



Graduate Systems Engineering Programs: Report on Outcomes and Objectives

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Part I: Background

- ‘Gracie’ Context
- Definitions: Outcomes and Objectives
- Overview of SE Masters Survey Results
- Current Thinking/Challenges

Part II: Group Activity

- Food for Thought
- Audience Participation/Feedback



Part I: Background

GRCSE Context

- BKCASE: Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE). A three-year effort to produce two version 1.0 products by 2012:
 - SEBoK: Systems Engineering Body of Knowledge
 - GRCSE: Graduate Reference Curriculum in System Engineering

Version 0.25 available for limited review in December 2010

Current GRCSE Outline

- **Guidance:** Construction and Maintenance of GRCSE
- **Expected Objectives:** Graduate Has 3-5 Years' Experience
- **Expected Outcomes:** When Student Graduates
- **Expected Student Background:** Entering Master's Program
- **Curriculum architecture:** Framework
- **Core Body of Knowledge (CorBOK):** Foundation/Extended
- **Assessment**
- **Anticipated GRCSE Evolution:** Going Forward
- *App A: Summary of Graduate SE-Centric Programs*
- *App B: Bloom's Taxonomy of Educational Outcomes*
- *App C: Assessment & Achievement of Learning Outcomes*

The Goal

- The goal is to transform entrants to the program, who have attained the stated entry criteria, into graduates who have achieved the outcomes and are educated so that they should be able to achieve the objectives in the relevant timeframe.

Outcomes

- The educational output state of new graduates from a program including the knowledge and competencies that are expected of graduates at the time of completing the program.
- The expected outcomes are intended to express what is required to commence professional practice.
- The expected outcomes include a mix of technical, scientific, reasoning, ethical, personal, and other attributes, reflecting the diverse skills that graduates require to become successful as system engineers.

Objectives

- The competencies that the program enables the graduate to build with the addition of workplace experience about 3 to 5 years after graduation.
- The ability of a graduate to achieve the objectives is significantly affected by the kind of educational experience that they have had and the kind of learning that they have achieved through their masters program.
- In the development of a curriculum and the assessment of achievement within the curriculum it is necessary for the whole package to develop a student in a suitable manner to achieve the objectives post graduation that are intended.

Survey: Masters in SE

- Sent to 63 universities (33 domestic)
- Focus was on systems-centric SE programs (rather than domain-centric SE programs)
- Received responses from about half
- Universities were not intended to be a comprehensive set, but rather effort was to get a baseline of current state of Masters in systems engineering around the world.

MSE Program Attributes

- Delivery Method
 - 94% Face-to-face (all but 2)
 - 41% Online (2 exclusively)
 - 25% Hybrid (mix of online/face-to-face)
 - 40% Multi-Modal (Synchronous/Asynchronous)
- Course length: 12 to 19 weeks
- Program length: 1 to 2.5 years
- Project Thesis/Capstone Required: 94%

MSE Entry Requirements

- Undergraduate degree:
 - Engineering (88%)
 - Science/Physics/Math (81%)
 - Other (30%)
- Undergraduate GPA:
 - 3.0 GPA (60%)
 - No requirement (28%)
 - No response (12%)
- GRE Required?
 - Yes (28%)
 - No (50%)
 - No Response (22%)
- Years of Experience
 - Average 3 years (40%)
 - No Requirement (44%)
 - Company Sponsored (16%)

MSE Outcomes Example:



ABET-certified Program

- Demonstrate thorough **understanding of the SE process** from mission area analysis through requirements definition to system development, sustainment, and retirement.
- Demonstrate **application of the SE process and methods** on contemporary problems of interest to the DoD.
- Proficient with many of the **tools for implementing the SE process**, including development of system architectures, tradeoff and decision analysis, risk management and test planning.
- Able to **identify deficiencies/gaps in the current SE body of knowledge**; capable of proposing new approaches to bridge gaps.
- Demonstrate the ability to **effectively communicate** technically complex ideas and concepts in both spoken and written formats.
- **Develop detailed understanding in at least one technical specialty area** - airborne systems, space systems, cyber-warfare, etc.0



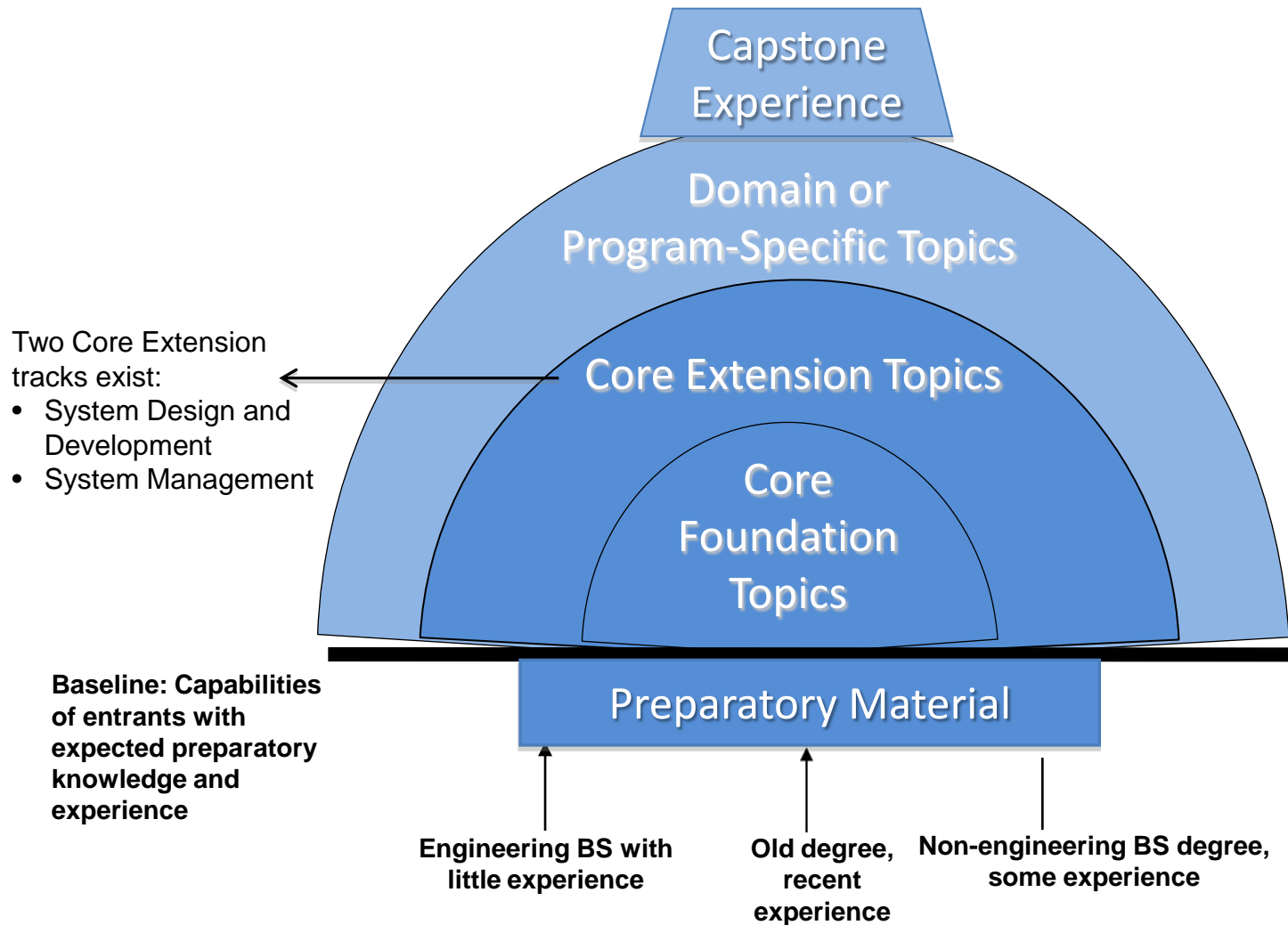
MSE Outcomes Example: Miscellaneous

- Enable working professionals to become systems thinkers and problem solvers through a unique blend of formal education integrated with personal work experience.
- Ability to integrate, express and present research results.
- Be able to generate innovative system concepts to address identified stakeholder needs.
- Enhance promotion opportunities and greater personal marketability for new job opportunities.

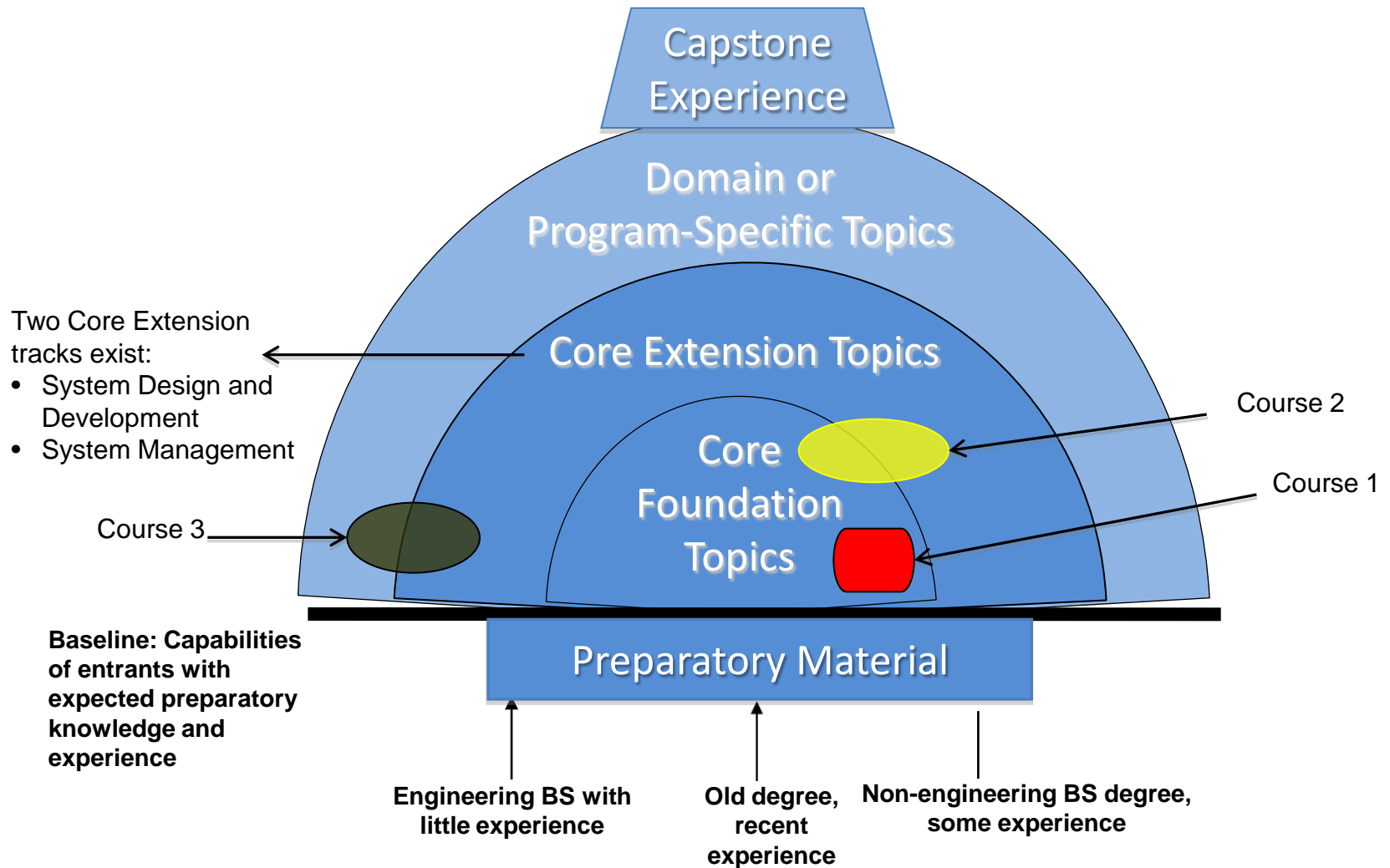
GRCSE Outcomes

- The current proposal (for GRCSE 0.25) is for a three levels of Knowledge based Outcomes:
 - Core Knowledge, which all graduates must have
 - Extended Core Knowledge, related to potential roles
 - Elective or University Specific Knowledge
- In addition, there will be outcomes associated more with the Blooms Cognitive domain and concerned with equipping students to take Professional Posts in the 3-5 year timescale

Proposed GRCSE Curriculum Architecture



Proposed GRCSE Curriculum Architecture





GRCSE Knowledge Outcomes

- Master the Shared Core Systems Engineering Body of Knowledge CorBOK
- Master the Extended Core Systems Engineering Body of Knowledge, as appropriate for the type of program.
- Master at least one KA or sub-area from the CorBOK to the Bloom Synthesis level.
- Master systems engineering in one application domain, such as finance, medical, transportation, or telecommunications
- Be able to analyze a current significant technology*, articulate its strengths and weaknesses, compare it to alternative technologies, and specify and promote improvements or extensions to that technology.

* The use of Technology here relates to all kinds of solution at all level of Enterprise Service and Product. This might include Hardware, Software People, Procedures, Infrastructure, Organization, etc.



GRCSE Professional Outcomes

- Be able to make ethical professional decisions and practice ethical professional behavior.
- Be
 - an effective member of a multi-disciplinary team,
 - effectively communicate both orally and in writing, and
 - lead in one area of system development such as project management, requirements analysis, architecture, construction, or quality assurance.
- Be
 - able to reconcile conflicting project objectives,
 - finding acceptable compromises within limitations of cost, time, knowledge, risk, existing systems, and organizations.



GRCSE Professional Outcomes

- Understand and appreciate feasibility analysis, negotiation, and good communications with stakeholders in a typical domain environment, and
- perform those tasks well;
- have effective work habits and be a leader.

- Be
 - able to learn new models, techniques, and technologies as they emerge, and
 - appreciate the necessity of such continuing professional development.

- Understand the relationships between Systems Engineering and other disciplines such as Project Management and Software Engineering.

Early Draft Decisions /Challenges

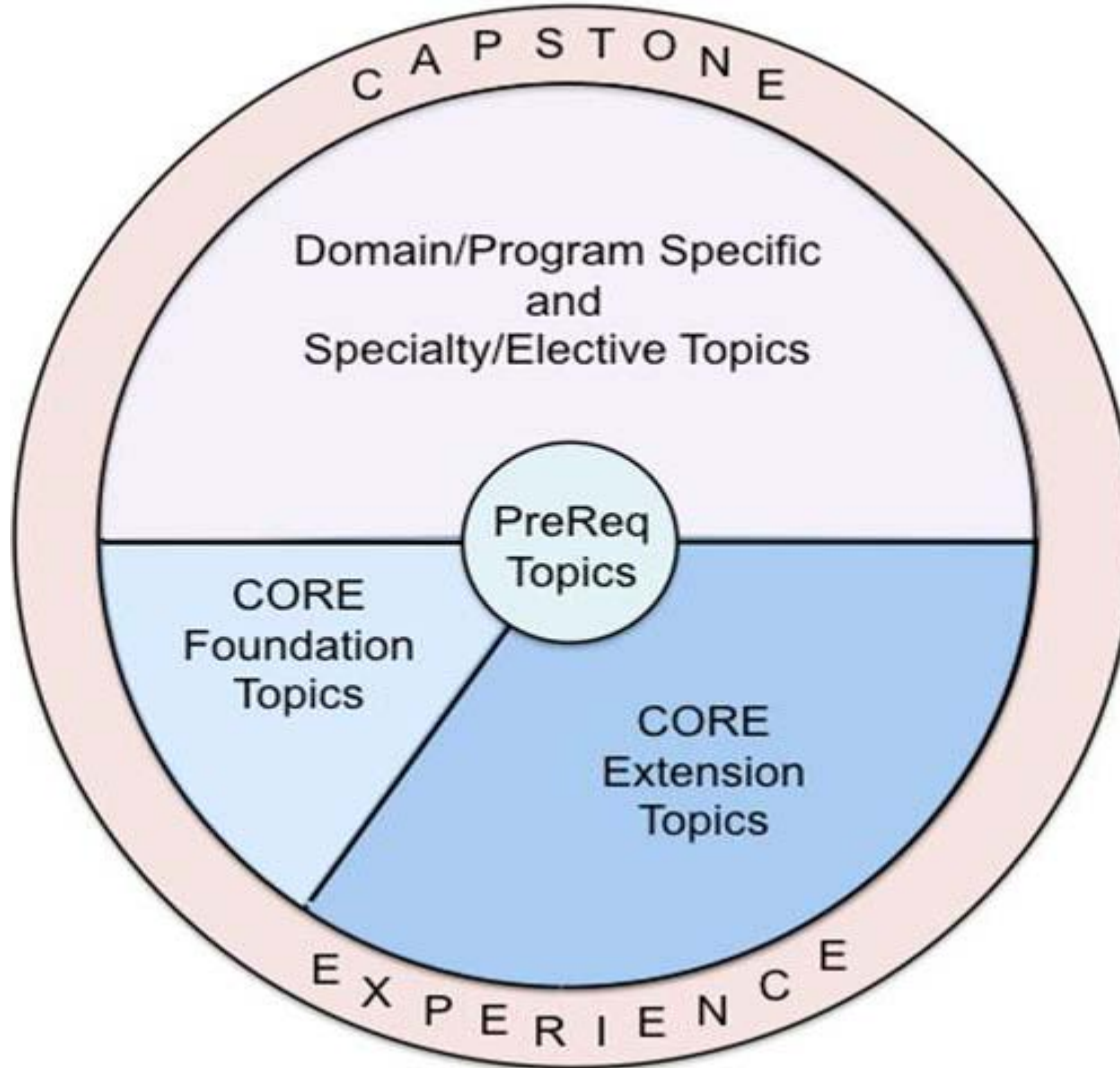
Challenge	Early Decision for GRCSE 0.25
Should GRCSE scope include Domain-Centric SE programs or just Systems-Centric programs?	Systems-Centric only
How much experience should be expected of program entrants?	At least 2 years of practical experience in some aspect of SE
Focus on traditional product SE or on services and enterprise SE as well?	All 3 – product, services, and enterprise SE
One set of outcomes and objectives or several sets, reflecting the range of SE educational practice?	One set

Decisions will be revisited for GRCSE

Early Draft Decisions /Challenges

Challenge	Early Decision for GRCSE 0.25
Expect an undergraduate degree in engineering, physical science, or mathematics?	Yes
Program be ABET accreditable or accommodate a range of program focuses	?
How much content should be standardized?	No more than 50%
Learn SE abstractly or in the context of an application domain	In context of application domain

Decisions will be revisited for GRCSE



Still looking for help

- Reviewers for the limited release this December
- Authors
- Early adopters

- Version 0.5 will be available for world-wide comment in December 2011.



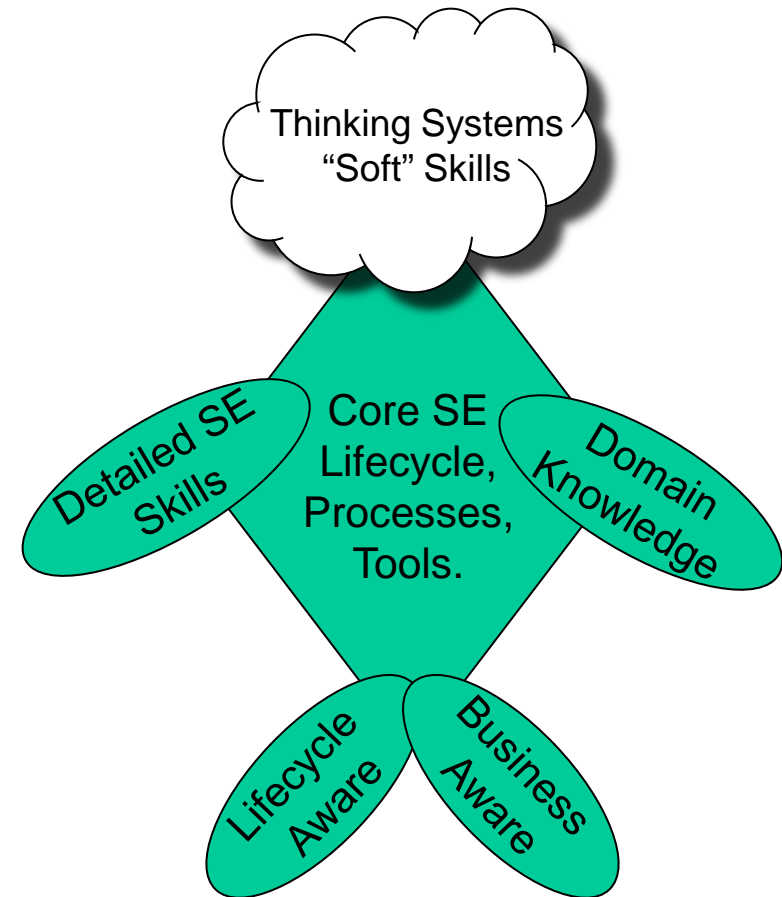
Call for Authors, Subject Matter Experts,
Reviewers and Early Adopters

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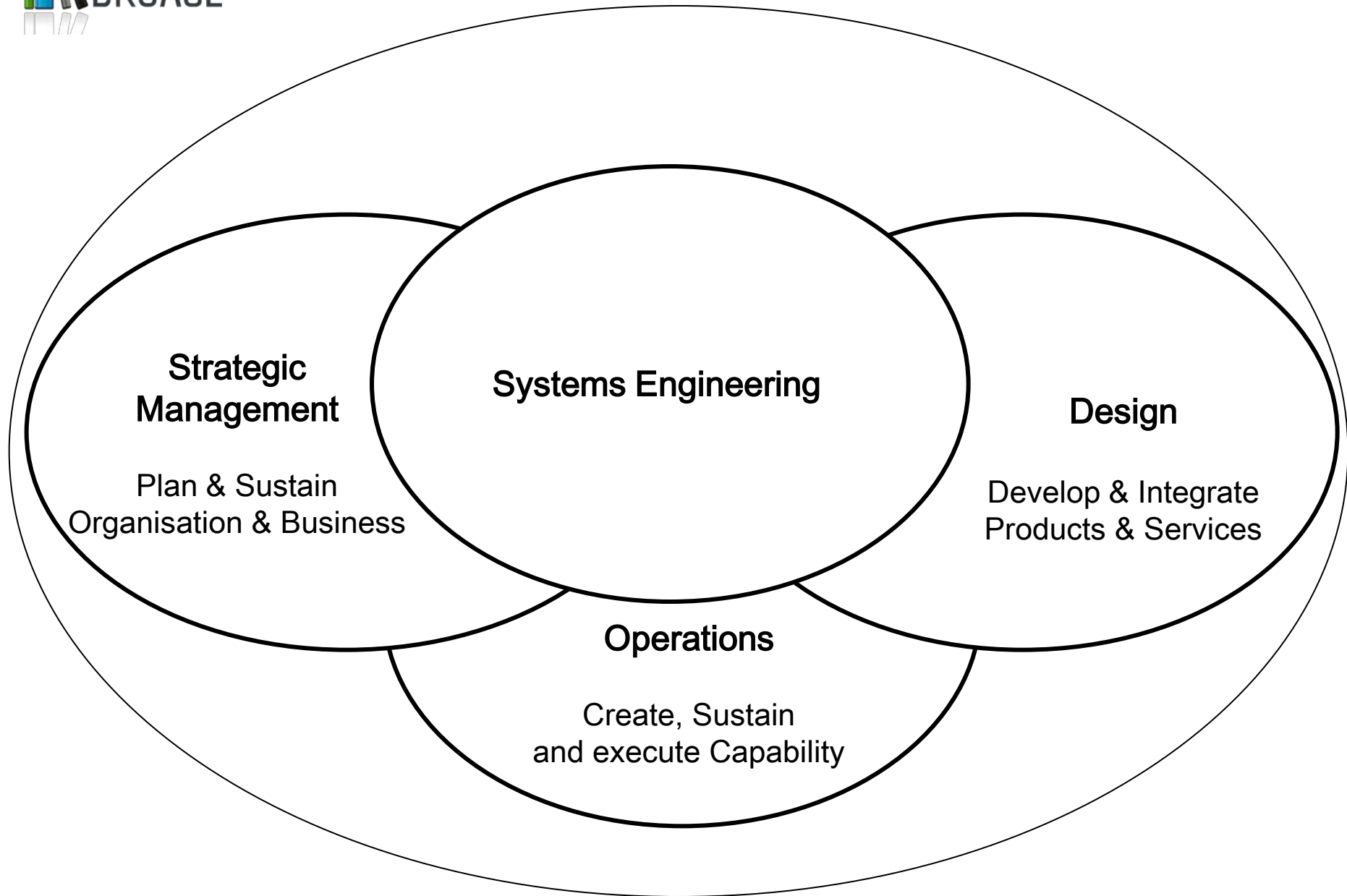
[*bkcase@stevens.edu*](mailto:bkcase@stevens.edu)

Part II: Group Activity

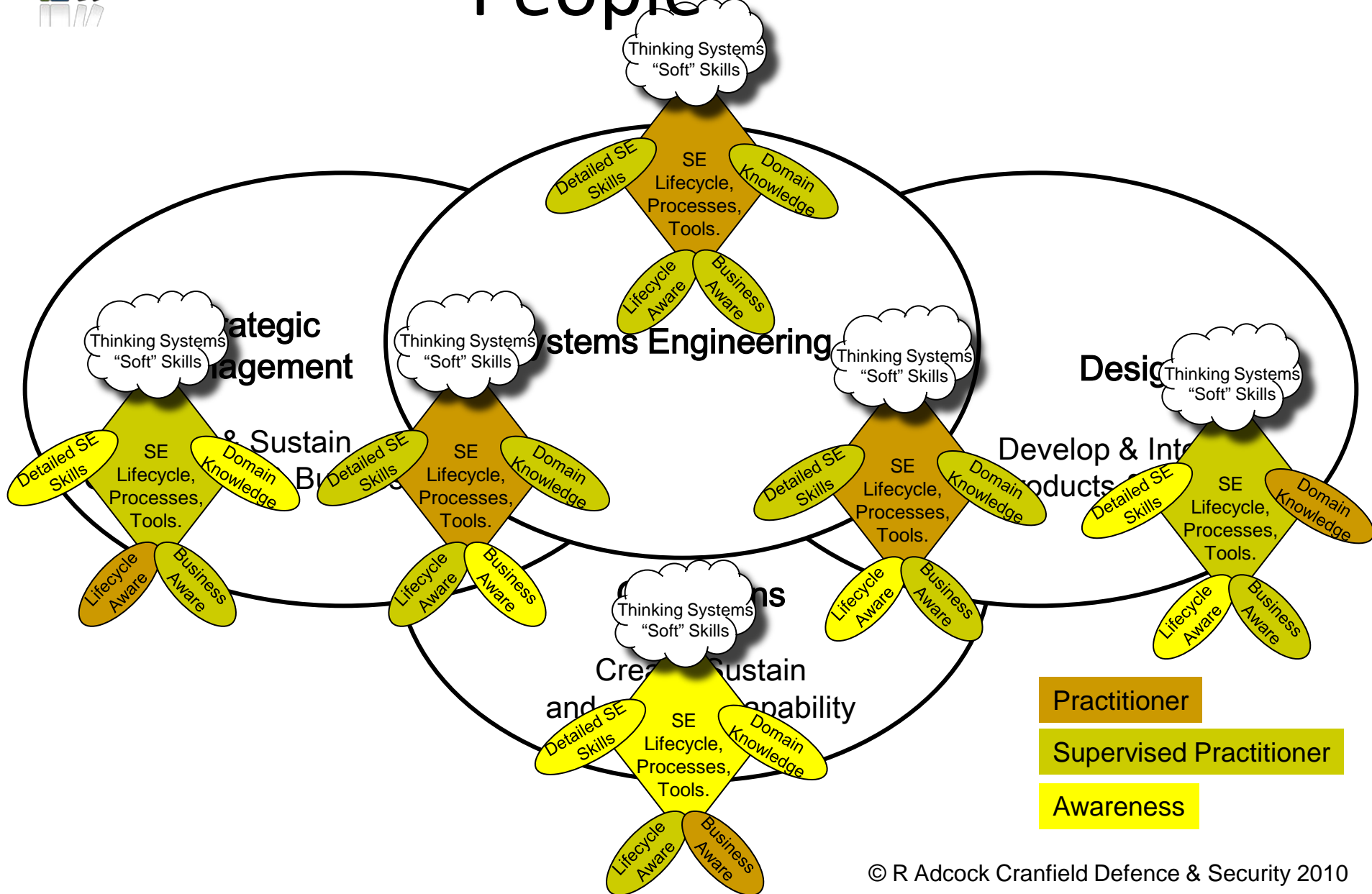
- Behaviours (The Head)
 - Understanding system concepts and viewpoints
 - Working with people, information broker, etc.
- Core technical skills (The Heart)
 - Overview of SE processes and techniques
 - Understanding of the changing role of SE across lifecycle
- Specific technical skills (The Arms)
 - Areas of specific SE expertise, e.g. Requirements, Architecture, V&V
 - Areas of specific domain or application expertise, e.g. Safety, Reliability, Simulation
- Supporting Knowledge (The Legs)
 - Awareness of wider lifecycle issues
 - Awareness of wider business or operational issues



Relationship Between SE and other Disciplines



Types of System People



INCOSE CSEP – 14 Areas

- **Requirements Engineering**
- **Risk and Opportunity Management**
- **Baseline Control**
- **Technical Planning**
- **Technical Effort Assessment**
- **Architecture/Design Development**
- **Qualification, Verification, and Validation**
- **Process Definition**
- **Tool Support**
- **Training**
- **Systems Integration**
- **Quality Assurance**
- **Specialty Engineering**
- **Other**

SEBoK Knowledge Areas

- ***Systems Concepts***
 - *Types of Systems*
 - *System Topologies*
 - *System-of-Interest*
 - *System Perspectives*
 - *Complexity*
 - *Roles of Systems*
- ***Systems Thinking***
 - *Hard and Soft Systems Thinking*
 - *Paradoxes*
 - *Models and Languages*

SEBoK Knowledge Areas

- ***SE Overview***
 - ***Fundamentals of SE***
 - ***Principles of SE as a Life Cycle Approach***
 - ***Principles of SE as a Service Integration Approach***
 - ***Principles of SE as an Enterprise Approach***
 - ***Relationship to Other Disciplines***
 - ***Socio-technical issues***
 - ***SE Standards***
- ***Generic Life Cycle Stages***
 - ***Life Cycle Characteristics***
 - ***System Life Cycle Process Drivers and Choices***
 - ***Representative System Life Cycle Process models***

SEBoK Knowledge Areas

- ***Service SE (TBD)***
- ***Enterprise SE***
 - ***The Enterprise as a System***
 - ***Related Business Activities***
 - ***Enterprise systems engineering***
 - ***ESE Process Activities***
 - ***Enterprise Capability Management***
- ***Enabling Systems Engineering in the Organization***
 - ***Managing SE at the Business level***
 - ***Stand-up, Improve, Intuitionize SE in Organization***

SEBoK Knowledge Areas

- ***Systems Engineering Management***
 - *SE Planning*
 - *SE Assessment and Control*
 - *SE Risk Management*
 - *SE Measurement*
 - *SE Decision Management*
 - *SE Configuration Management*
 - *SE Information Management*
- ***System Definition***
 - *Stakeholder Requirements and Mission Analysis*
 - *System Requirements*
 - *Architectural Design*
 - *System Analysis*
- ***System Realization***
 - *Implementation*
 - *System Integration*
 - *System Verification*
 - *System Validation*

SEBoK Knowledge Areas

- ***System Deployment and Use***
 - *Operation of the System*
 - *System Maintenance*
 - *Logistics*
- ***System Life Management***
 - *Service Life Extension*
 - *Capability Updates, Upgrades, and Modernization*
 - *System Disposal and Retirement*
- ***Systems Engineering Agreement***
 - *Acquisition Process*
 - *Supplier Processes*
- ***Systems Engineering Competency***
 - *System Deployment*
 - *Application*
 - *Future Work*

SEBoK Knowledge Areas

- ***Cross-Cutting***

- ***Integration of Specialty Engineering***
- ***Affordability/Design to Cost***
- ***Human System Integration***
- ***Safety***
- ***Security***
- ***Spectrum Management***
- ***Electro-Magnetic Interference/TEMPEST***

- ***Radiation Hardness***
- ***Reliability and Maintainability***
- ***Manufacturing and Production***
- ***Quality***
- ***Logistics/Supportability***
- ***Occupational Health/Work Environment***
- ***Disposal***
- ***Resilience***

Bloom's Levels

- Knowledge
- Comprehension
- Application
- Analysis
- Synthesis
- Evaluation



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Open Discussion, Q1

- What are the top three competencies you expect from a graduate of a Masters in SE program?

Open Discussion, Q2

- What are the top three objectives you expect your systems engineers to achieve three to five years after completing a Masters in SE.

Open Discussion, Q3

- Should graduate level systems engineering education try to provide a basic ‘one size fits all’ solution with modest variability achieved through elective courses,

OR
- Should there be recognizable traditions of programs organized around the particular emphases?

Questions?

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