals and objectives, and then continue into detail design and testing of course lessons. We are in the second course development at the time of the writing of this paper. Eventually, we will have eight e-Learning courses in the series and the students will select two or three courses to complete.

We felt that the group work and networking are important parts of the students' development in ***SE**works*. After examining a variety of pair wise and group designs, we chose a virtual, mentored group approach with a small number of students (8-9), a more senior SE mentor from the MITRE Center projects, and a MITRE Institute facilitator. We licensed a collaboration tool that would allow us freedom in scheduling our meetings, audio and video support, file and presentation support, and the capability to archive materials and meetings. The group sessions focus on pre- and post-course work, new content that amplifies existing course content (but would not fit into the instructor-led courses), and their on-the-job projects. There are three main purposes to the group work and networking activity: self-reflection, internalization of program learnings, and building of their own personal networks.

The overall ***SE**works* program design is a three-tiered program. Both technical and non-technical content and competencies will be addressed at each level. Sections of the competency model are the focus of each level. At least two levels of proficiency will be delivered in each competency at each level of the program. Two non-technical competencies were deemed important enough to be a focus in two levels of the design. Two technical competencies will be focused on in all three levels of the ***SE**works* program. Other technical

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competencies could become the focus of two levels of the program, as the second and third levels of the program design are completed. The three-tiered approach will be delivered through a corporate nomination program, with the MITRE Institute suggesting criteria for the students at each level, and MITRE managers nominating staff members to be students at each level of the program.

A special consideration in the design of this program is the inclusion of the non-technical competencies. These competencies were deemed important from the earliest stages of this project, so they were specifically included in the SE CM. At all levels of the program design, we have included non-technical development, including in the instructor-led programs, in the group work and networking activities, and in the on-the-job project. This is the first time that non-technical development has been a substantial component of the design of a major technical program in the MITRE Institute. Time and measurement will shed light on the effectiveness of the approach.

On the detailed development of technical and non-technical courses, we complete a build versus buy analysis on areas of the training and on individual courses. Factors considered are availability and quality of internal SMEs, customization of the content to MITRE's students, cost, platform skills, and the "road tested" nature of the materials. With these considerations we decided that we would develop our non-technical courses through procurement activities with external vendors and consultants. The technical courses will be developed with both internal and external resources; decisions will be made on a case-by-case basis for each course. On both external and internal developments, the MITRE Institute will be involved with defining the content, the examples, and the case studies to ensure that all the materials are relevant to the MITRE engineering population.

The ***SE****works* program will have three tiers in relation to MITRE's technical staff levels. These tiers will be rolled out over a three-year period. We sized the program by completing a corporate job family analysis of those employees (and their managers) who might potentially be interested in the various program levels. We accomplished this by estimating the maximum population sizes. Subsequently, we suggested cohort sizes for each level of the program to senior MITRE managers, with the assumption that the programs might move toward a steady state over five to seven years.

Measurement approaches built into the program include Kirkpatrick levels 1, 2 and 3 on different program levels and sections. Level 1 assessments will allow us to improve individual technical and non-technical courses at specific program levels. Level 2 assessments will be used in e-Learning courses, when no instructor is present. Level 2 assessments will be judiciously used for pre- and post-course testing to examine our course designs and also for students to see their progress. Finally, behavioral change (Kirkpatrick level 3) will be examined to see whether the students improved in the competency behaviors they focused on for their on-the-job projects. The ***SE****works* program goal is an 80% improvement of the competency behaviors they are focusing on for their projects. Long-term trend analyses will also look for corporate staff improvements by technical staff level for each competency.

ACKNOWLEDGMENT *(HEADING 5)*

While I am the project leader for this effort and I am responsible for the information presented herein, whether correctly or incorrectly stated, a number of my colleagues have helped to challenge and shape my thinking and helped to modify the designs. I would like to thank Dr. Lisa Bender and Dr. Louis Metzger, both MITRE Vice Presidents, for providing strategic management support, guidance, and funding during the development of this program. I would like to thank Stacey Zlotnick, Director of the MITRE Institute, for continually challenging my thinking at many decision points, and for her editing support on the final stages of the competency model. On my staff, I would especially like to thank Dr. Janice Ziarko, who worked with me and provided input, ideas, and support at every stage of this program development. Her assistance in the development of the competency model and in program design areas was extremely helpful. As we moved into the final design stages, Kisha Salters, James Dingwall, and Al Florence joined our staff and provided many new ideas and approaches for consideration, and Kara Ryan brought professional e-Learning development into our group. Jim Faulk and Bo Kaufmann provided surveying and logistical support to this program while they were busy on our other programs. I would like to thank our support staff, Kim O'Brien and Joann Baltimore, who continually help to deliver our programs. Finally, I would like to thank the 100-200 MITRE staff, including the whole Corporate Goal 4 Team on Practicing Systems Engineering, who provided us with input, review, and constant guidance as we moved through a very systematic approach of enhancing our internal SE T&D program.

BIOGRAPHY

Dr. Philip N. Trudeau is the Manager of Technical Programs at the MITRE Institute, the corporate education, training, and development group in Human Resources at The MITRE Corporation. Between 1978-1988, Dr. Trudeau worked with four technical divisions at MITRE – environment, energy, advanced transportation, and the Army – as a Technical Staff, a Group Leader, and then a Project Leader. He worked on environment and energy projects for EPA/DOE, hardware and software systems development projects for DOI and NOAA, and communications and information flow projects for the Army. In 1988, he assumed a role as a lead technical development specialist at the MITRE Institute, and concentrated on building curricula in software engineering, advanced operating systems, and advanced tools. Presently, he manages the Technical Program at the MITRE Institute, which includes systems, software and domain engineering; advanced tools; and business applications. Dr. Trudeau holds a BA in chemistry from Boston University, an MS and Ph.D. in biology and

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systems ecology from University of Massachusetts/Amherst, and an MS in computer science from Virginia Polytechnic Institute (VPI) and State University. Dr. Trudeau has been a member of the IEEE since 1988 in both the Computer Society and the Education Society. He is also a member of the International Council on Systems Engineering (INCOSE) and the American Society of Training and Development (ASTD).

REFERENCES

[1] Meeting Ever Increasing Training Delivery Needs (earlier IEEE article) .

[2] The Process of Enhancing a Systems Engineering Training and Development Program (earlier IEEE article)

[3] Personal Communication. Dr. Kenneth Kerber, Consultant, Chart Resource Group, Newton, MA. In addition to consulting, Dr. Kerber teaches at Bentley and Simmons Colleges in the Boston area.

[4] Anntoinette Lucia and Richard Lepsinger, The Art and Science of Competency Models – Pinpointing Critical Success Factors in Organizations, New York: John Wiley & Sons, 1999.

[5] Scott B. Parry, "The Quest for Competencies," Training 33:48-56, July 1996.

[6] Personal Communication. Ms. Stacey Zlotnick, Director of the MITRE Institute. Previous to her present job as Director of the MITRE Institute, Ms. Zlotnick held a number of internal consultant positions in commercial companies.

[7] Biech, Elaine (Ed.), ASTD Handbook for Workplace Learning Professionals. Alexandria, VA: ASTD, 2008.

[8] Kirkpatrick, Donald L. and James D. Kirkpatrick, Evaluating Training Programs: The Four Levels, 3rd Edition. San Francisco, CA: Berrett-Koehler, 2006.

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