



Preparing Students for Systems Engineering Challenges of the Future

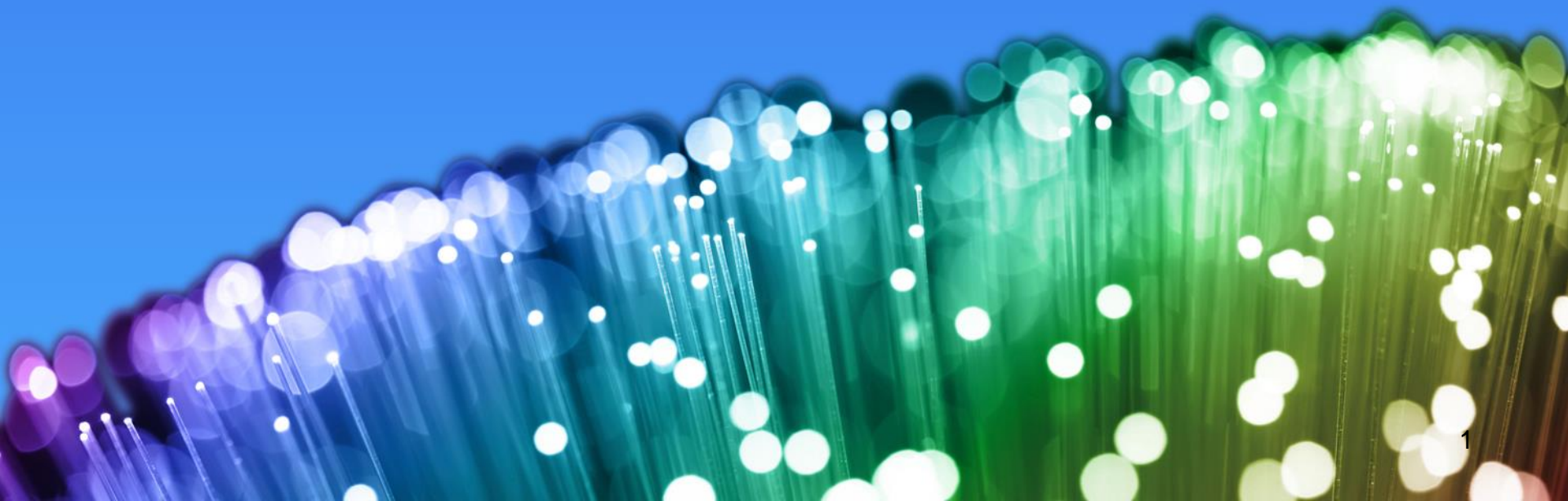
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Disclaimer & Acknowledgment

- 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/>



- 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*

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.

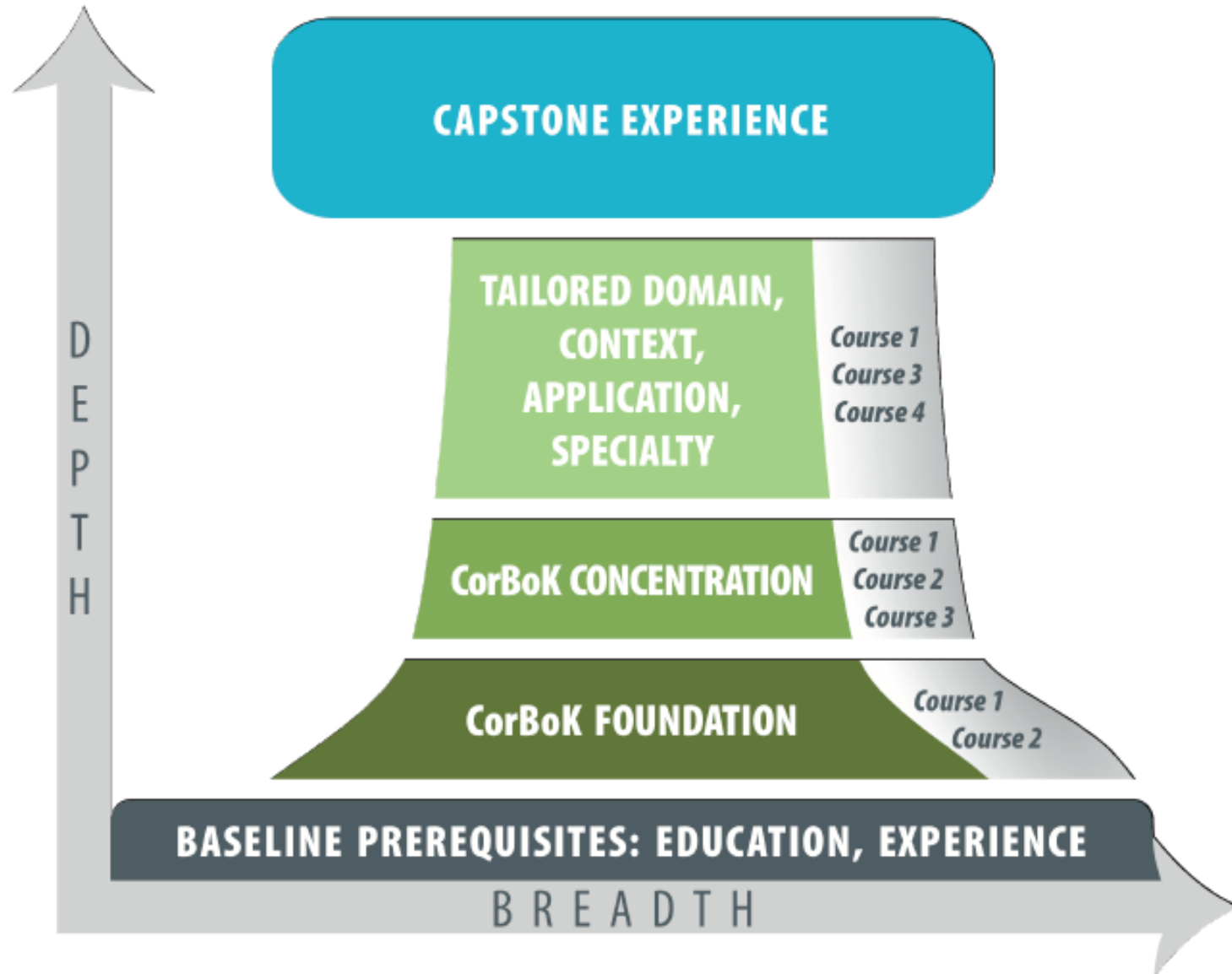


Outcomes — When a Student Graduates

- 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

The screenshot shows a web browser window with the address bar displaying "sebokwiki.org/wiki/Risk_Management". The page title is "Risk Management - SEBoK". The main content area features the SEBoK logo and the text "Guide to the Systems Engineering Body of Knowledge". Below the logo, there are navigation options: "Page", "Read", "View source", "Go", and "Search". The main heading is "Risk Management", followed by a sub-heading "Risk Management". The text describes the purpose of risk management: "The purpose of **risk management** is to reduce potential **risks** to an acceptable level before they occur, throughout the life of the product or project. Risk management is a continuous, forward-looking process that is applied to anticipate and avert risks that may adversely impact the project, and can be considered both a **project management** and a **systems engineering** process. A balance must be achieved on each project in terms of overall risk management ownership, implementation, and day-to-day responsibility between these two top-level processes." It also states: "For the SEBoK, risk management falls under the umbrella of **Systems Engineering Management**, though the wider body of risk literature is explored below." Below the text is a "Contents [hide]" section with a list of links: "1 Risk Management Process Overview", "1.1 Risk Planning", "1.2 Risk Identification", "1.3 Risk Analysis", "1.4 Risk Handling", and "1.4.1 Risk Handling Plans". On the left side, there are "Quicklinks" and "Outline" sections. The "Quicklinks" section includes links for "Main Page", "Letter from the Editor", "BKCASE Governance and Editorial Board", "Acknowledgements and Release History", "How to Read the SEBoK", "Download SEBoK PDF", "Copyright Information", "Cite the SEBoK", "About the SEBoK", and "Sandbox". The "Outline" section includes "Table of Contents" and "Part 1: SEBoK Introduction", "Part 2: Systems", and "Part 3: SE and Management".

Risk Management - SEBoK

sebokwiki.org/wiki/Risk_Management

sebok risk management

Log in

Page Read View source Go Search

Risk Management

Risk Management

The purpose of **risk management** is to reduce potential **risks** to an acceptable level before they occur, throughout the life of the product or project. Risk management is a continuous, forward-looking process that is applied to anticipate and avert risks that may adversely impact the project, and can be considered both a **project management** and a **systems engineering** process. A balance must be achieved on each project in terms of overall risk management ownership, implementation, and day-to-day responsibility between these two top-level processes.

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Quicklinks

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Outline

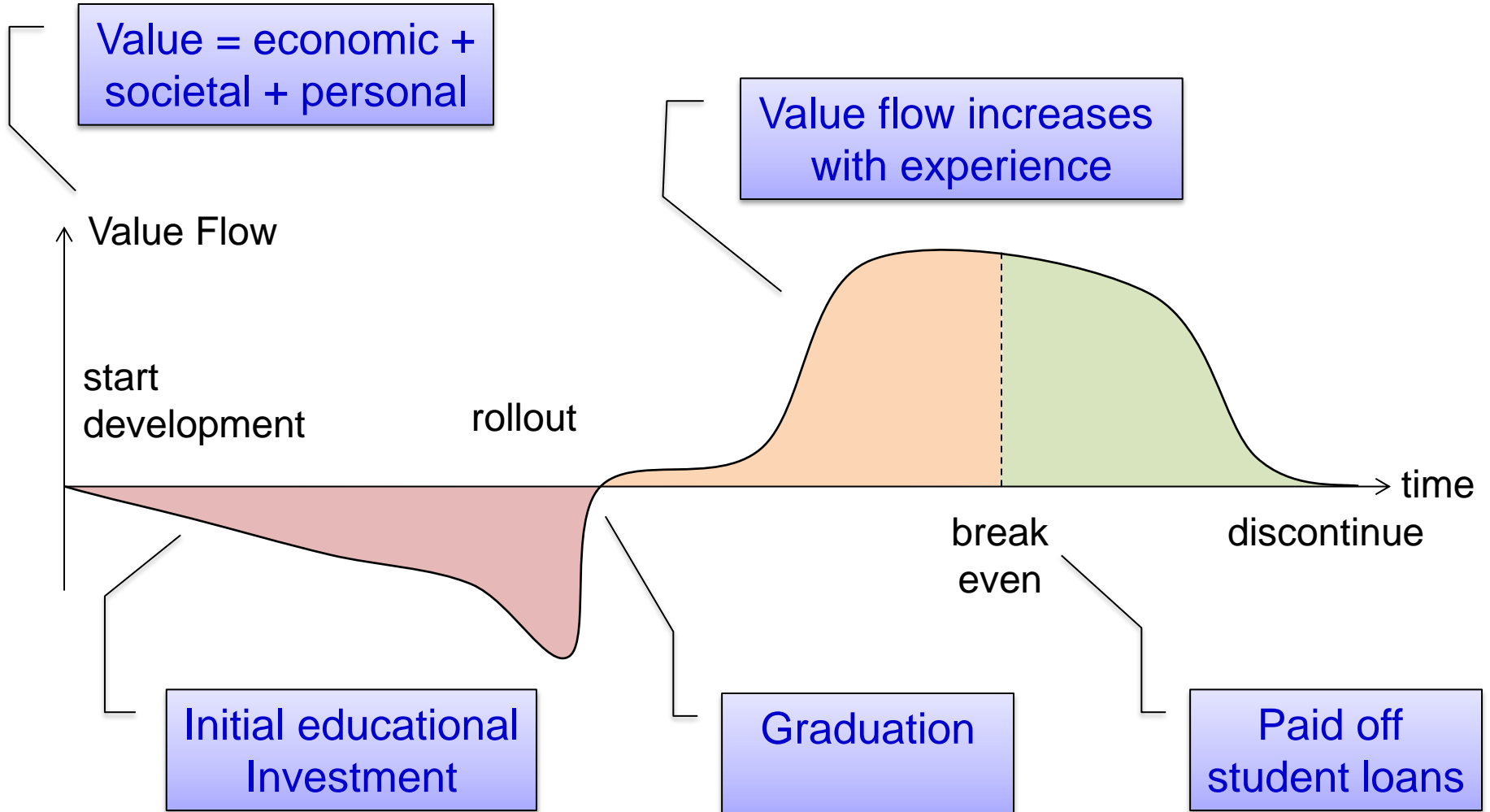
- Table of Contents
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- Part 2: Systems
- Part 3: SE and Management

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

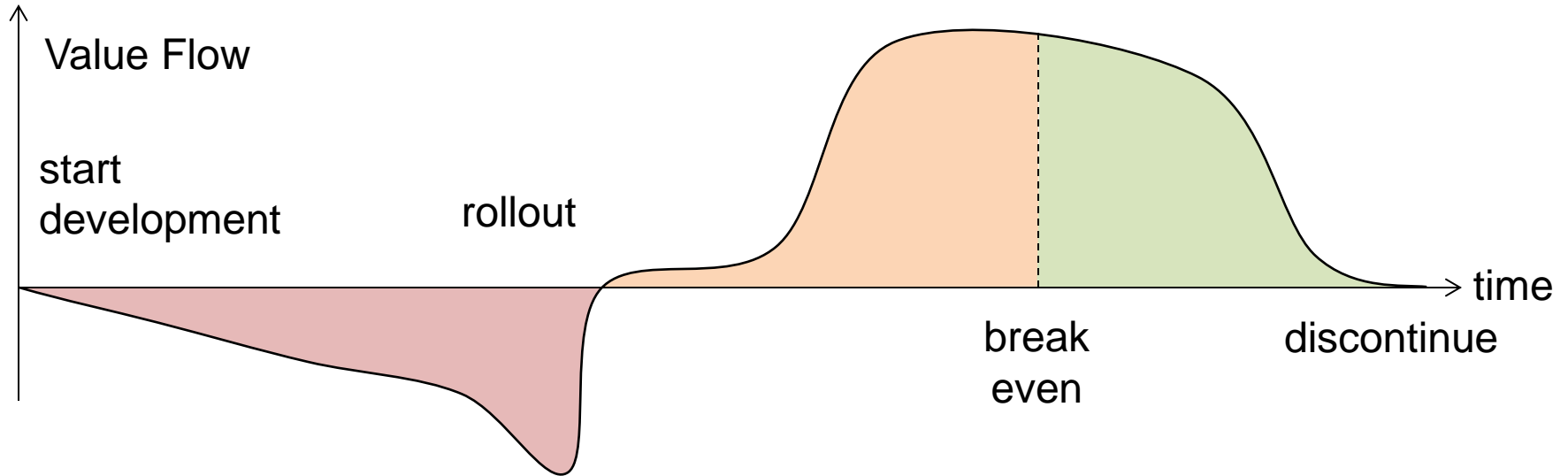
A Systems Engineering Perspective

- 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

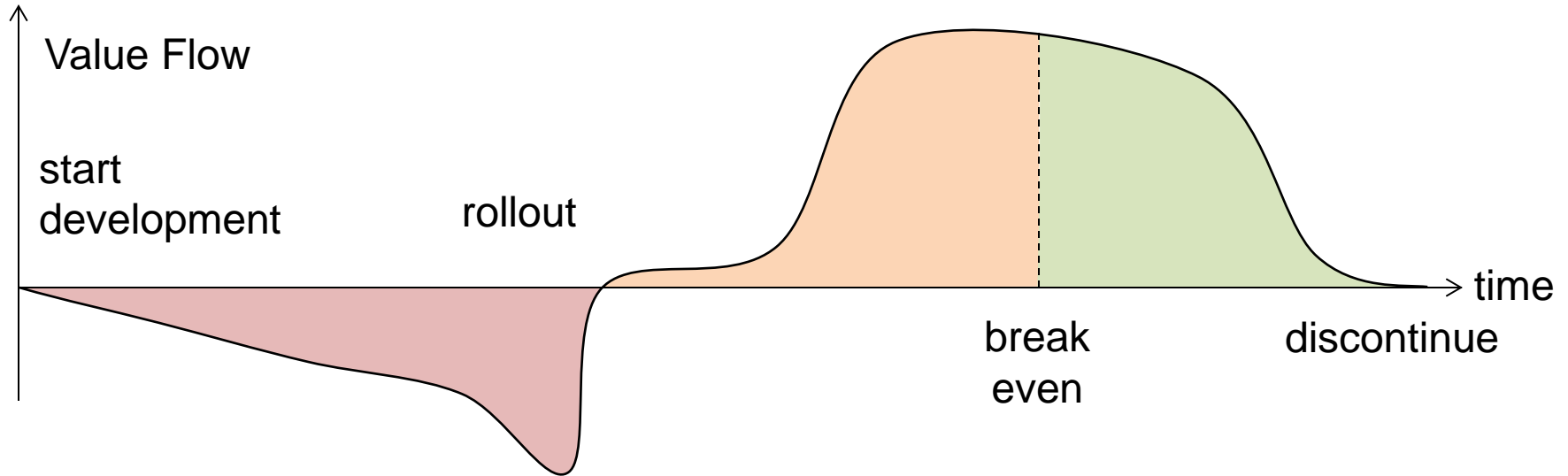
How is the Expected NPV influenced by the curriculum?



- **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

SE Practice

Concept Definition

System Architecting

Functional Analysis

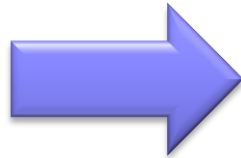
Risk Management

Requirements Engineering

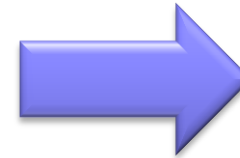
Interface Definition

Tradespace Analysis

Observe & Describe



Understand & Explain



Extend & Improve

Systems Theory

Probability Theory

Organizational Theory

Behavioral Economics

Foundations

Decision Theory

Economics

Psychology

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

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

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

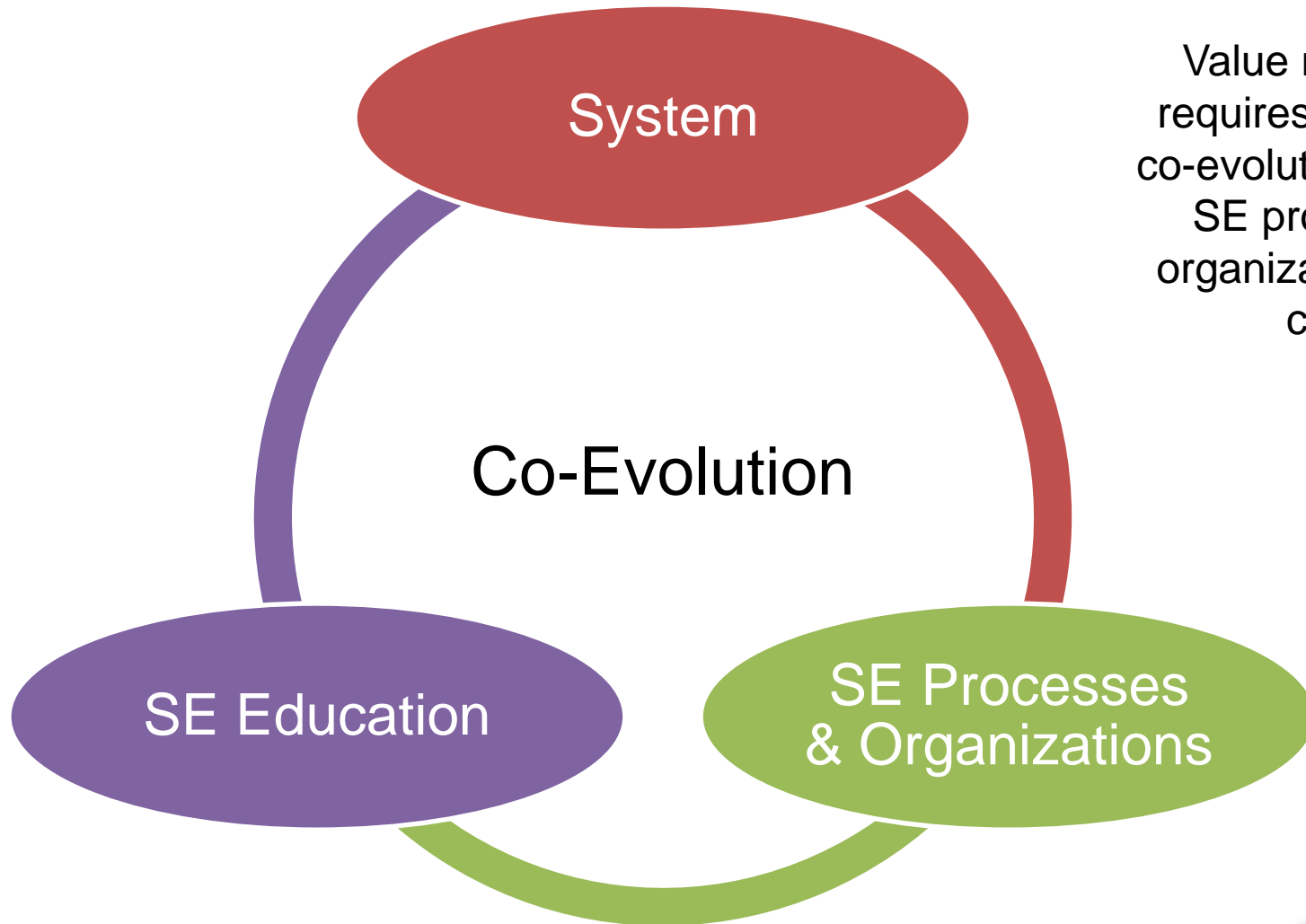
- Introduction to Systems Engineering
- Leading Engineering Teams
- Systems Design and Analysis
- Systems Modeling and Optimization
- Systems Modeling with SysML
- Systems Engineering Laboratory

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