Improving Systems Engineering Curriculum Using a Competency-Based Assessment Approach

Alice Squires,
alice.squires@stevens.edu
School of Systems and Enterprises
Stevens Institute of Technology

Why Competencies?

- To meet government/industry needs … today.
- Government and Industry groups have defined knowledge, skills and abilities (competencies) that are important to their success.
  - behaviors, attitudes, attributes = also competencies
  - performance/output minimum = competences
- Curriculum can be designed to address these competencies.
  - learning objectives
  - course content
  - activities

What is a Competency-Based Approach?

- An approach to teaching and learning that is based on the successful student achieving a specific level of proficiency in a specific set of competencies.
- Compare:
  - current level – 'as is'
  - desired level – 'to be'
- Identify gaps – focus areas
- Put a plan in place to bridge the gap

An Example of 'Individual' SE Competency Models -- FAA

- FAA SE Manual, October 11, 2006: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/operations/sysengsaf/seman/
  - Armstrong, J. R., & Henry, D. (2009). Competencies required for successful acquisition of the next generation air transportation system. In *IEEE syscon 2009, 3rd annual IEEE international systems conference, vancouver, canada, march 23-29, 2009.*
  - Armstrong, J., Henry, D., & Pyster, A. (2009, September 8). *Systems engineering, systems integration, and software engineering competencies required for successful acquisition of the next generation air transportation system. School of Systems and Enterprises, Stevens Institute of Technology, Castle Point on Hudson, Hoboken, NJ.*
  - Turner, R., Verma, D., & Weitekamp, W. (2009, August 31). *The next generation air transportation system (nextgen). School of Systems and Enterprises, Stevens Institute of Technology, Castle Point on Hudson, Hoboken, NJ.*

Other examples: MITRE, SAIC, BAE Systems, Nokia, Boeing, LM, etc….

Examples of 'Jointly' Developed SE Competency Models

- DAU Systems Planning, Research, Development and Engineering (SPRDE)–SE/PSE Model: https://acc.dau.mil/CommunityBrowser.aspx?id=315691
  - Analytical (13), Technical Management (12), Professional (4)
- INCOSE UK: Systems Engineering Competencies Framework and Guide to Competency Evaluation
  - final due out Oct 2009
  - Holistic LifeCycle, Systems Thinking, Systems Engineering Mgmt
- NASA/Industry: See http://www.nasa.gov/pdf/303747main_Systems_Engineering_Competencies.pdf
  - Model shown and used in this presentation

NASA/Industry SE Competency Model

- International Academy of Astronautics (IAA): Space industry SE competency model:
  - 10 Competency Areas
  - 37 Capabilities within these ten areas
  - 4 Proficiency Levels
- Successfully Leveraged to Develop Stevens' SSE Domain Centric Space Systems Engineering Masters Program
- Used to Assess Legacy Core Courses for Stevens' SSE SE Discipline Centric Masters Program

Ten Competency Areas (# of capabilities)

1. Concepts and Architecture (4)
2. System Design (4)
3. Production, Product Transition and Operations (6)
4. Technical Management (8)
5. Project Management and Control (4)
6. Organizational Environments (3)
7. Human Capital Management (2)
8. Security, Safety and Mission Assurance (2)
9. Professional and Leadership Development (3)
10. Knowledge Management (1)

Four Proficiency Levels*

- Level I – **Participate (Know)**: Performs fundamental and routine SE activities while supporting a Level II-IV systems engineer as a member of a project team
- Level II – **Apply (Perform)**: Performs SE activities for a subsystem or simple project (e.g. no more than two simple internal/external interfaces, simpler contracting processes, smaller team/budget, shorter duration)
- Level III – **Manage (Lead)**: Performs as a systems engineer for a complex project (e.g. several distinct subsystems or other defined services, capabilities, or products and their associated interfaces)
- Level IV – **Guide (Strategize)**: Oversees SE activities for a program with several systems and/or establishes SE policies at top organizational level.

*from NASA's Academy of Program/Project and Engineering Leadership (APPEL)

Space Systems Engineering Example

	Fundamentals of Systems Engineering	System Architecture and Design	Designing Space Missions and Systems	Mission and System Design Verification & Validation	Systems Integration	Project Management of Complex Systems	Human Spaceflight	Space Launch and Transportation Systems	Cost Effective Space Mission Operations	Crew Exploration and Vehicle Design	Modeling and Simulation	Design for Reliability, Maintainability and Supportability	Decision and Risk Analysis
	Core						Specialty						
1.0													
1.1	X	X					X	X	X	X			
1.2	X	X	X		x*		X	X	X	X			
1.3	X	X	X		x*		X	X	X	X	X	X	X
1.4	X	X			x*					X		X	
2.0													
2.1	X	X				X	X	X	X	X	X	X	X
2.2	X	X		X	X		X	X	X	X		X	
2.3		X											
2.4		X	X	X	x*		X	X	X	X		X	
3.0													
3.1	X												
3.2		X		X	X								
3.3	X		X	X	X								
3.4	X			X	X								
3.5													
3.6			X					X	X				

x* - for enabling systems

The Team: Years of Experience

	Government/ Industry	Research/ Academia	SE Related	*TOTAL*
1	42	1	**43**	***43***
2	35	5	**35**	***40***
3	27	3	**23**	***30***
4	29	3	**20**	***32***
5	27	6	**30**	***33***
6	26	12	**18**	***38***
7	21	10	**10**	***31***
8	6	6	**5**	***12***
9	30	9	**39**	***39***
10	26	7	**23**	***33***
11	23	4	**13**	***27***
12	27	4	**15**	***31***
13	9	12	**20**	***21***
	328	82	**294**	***410***

Process

- Select the Competency Model to Use
- Validate the 'Critical' Competencies
- Identify the 'As is' State of the Curriculum
- Identify the 'To Be' State of the Curriculum
- Summarize/Evaluate the Gap Areas
- Put a Plan of Action in Place to Assess those Gaps
- Revisit!

Validate the Competencies

Systems Engineering Capabilities	IAA Global 'Apply'	Stevens 'Apply'	
3.0 Production, Product Transition and Operations			
3.1 Implement the Product	Optional		5
3.2 Integrate System	**Critical**	**Critical**	**10**
3.3 Verify the System	**Critical**	**Critical**	**9**
3.4 Validate the System	**Necessary**	**Critical**	**9**
3.5 Transition the System	Optional		4
3.6 Conduct Operations	Necessary		2

Determine Current State: 'As is'

Stevens Institute of Technology: Critical Systems Engineer Capabilities	Fundamentals of Systems and Software Engineering	System Architecture and Design	Systems Integration	Project Management of Complex Systems
3.0 Production, Product Transition and Operations				
3.2 Integrate System		Low	Medium	
3.3 Verify the System	Medium		Medium	
3.4 Validate the System	Medium		Medium	

Determine Desired State: 'To Be'

Stevens Institute of Technology: Critical Systems Engineer Capabilities	Fundamentals of Systems and Software Engineering	System Architecture and Design	Systems Integration	Project Management of Complex Systems
3.0 Production, Product Transition and Operations				
3.2 Integrate System		Low	**High**	
3.3 Verify the System	Medium		**High**	
3.4 Validate the System	Medium		**High**	

Evaluate Gaps

Stevens Institute of Technology: Critical Systems Engineer Capabilities **1 circle = Low** **3 circles = Medium** **5 circles = High** **● = current 'as/is'** **❍ = 'to/be'**	Fundamentals of Systems and Software Engineering	System Architecture and Design	Systems Integration	Project Management of Complex Systems
3.0 Production, Product Transition and Operations				
3.2 Integrate System		●	●●●❍❍	
3.3 Verify the System	●●●		●●●❍❍	
3.4 Validate the System	●●●		●●●❍❍	

Develop an Action Plan

Systems Integration		
SE Capabilities	**Gaps**	**Examples of Potential Actions To Address Gaps**
3.0 Production, Product Transition and Operations		
3.2 Integrate System^{P}	●●●❍❍	Increased emphasis will be placed on integration strategies to address interface risks early in a program.
3.3 Verify the System^{P}	●●●❍❍	May introduce Design of Experiments (DOE) in this context.
3.4 Validate the System^{P}	●●●❍❍	Increased emphasis on tie to risk of non-acceptance of system by the customer.

Related Journal Papers To Be Published

- Squires, A., Larson, W., and Sauser, B. (2010). "Mapping Space-Based Systems Engineering Curriculum to Government-Industry Vetted Competencies for Improved Organizational Performance", *Systems Engineering, 13(2 or 3), TBD.*

- Squires, A., and Larson, W. (2009). "Improving Systems Engineering Curriculum Using a Competency-Based Assessment Approach", Special Issue on Systems Engineering Education of the *International Journal of Intelligent Defence Support Systems (IJIDSS), TBD(TBD), TBD.*

Thank You!

Questions?

Alice F. Squires, asquires@stevens.edu