Preparing Students for Systems Engineering Challenges of the Future

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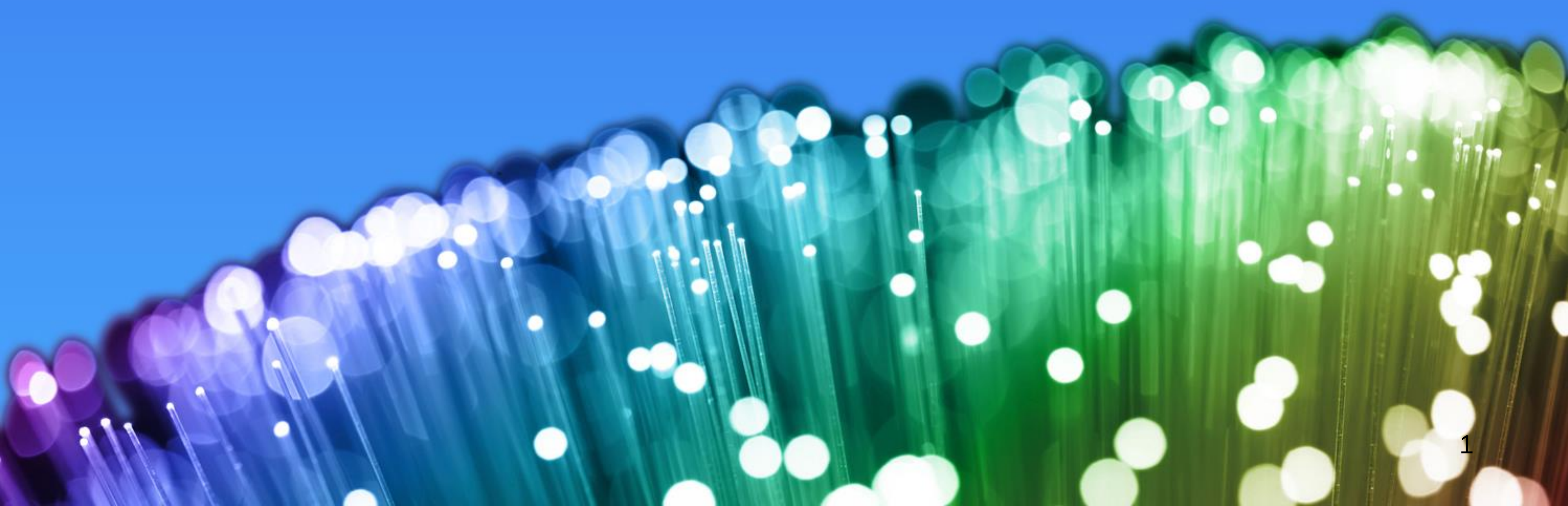

Disclaimer & Acknowledgment

- Disclaimer: Any opinions, findings, and conclusions or recommendations expressed in these slides are those of the author/presenter and do not necessarily reflect the views of the National Science Foundation.

The Curriculum Design Challenge

Educating the Systems Engineers of the Future

- Objective (to achieve in 5+ years):

A successful systems engineer:
a broad range of SE
knowledge, skills, abilities & experience

- Curriculum Design:
  - Develop a set of educational experiences that lead to this desired objective

Graduate Reference Curriculum for SE

- http://www.bkcase.org/grcse-2/

GRCSE™ BKCASE

- Guided by curriculum objectives and outcomes
  - Objective: broad statements of what student is expected to attain 3-5 years after graduating
  - Outcomes: at the time of graduation — *skills, knowledge, and behaviors that students acquire as they progress through the program*

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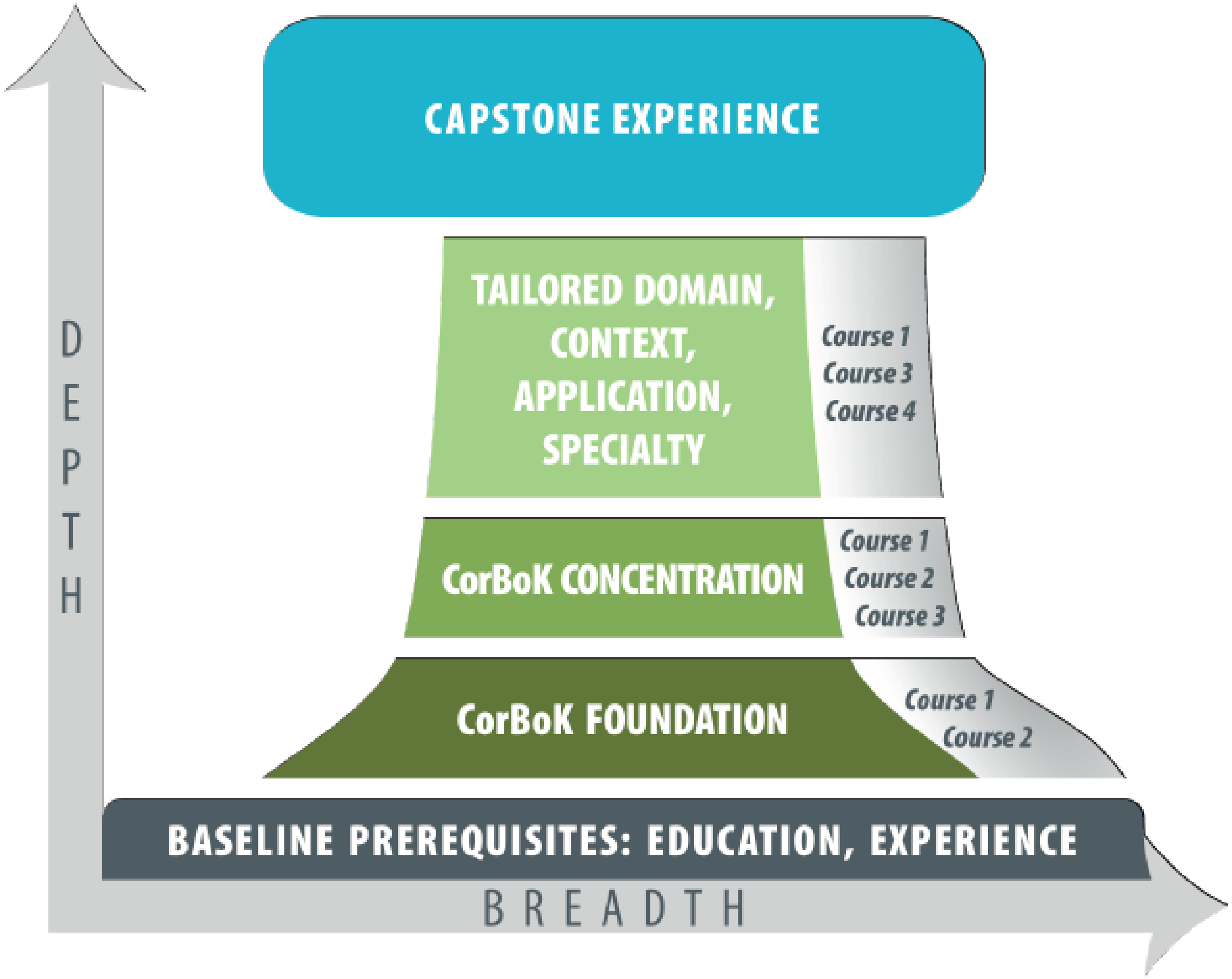
Generic SE Program Objectives (3-5 Years)

1. **SE Lifecycle:** Effectively analyze, design, or implement feasible, suitable, effective, supportable, affordable, and integrated system solutions to systems of products, services, enterprises, and system of systems, throughout the entire life cycle or a specified portion of the life cycle. This could be tailored by explicitly stating the types of systems that graduates develop and a given domain (e.g., aerospace).
2. **Multi-disciplinary:** Successfully assume a variety of roles in multi-disciplinary teams of diverse membership, including technical expert and leadership at various levels.
3. **Professionalism:** Demonstrate professionalism and grow professionally through continued learning and involvement in professional activities. Contribute to the growth of the profession. Contribute to society through ethical and responsible behavior.
4. **Communication:** Communicate (read, write, speak, listen, and illustrate) effectively in oral, written, and newly developing modes and media, especially with stakeholders and colleagues.

Outcomes — When a Student Graduates

- SE Concepts
  - Foundation
  - Concentration
  - Topic Depth
- SE Role
  - Application Domain
  - Specialty
  - Related Disciplines
  - Software in Systems
- SE Practice
  - Requirement Reconciliation
  - Problem/Solution Evaluation
  - Realism
- SE Professionalism
  - Professional Development
  - Teamwork
  - Ethics

Curriculum Architecture



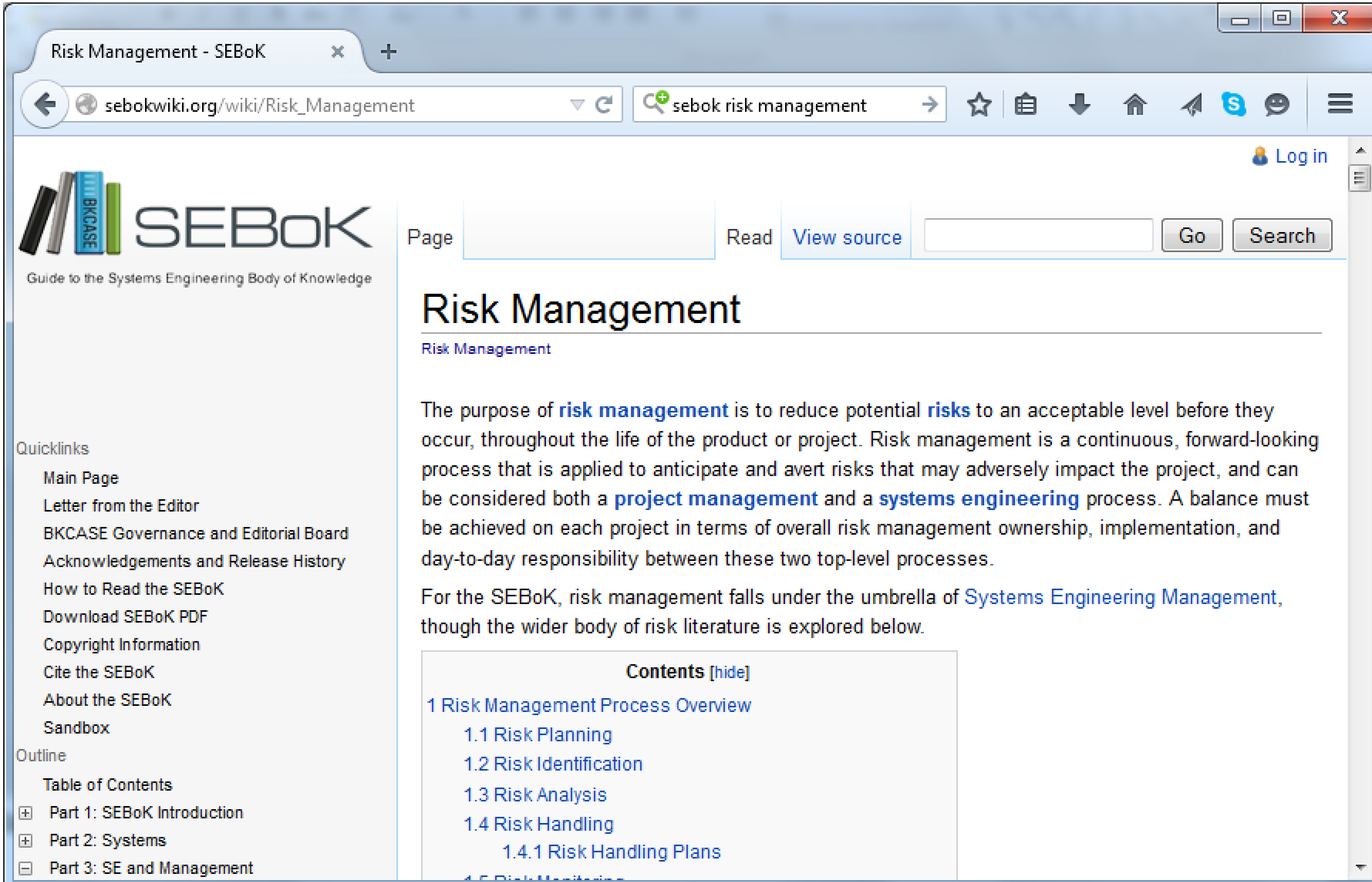
CorBoK: Core Body of Knowledge

- Part of the SEBoK
  - Part 1: SEBoK Introduction
  - Part 2: Systems Topics
  - Part 3: SE and Management
  - Part 4: SE Applications
  - Part 5: Topics on Enabling SE
  - Part 6: Related Disciplines
  - Part 7: SE Implementation

CorBoK

- Concentrations
  - SE Management
  - Systems Design and Development

SE Body of Knowledge

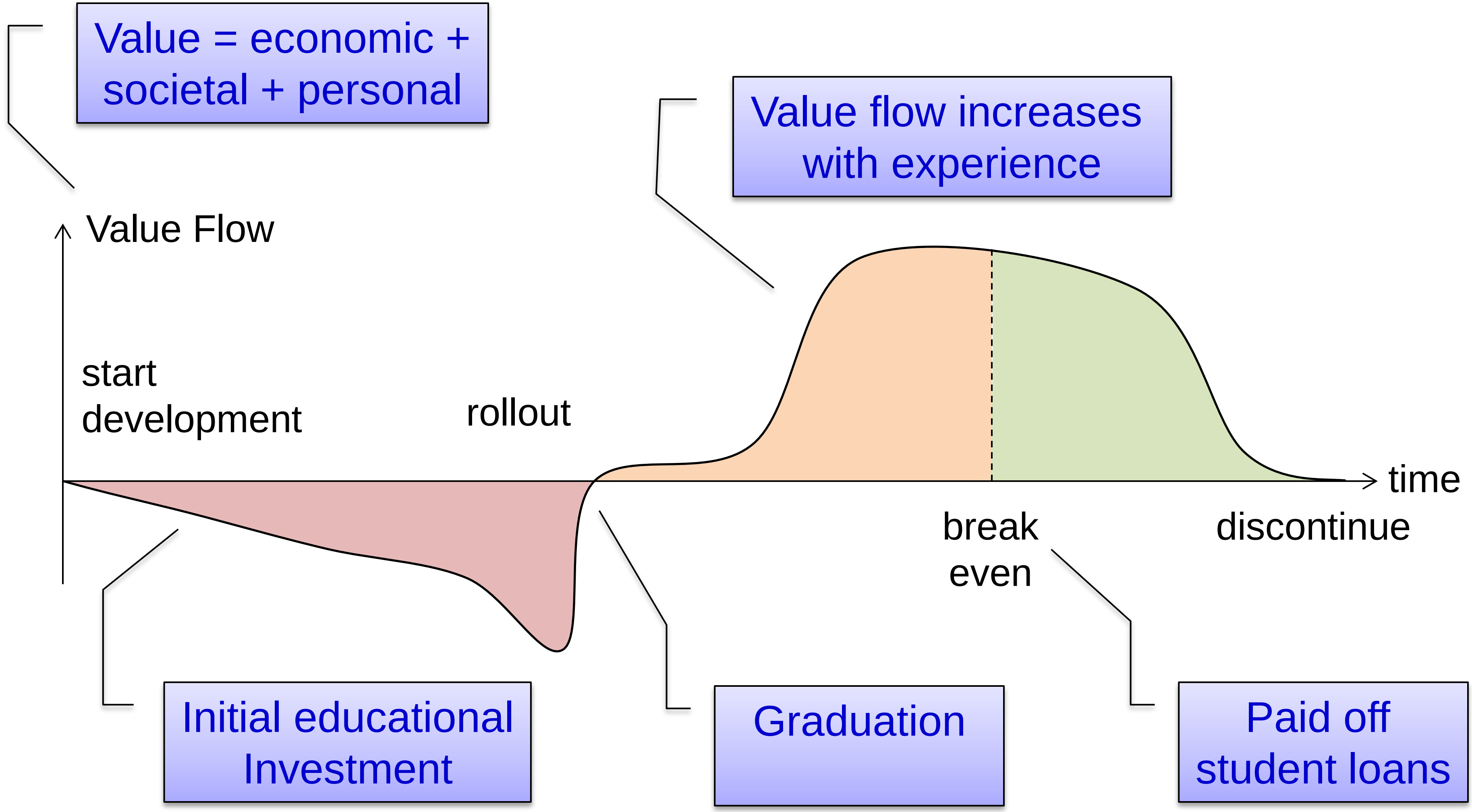


Presentation Outline

- The Curriculum Design Challenge
- The value proposition of an SE education
- Future core SE skills, knowledge, abilities

System of Interest = Student

Value Flows Throughout the Lifecycle



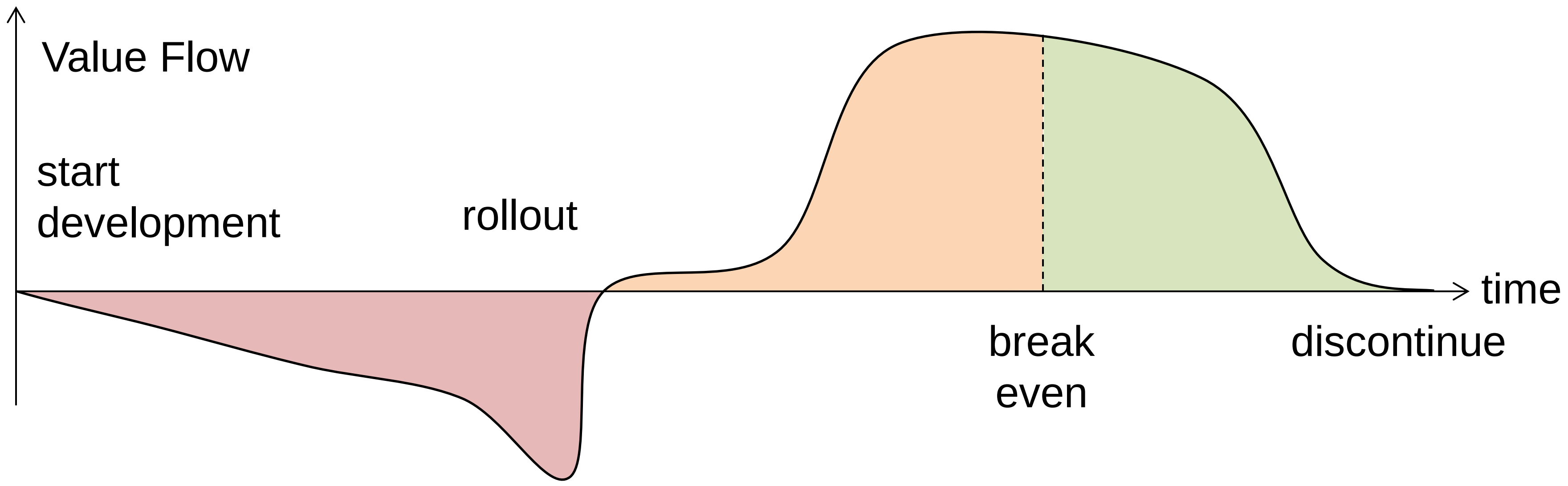
The Curriculum Design Challenge

A Systems Engineering Perspective

- Search space
  - Set of educational activities
- Objective
  - Maximize the expected NPV of student-systems-engineer over the course of a career
- Constraints
  - To be practical, the activities must be packaged in a standard curriculum: BS, MS, (PhD)

The Curriculum Design Challenge

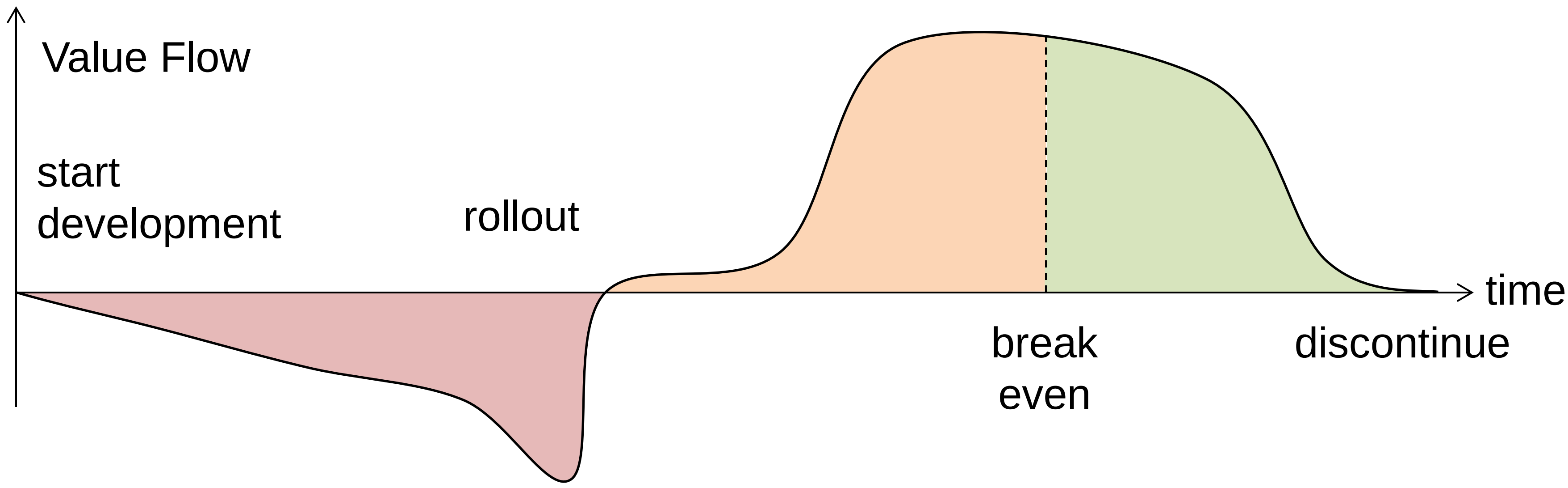
How is the Expected NPV influenced by the curriculum?



- Cost — Educational activities carry a cost — tuition, time, effort…
- Employability — Future value flows depend on short-term employability…
- Continuing education — not all the skills, knowledge and abilities need to be acquired during the educational program
- Future earnings potential — training in processes may lead to desired short-term skills, but will limit growth potential

The Curriculum Design Challenge

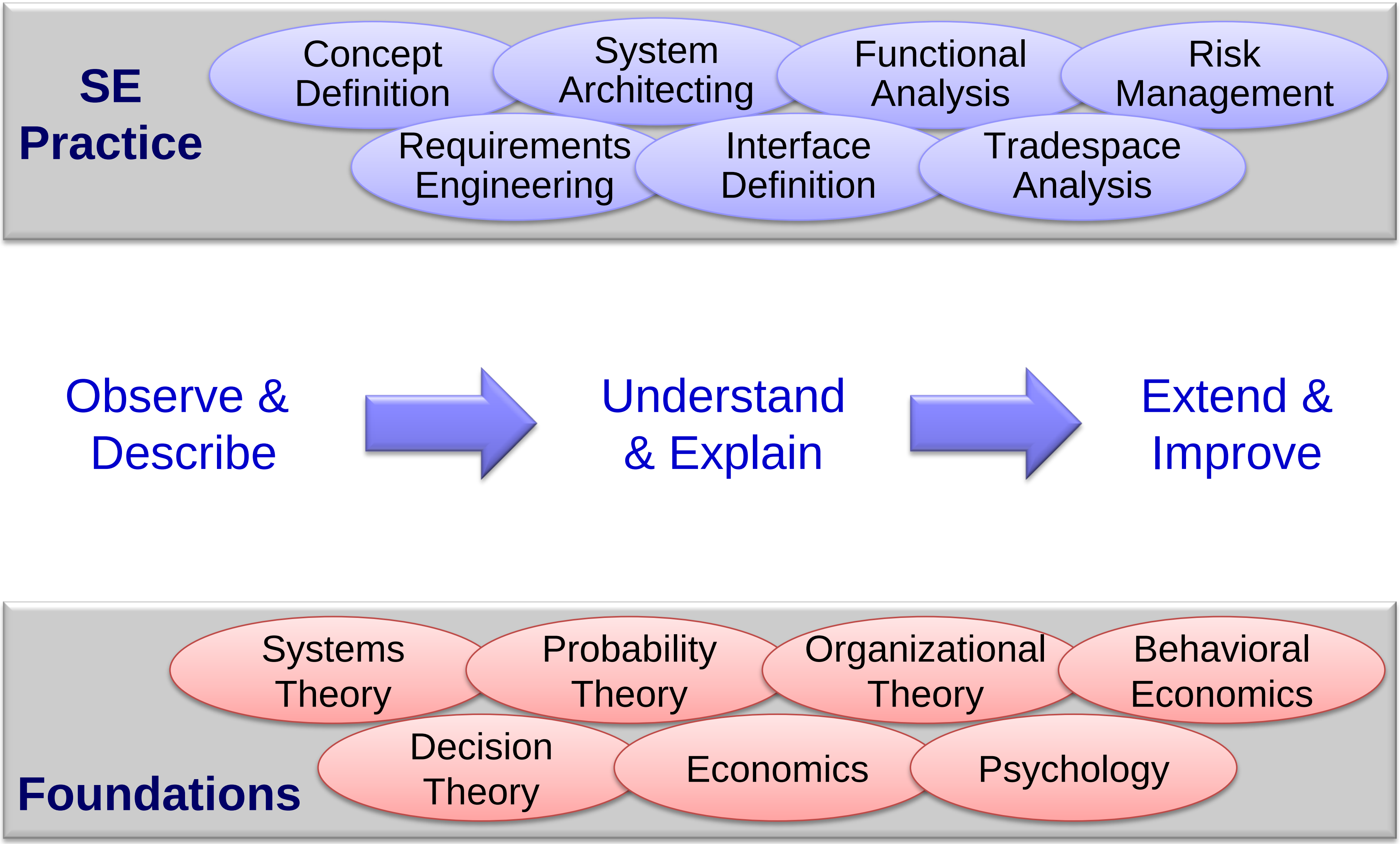
How is the Expected NPV influenced by the curriculum?



- Variability — The value of an educational activity is different for different students → customization may add value…
- Domain – Different students may pursue different SE domains
- Continuing education — Some skills/knowledge are more difficult to acquire after graduation (e.g., theory vs. domain expertise)
- Uncertainty — Most of the value will be realized 30-40 years out → education should be robust to the uncertain future

Theoretical Foundation for SE

A Rigorous, Scientific Methodology



The Curriculum Design Challenge

Some tough choices…

- Theory vs. practice
- Knowledge vs. skills
- Training vs. Education
- Short-term vs. Long-term outcomes
- Generic vs. Domain-specific
- Lead vs. Lag

Presentation Outline

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What are the Core Characteristics of SE?

Guide the collaborative development of complex systems

- Holistic consideration of the to-be-developed system in its context
- Ideation / analysis / evaluation of system alternatives
- Decomposition and delegation of subsystems and concerns
- Integration of outcomes of delegated tasks
- Oversee the delegated tasks and coordinate, adjust as needed — specifically at the interfaces

What are the Core Skill, Knowledge, Abilities?

How will this change for a model-based future?

- Systems thinking
  - Holistic consideration of system
  - Familiarity with common concerns and influences
- Making decisions under uncertainty
  - Ideation, creativity
  - Probability theory, decision analysis
  - Modeling — information modeling, predictive modeling
  - Model-based inference/reasoning, data analytics
- Decomposition — Integration
  - System architecture, systems-of-systems, requirements engineering
- People — organizations
  - Organizational theory and design
  - leadership, communication
  - Project management

Which Domain Knowledge?

How will this change for a model-based future?

- Customize the curriculum to student interests through electives and flexible project-based learning
- Some domain knowledge is so pervasive that it may need to become part of the core
  - Cyber-physical systems
  - Service systems
  - Cyber-security
  - Sustainability

Example Curriculum — Current Practice

How should this change for a model-based future?

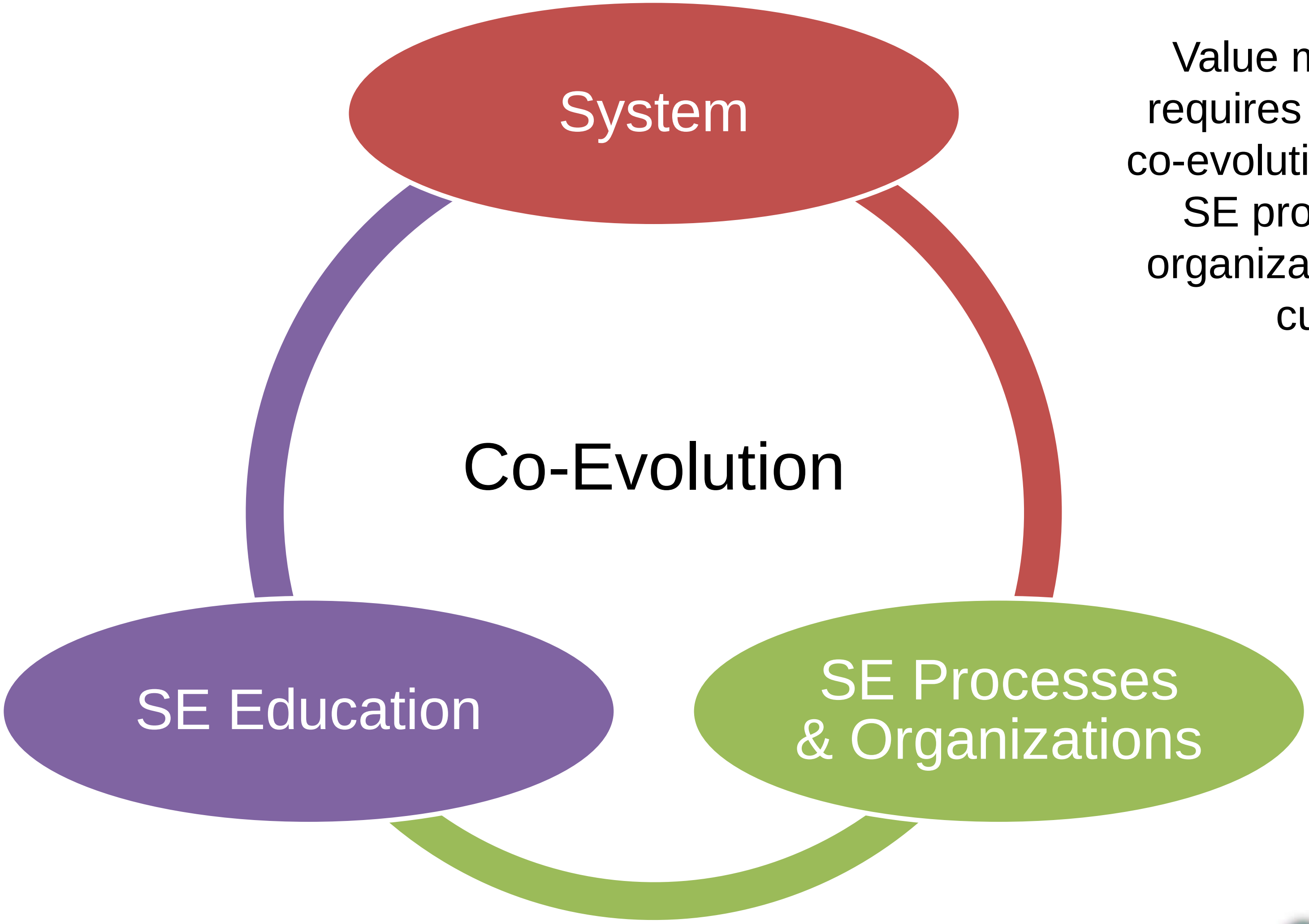
Year 1

- Introduction to Systems Engineering
- Leading Engineering Teams
- Systems Design and Analysis
- Systems Modeling and Optimization
- Systems Modeling with SysML
- Systems Engineering Laboratory

Year 2

- Analysis and Synthesis
  - Vehicle Systems
  - Sensor Systems
  - Information Systems
  - Human Systems
- Systems of Systems and Architectures
- Lifecycle and Integration
- Complex System Capstone Project

Curriculum Must Evolve within Context



Value maximization requires synchronized co-evolution of systems, SE processes and organizations, and SE curricula

Key Takeaways

- Approach: Maximize the expected NPV over the lifetime of the student
- The curriculum should be structured for future practices rather than current practices
- Difficult tradeoff between job readiness and long-term growth potential
- Importance of continuing education