Design Considerations in Building a Corporate Systems Engineering Training and Development Program

(NDIA 13th Systems Engineering Conference)

Philip Trudeau, Ph.D.
MITRE Institute
Human Resources
MITRE Corporation
October 25-28, 2010
trudeaup@mitre.org

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Stay ahead of the curve

MITRE Human Resources

Philip Trudeau, Ph.D.

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 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).

Presentation Purpose

Describe the design approach for enhancing MITRE Corporation's Systems Engineering (SE) training & development program

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Outline

- SE T&D General Approach – All Programs
- Design Approach and Best Practices
- Building & Use of Competency Model & Program Drivers
- Design of Three-Tiered Program - *SEworks*
- Design & Integration of Course, Group & Project Work
- SEworks - Level 1 & Level 2 Designs
- Integration – Skill Type, Training Approach, & OTJ

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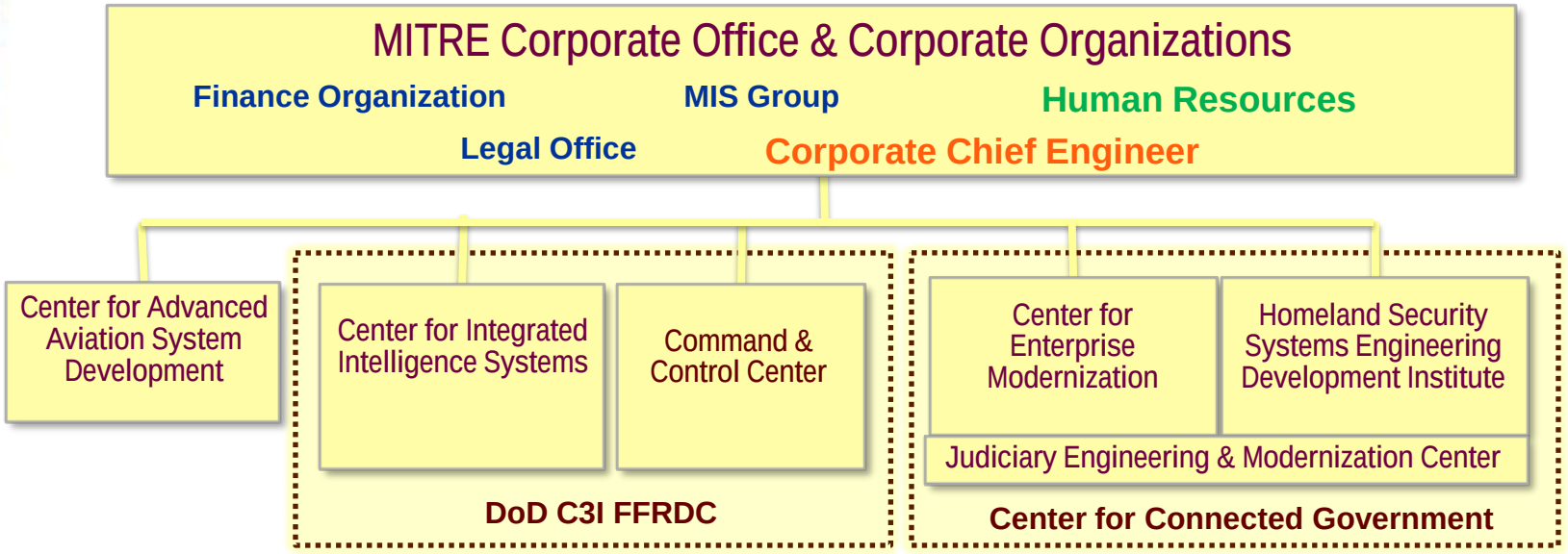

MITRE Institute in Human Resources Organization
MITRE Institute aligned with Chief Engineers Office on this project

- **MITRE Encompasses Five FFRDCs ~ 7,000 Employees**
  - SE – Core Competency
    - Two large SE Job Families (Multi-Disc SEs; Info SEs)
    - Four related SE Job Families

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SE Training & Development at MITRE Three-Pronged Approach

Program Name	Program Size (Students/ Year)	Hours/Yr or Hours/ Program	Educational Focus
JHU MS in SE	20	400	• Graduate Ed., All SE Topics • Well rounded & deep treatment • Considerable out of class work
SEworks	200-300	100	• Focus on content needed at different career levels • Less theoretical; more practical • Not as deep as MS in SE; fewer hours & less homework
SE Courses in MITRE Institute Catalogs	1,200	14	• Deepest training • Diverse topics – methods, tools, techniques, and processes • Only what students need when they need it

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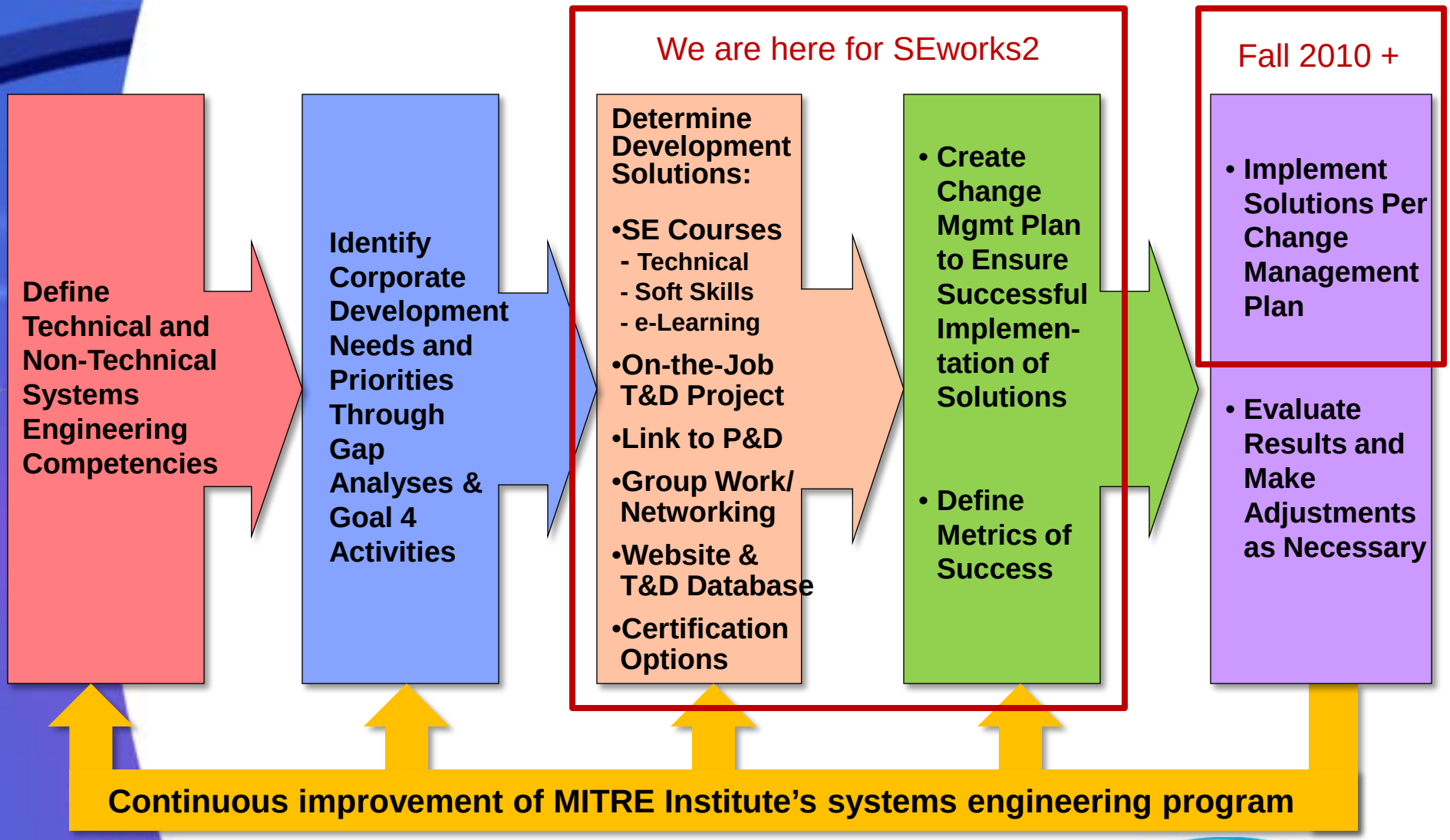
Methodology for the SEworks Program



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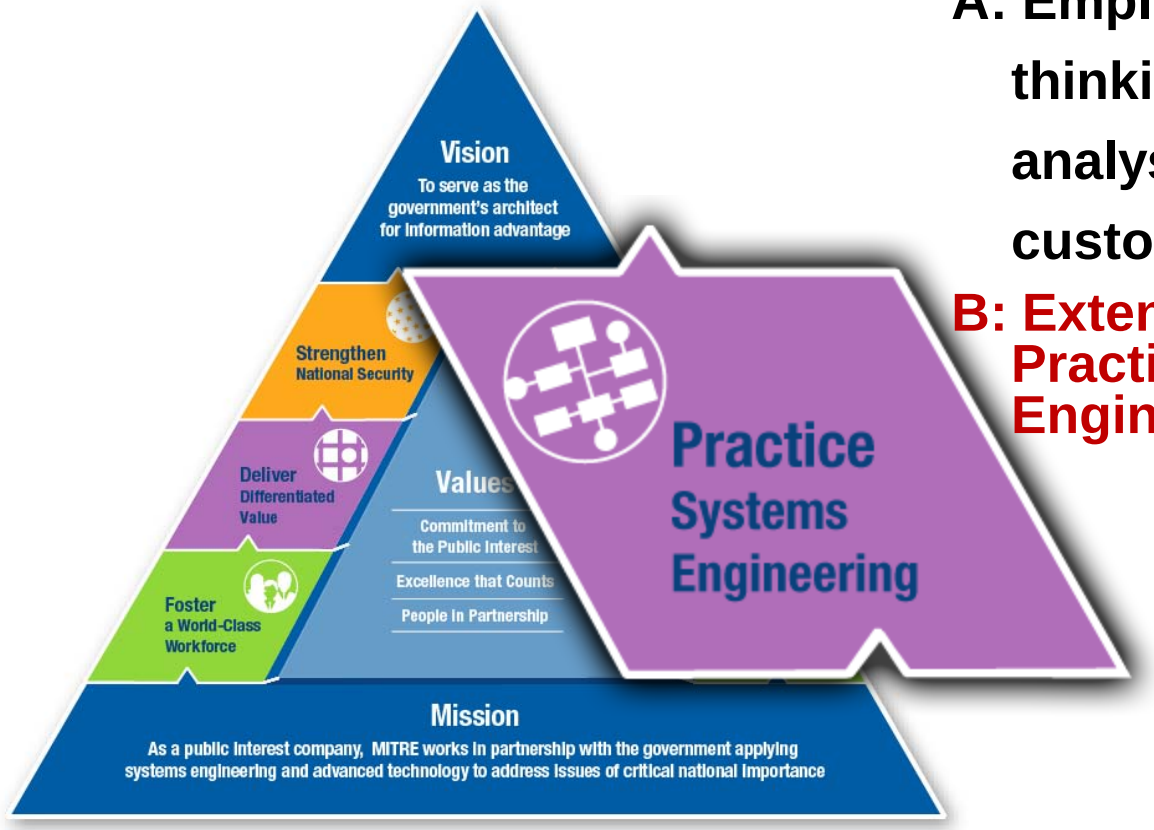
SE & MITRE's Strategic Framework



Goal 4 Objectives

A: Employ systems thinking & data driven analysis to achieve our customers' outcomes

B: Extend the State-of-the-Practice of Systems Engineering

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Best Practices & Technical Training Benchmarking Studies

- **Use competency models to drive training & development**
- **Measurement of success**
- **Perform needs analyses**
- **Teach geographically dispersed audiences**
- **Use multiple delivery methods to address learning styles**
- **"*Instilling common practices*" is one of the best outcomes from T&D – it helps to develop corporate culture**
- **Important T&D programs need both verbal and financial support from senior management**

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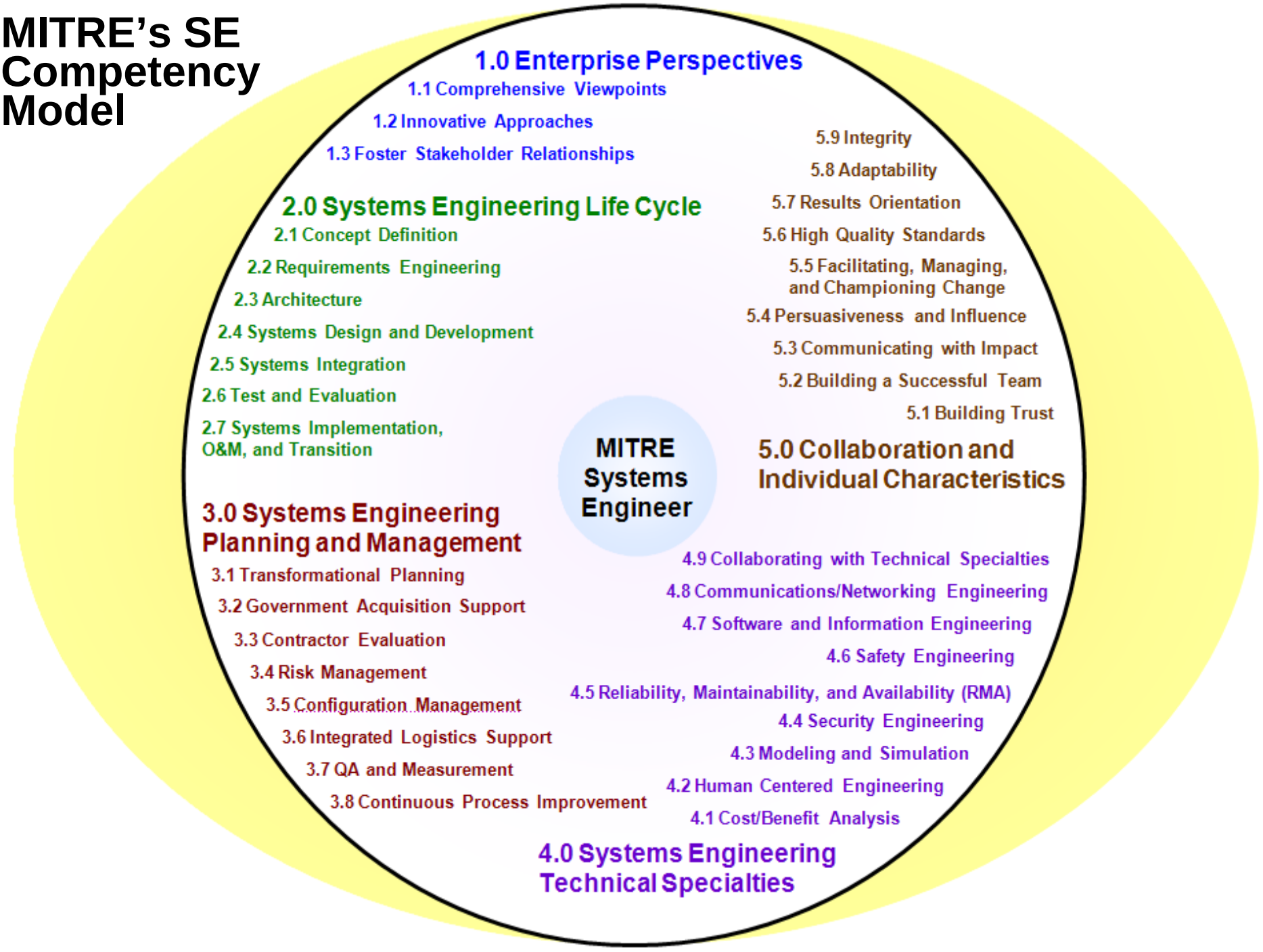
Building SE Competency Model

- **Hired a consultant to help**
- **Data gathering**
  - Spiral approach – 10, day-long focus groups
    - All MITRE Centers at two staff grouping levels
    - Re-wrote & re-published model 4-5 times
- **Information prioritization & analysis**
  - All focus group members prioritized all competencies 1 to n
    - Varied from 25 to 55 competencies; settled on 36
  - Soft skills became more important as increased staff level
- **Information organization/compression/editing**
  - Removing intra-competency redundancy hard
  - Removing inter-competency redundancy very hard
  - 4+ months for final editing
- **Presently – collecting ESE data for improvements**

MITRE's SE Competency Model



Uses of SE Competency Model

- Corporate baseline assessments
- Curriculum development
- Assessment of incoming students to customize their program with an on-the-job project
- Additional data collection now on – ESE Update
- May be used for other HR functions – promotions & hiring

SE Program Drivers

- **What our data told us:**
  - Close the soft skills gaps
- **What corporate agenda told us:**
  - Corporate Goal: *"Provide a workforce that can skillfully apply MITRE-Government brand of systems engineering"*
  - Need to develop baseline knowledge and capability in SE at various career levels.
- **Other widespread feedback or considerations**
  - Core elements need to be included at all staff levels
  - Build MITRE consistency of SE practice through the training materials, but demonstrate flexibility in examples to allow tailoring on the job

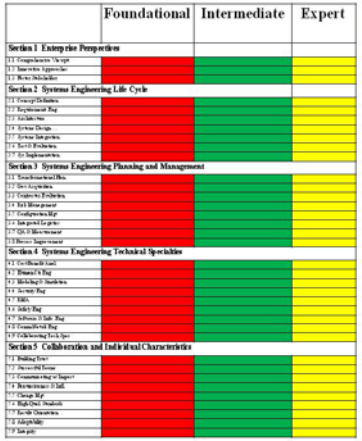
Program Constraints

- Cost of program development & delivery
- Number of hours staff in training and away from project work
- Cost of travel for remote site staff

Three-Tiered, High Level Design Approach

Simplest Model

Each level cover all competencies;
Red = Level 1; Green = Level 2; Yellow = Level 3

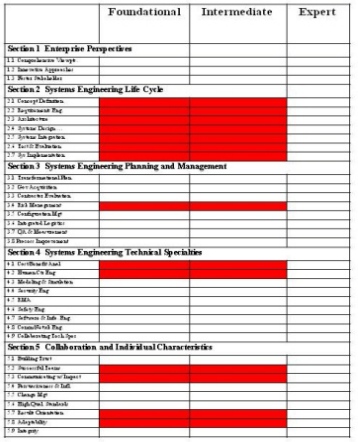


Problem with Approach

Only 2 hours coverage per competency, given total hours constraint

By Career Level

Okay, but needed to cover multiple competency levels



Final Approach

1. **Cover competencies appropriate for different career levels**
2. **Cover multiple proficiency levels**
3. **Repeat some soft skills on multiple levels also**

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SEworks - Systems Engineering at MITRE

	Technical Competencies	Non-Technical Competencies	e-Learning & Vertical Integration
SEworks 1 **AC 2/3**	**Apply Rigor to SE Lifecycle Activities & Effectively Communicate & Collaborate**		
	Competency Model–Section 2 Concept, Requirements, Architecture, Design & Development, Integration, Test & Evaluation, and System Implementation	**Competency Model–Section 5** Teams, Communicating with Impact, Adaptability, and Results Orientation	**Competency Model–Section 4** HCE, CBA, M&S, and Security Eng. **Vertical Integration** ESE, Risk
SEworks 2 **AC 4/5**	**Lead and Manage SE Activities & Build Successful Relationships with Stakeholders**		
	Competency Model–Section 3 Transformational Planning, Acquisition Support, Contractor Evaluation, Risk, Configuration Management, Logistics, QA, and Process Improvement	**Competency Model–Section 5** Teams, Trust, Quality Standards, and Persuasiveness & Influence	**Competency Model–Section 4** MA, SwEng., Comm\Netwking & Safety **Vertical Integration** ESE, Risk
SEworks 3 **AC 6/7**	**Leverage SE in the Enterprise Environment & Influence Key Stakeholders to Transform the Enterprise**		
	Competency Model–Section 1 Comprehensive Viewpoints, Innovative Approaches, and Foster Stakeholder Relationships	**Competency Model–Section 5** Persuasiveness & Influence and Change Management	**Vertical Integration** Problems & Case Studies Set in Context of Life Cycle and Lead & Manage Enterprise Simulation

All Program Levels Will Include These Components

- Programs will last approximately 8-10 months & Video broadcast
- On-the-Job Project (2-3 competencies)
- Group Work & Networking with Other Center & Site Staff
- Training & Development Database Resources
- INCOSE Certification Option

Technical Course Design

- **MITRE staff internal development approach**

Advantages – Internal Instructors	Disadvantages – Internal Instructors
1. Easier to customize content	1. Difficult to get SMEs when desired
2. Development cost for quality products ~ the same as external	2. Platform skills not as good as commercial trainers
3. Delivery costs less expensive in long run	3. Internal SMEs may back out due to internal work/project commitments
	4. Vendor material – road tested, maybe 50 times

- **External vendor/consultant approach – flip table**
- ***Solution:*** **deal with the technical courses on a case by case approach – try to obtain best content & delivery capability within constraints noted above**

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Non-Technical Course Design

- **Theoretically, same as make vs. buy decision as for Technical courses, with one big difference: lack of SMEs with road tested materials**
- ***Solution:*** **work with external vendors/consultants**

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e-Learning Course Design

- e-Learning make vs. buy
- Hired new staff member
- First task – tool choice
- Developed e-Learning standards for department
- Delivery platform
- ***Solution:*** **developing eight (8) e-Learning courses for Section 4 of Competency Model – Tech Specialties**

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Group Work & Networking Design

- **Self-reflection**
- **Internalize learning**
- **Build personal networks in corporation**

Possible Group Work and Networking Approaches	
Self-Reflection (ex., journaling)	
With Another Individual • Buddy System • Rotation Buddy System • With student's manager • With student's mentor	With Group • Electronic Forum (e.g., Social Networking Community) • Live and/or Remote Groups (VTC/MeetingPlace) • Self-monitoring group • Mentored Group • Coached Group

Group Work & Networking Design

- **Solution chosen – *SEworks1***
  - **Virtual, mentored groups**
  - **Build personal networks**
  - **Technology, facilitators and mentors available**
  - **Audio, content, chat & pictures**
  - **Requested mentors through senior management**
- **Sessions every other week at lunch – 1 hr.**
  - **Technical & Non-technical topics**
  - **Content not delivered in class, but related delivered**
  - **Project work**
  - **Build personal networks**

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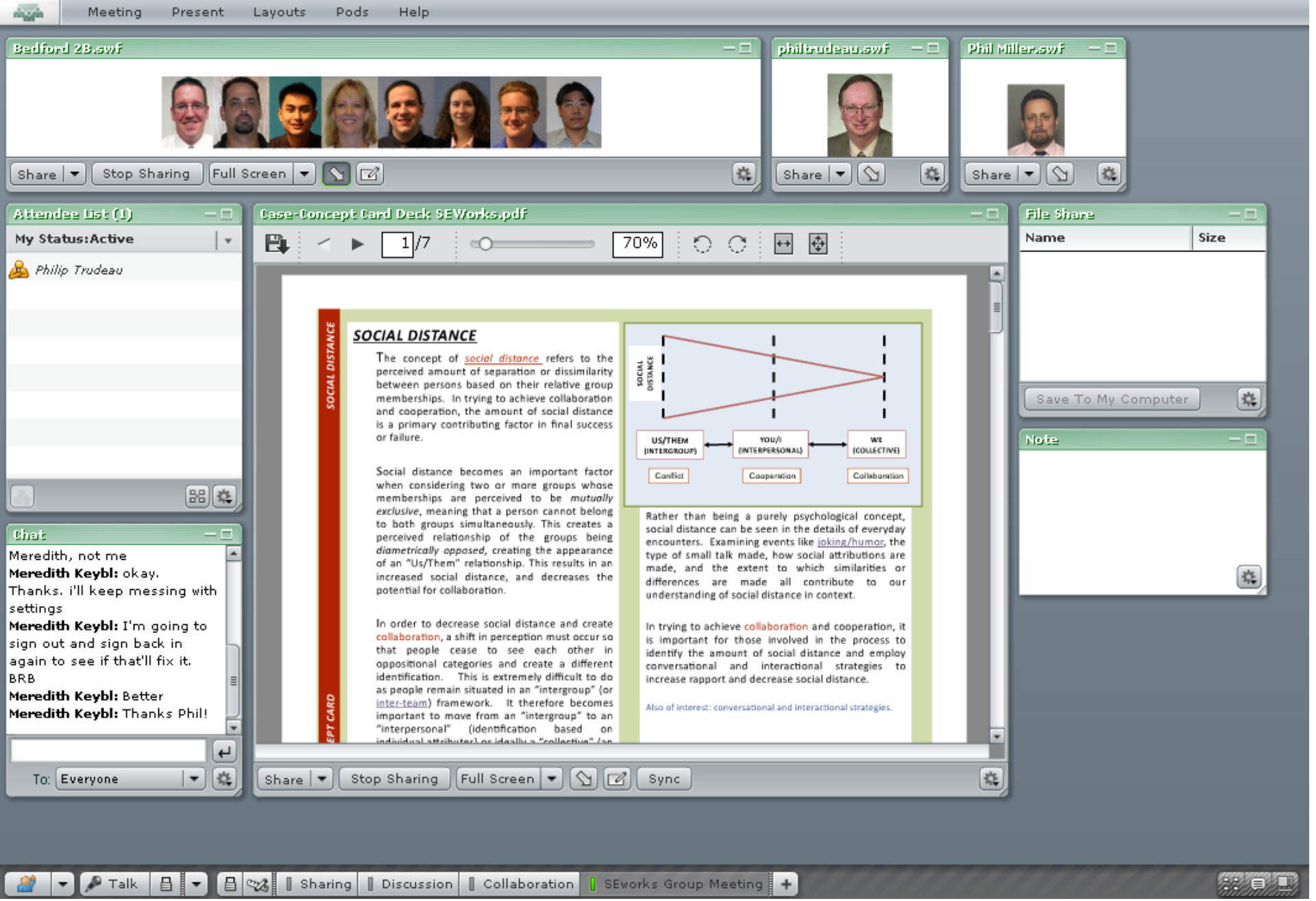

*SE*works1 – Virtual Mentored Meetings

SE Competency Model Assessment

- **Purpose – take learning out on the job**
  - Increase usefulness and retention
  - Allows students/managers to customize their T&D
- **Student & manager complete assessment against CM**
  - Self-assess: how proficient am I compared to competencies
  - Target proficiency: where do I need to be for my job
- **Assessment system then develops a gap analysis**
  - Focus on high priority & low capability competencies

On-the-Job Project

- **Purpose – practice what they are learning**
  - Increase usefulness and retention
  - Allows students/managers to customize their T&D
- **Try to avoid adding to their workload**
  - Five-month projects
  - Template to help them focus
    - Objectives, description, milestones and confidence of milestone completion
- **Use T&D database to find resources**
  - Screen shot next page

Training & Development Database

Training Resources

Temporary: Training Resources currently under review by MITRE Staff and may change.

- \+ 1.0 Enterprise Perspectives
- − 2.0 Systems Engineering Life Cycle
  - 2.1 Concept Definition
  - 2.2 Requirements Engineering
  - 2.3 Architecture
  - 2.4 Systems Design and Development
  - 2.5 Systems Integration
  - 2.6 Test and Evaluation
  - 2.7 Systems Implementation, Operations and Maintenance, and Transition
- \+ 3.0 Systems Engineering Planning and Mangement
- \+ 4.0 Systems Engineering Technical Specialities
- \+ 5.0 Collaboration and Individual Characteristics

2.2 Requirements Engineering

Systems engineers integrate business/mission and operational needs and transform these needs into system requirements. They analyze, manage, and trace systems requirements, facilitate stakeholder agreement about changes to and management of the systems requirements, and recommend critical performance measures and safety features.

View Key Actions & Behaviors

By Category | By Level

Click on the arrow to expand/collapse

Instructor-Led Courses

E-Learning Courses

Eliciting Requirements

Level(s): Foundational; Intermediate **Type:** CBT

Requirements elicitation is the gathering or – "drawing out" – of system requirements. This is done by communicating with users, customers, and any other stakeholders in the development of a system. It is a pivotal knowledge area of business analysis and, as such, the business analyst must be able to elicit requirements...More

Source: SkillSoft
Duration: 3:30:00 **Date:** 5/15/2007

Books

Papers and Articles

Websites

Program Measurement & Assessment

- **Two types of measurements & assessments**
  - Kirkpatrick Levels 1, 2, and 3
  - Assessment against competency model (students & group)
- **Course evaluations – *Kirkpatrick Level 1 (L1)***
  - **17 numerical & 5 open-ended questions**
- **Programmatic evaluation for non-course activities *(L1)***
- **Pre- & Post-Tests, Two Tech Crses – *Kirkpatrick L2***
  - **Examine course content design & "get ready to learn"**
- **Long-term behavioral assessments – *Kirkpatrick L3***
  - **Behavior change – manager assess student after project**
    - **Looking for 80% improvement**
  - **Corporate benchmarking over time – long term trends**

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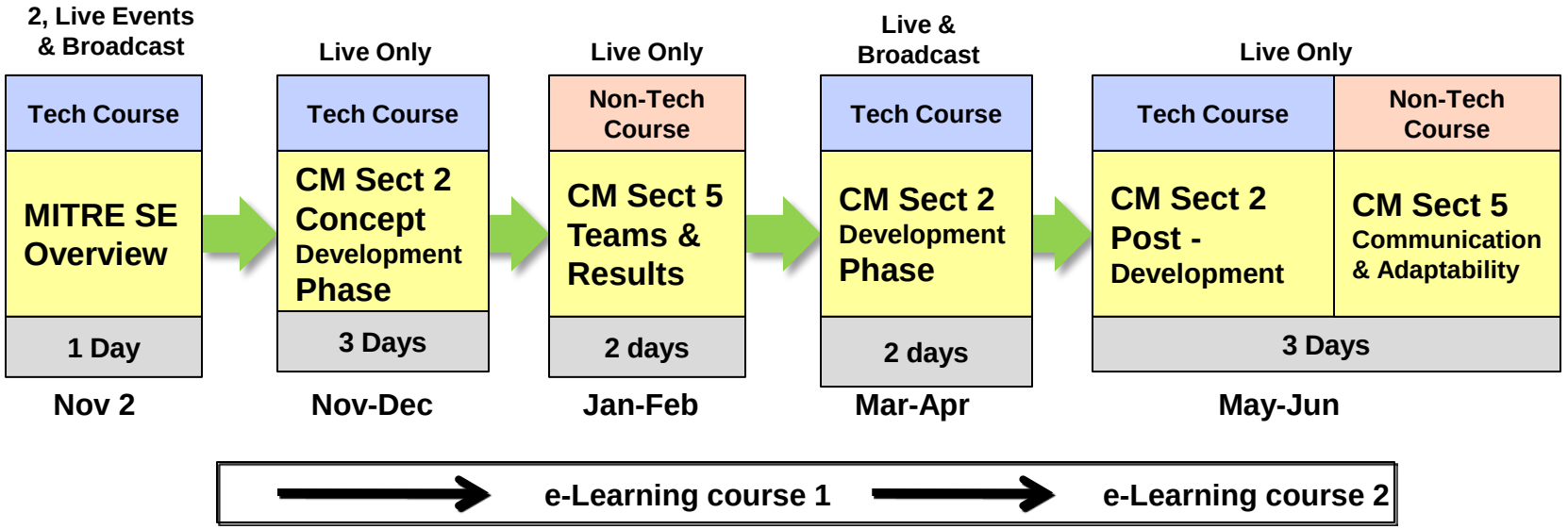
SEworks Program



Technical Courses
TSE300 Overview of SE at MITRE
TSE301 SE Life Cycle Pre-Development Phase
TSE302 SE Life Cycle Development Phase
TSE303 SE Life Cycle Post-Development Phase

Non-Technical Courses
DSE300 SE Successful Teams and Results
DSE301 SE Effective Communications and Adaptability

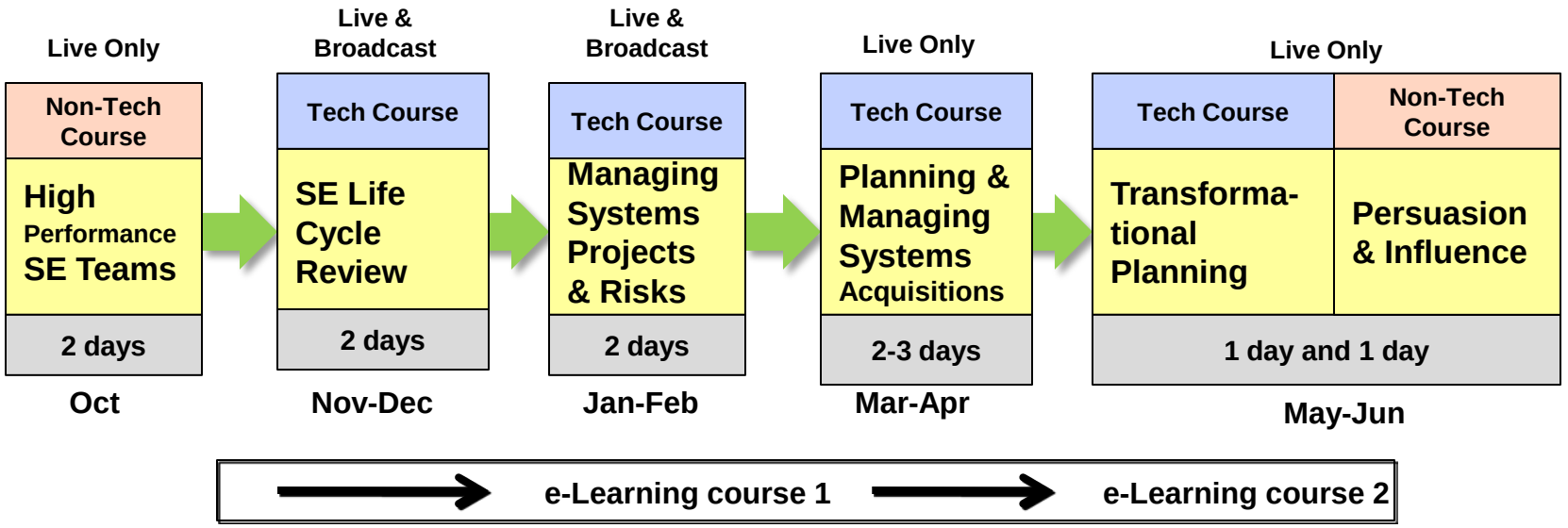
Class size: Groups of ~25

Group Work and Project:

Group Work – Facilitated & mentored, virtual teams; 1 hour at lunch every 2 weeks; pre-reading & discussions

On-the-Job Project Work – Project determined by Student & Manager – focus high priority competencies

SEworks 2 Program



Technical Courses
TSE600 SE Life Cycle Review
TSE601 Managing Systems Projects and Risks
TSE602 Planning & Managing Systems Acquisition
TSE603 Transformational Planning

Non-Technical Courses
DSE600 Building High Performance SE Teams
DSE601 Persuasion and Influence

Class size: Groups of ~25

Group Work and Project:

Group Work – Self-directed, virtual mentored teams; 1 hour at lunch every 2 weeks

Project Work – "Give Back to Company" – group project on acquisition or individual project for SEG

Integration in Design

- **Content types integrated**
  - Technical and soft skill courses in each program level
  - Technical & non-technical content in opposite classes
- **Training approaches integrated**
  - Live, instructor-led training (& remote broadcasting)
  - e-Learning
  - Readings, group work, and on-the-project work
- **Type of measurements & assessments**
  - Kirkpatrick Levels 1, 2, and 3 included in one or multiple training approaches

Customized Learning: Group Projects (*SEworks2*)

- **Important for reflection & networking & reach back**
- **Assessment – Student and Manager – Both asked**
  - 1. How do you compare against the competency model?
  - 2. What competencies most important in next 1-2 years?
  - Pick 1 or 2 technical and 1 soft skills competencies
  - MITRE Institute will group students with similar competency improvement interests
- **Group Work Activities – students meet virtually, online, every other week for an hour**
- **Self-direct work groups – Organize and direct own activities**
- **Accountable to higher level Mentors, attend ~ 3rd meeting**
  - Project proposal/Project Plan/Status Updates & Reviews
  - Final Project Presentation

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Customized Learning: Group Projects (*SEworks2*)

- **Student groups pick project – "*Give Back to MITRE*"**
  - **Looking for an internally publishable product**
  - **Helpful for SEs in company**
  - **Products published on internal SE websites - Examples**
    - White paper on hot SE topic
    - New tool or approach to an SE activity developed
    - Analysis or Ranking of a Set of SE Tools
    - Guidance for SE Milestone Meetings (PDR, CDR, etc.)
- **Groups kickoff & work in first course – High Performance SE Teams**
- **Competition: Final presentations judged for presentation to Engineering Advisory Council and/or Officers**

Summary - 1

- MITRE Institute developed new internal program to complement in-house MS SE & deep catalog programs
- Sought and obtained senior management support early and often
- Defined methodology included benchmarking, change management, & building a SE competency model (CM)
- CM used in benchmarking company, curriculum design, and student assessments
- 3-Level *SEworks* Program covers specific competencies at different career levels

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Summary - 2

- Make vs. buy decision made separately for technical, non-technical, and e-Learning content
- Many Group Work approaches examined
  - 1st Level – Virtual mentored groups
  - 2nd Level – Virtual, self-directed groups (?)
- On-the-job Project & Group Work integral to program
- Measurement types used judiciously on various program segments to control effort and costs
- Used all external benchmarking study results

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Backup

Individual Development Plan

Task/Activity	Measures/Outcome	Schedule
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 Communications and 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
Project: 2-3 Competencies Chosen	Agreed to with Manager and List Sent to MITRE Institute (1-2 technical and one non-technical)	Jan. 2010
Project Description Completed	Agreed to with Manager & Project Description sent to MITRE Institute, including milestones and outcomes.	Jan. 2010
Project Milestone Update	Meet with Manager/Mentor/Group – Updates to MITRE Institute	February – May 2010
Project Completion	• Final Write Up to MI • Student reports to Manager and Sub-cohort Group & Mentor • Manager evaluates performance of their student staff member	June 2010 June 2010 Late 2010 or Early 2010

Naming and Branding a Program

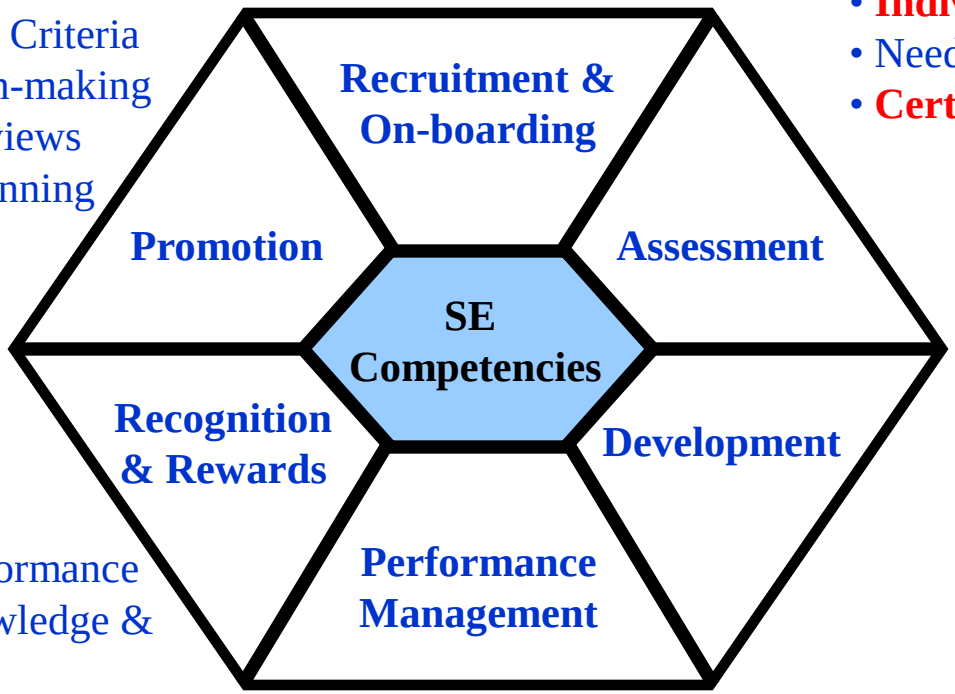
- **Create the Name**
  - Catchy, easy to remember
  - Demonstrate concept of level
  - Include main thrusts
  - Audience
  - Use of names – websites, email, communications, etc.
- **Iconify Name**
  - Graphic artists & many options
  - Consider uses
- **Color the Icons**
  - Effective for all purposes?

Value of Competencies: Integration into Organizational Programs & Processes

- Job Descriptions
- Sourcing
- Interviewing & Selection
- Orientation/Assimilation

- Promotion Criteria & Decision-making
- Talent Reviews
- Career Planning

- **Individual Assessment***
- Needs Analysis
- **Certification***



- Conferences
- Degree Programs
- **In-house Classroom Training***
- **On-the-Job Training***
- Technical Exchange Meetings
- **Stretch Assignments***
- Mentoring
- Communities of Practice
- Job Rotation
- Peer Reviews

- Recognition Programs
- Pay for Performance and/or Knowledge & Skills

- **P & D Goals***
- Performance Feedback

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* Probable areas for competency use

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Cohort Job Family Analysis

- Originally focused on two job families
- But staff in other job families & their managers will probably be interested
- Performed analysis to determine maximum group size by AC-level groupings & potential annual cohort size

Job Families	Percent Coverage Factor
Main Job Families	
Multi-Discipline SE's (MLTSYS)	**95%**
Information SE's (ISYSEG)	**95%**
Related Job Families	
InfoSec Eng/Sci (INFSEC)	**65%**
Defense/Space SEs (DEFSPC)	**65%**
Domain Oper Anal (DMOPAN)	**65%**
Software Sys SEs (SWSYEG)	**65%**
Remaining ~20 Job Families	**25%**

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SE Certification Path
Blending education, experience & knowledge

- **Enroll separately in catalog SE Certification Program**
  - INCOSE: Nationally/Internationally recognized
  - Reasonable cost
- **Manager & staff determine if certification appropriate**
  - Project provides testing funding
- **MITRE Institute provides pre-testing training**
- **SEPO may simplify the application process**
- **Probably complete in a non-SEworks year**
  - SEworks already increasing work load

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Overall Assessment of SECEP Program

- Cumulate data for 2-3 competencies/student over time
- Looking for 80% of students showing improvement on the competencies they worked on

	Competency #1	Competency #2	Competency #3	Competency #4	Competency #5	...
Student 1	↑		↑	↑		
Student 2		↓	↔		↑	
Student 3	↑	↑		↔		
Student 4	↓		↑		↔	
⋮						
Totals	80%	90%	70%	80%	75%	

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SEworks Design, Development and Delivery Schedule

Level	Design Time Periods	FYs & Levels Delivered
1	FY09 (2-9/09) – Level 1 Detailed Design	FY10 – Level 1
2	FY10 – Level 2 Detailed Design	FY11 – Level 1,2
3	FY11 – Level 3 Detailed Design	FY12 – Level 1,2,3

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