Program Overview:
Engineering & Systems Design (ESD)
Systems Science (SYS)

Version 1.14
Apr 14, 2015

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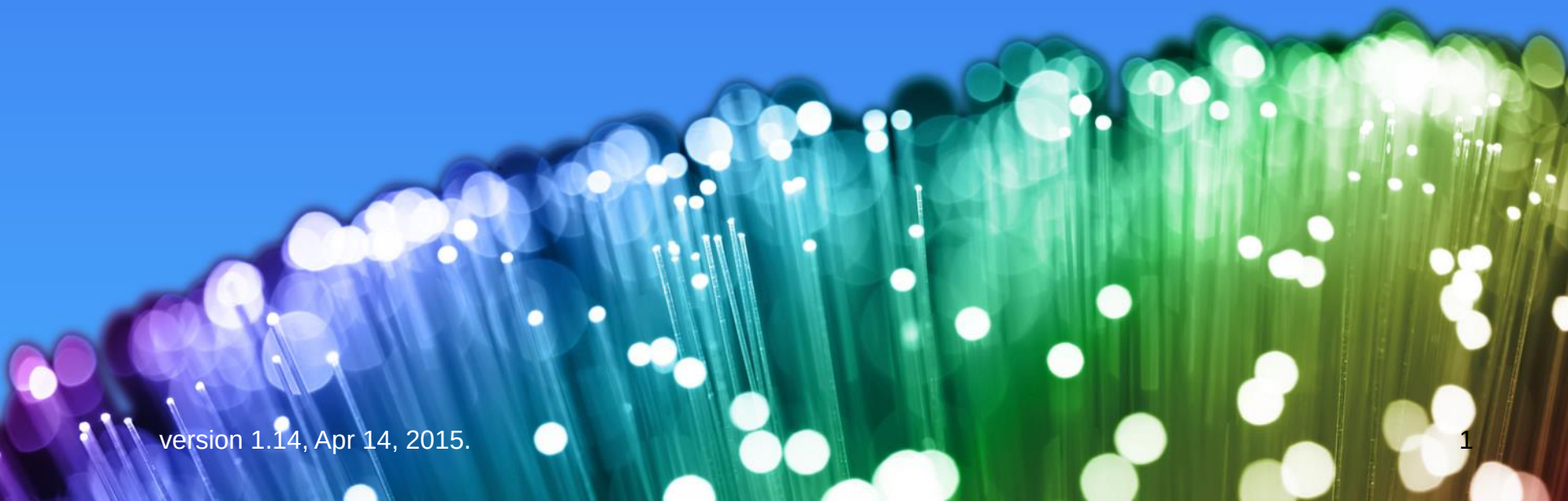


Disclaimer

- 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.

- In October 2014, a presentation similar to this one was recorded. The video is available at http://tinyurl.com/ESD-SYS

Outline

- A conceptual framework for systems engineering and design
- Systems Science
  - Program details, research examples, and future directions
- Engineering and Systems Design
  - Program details, research examples, and future directions
- Discussion

Starting from the Basics…

SE & Design are Processes with a Purpose

- What is the purpose of these processes?

→ To obtain a state of the world that is more preferred

→ To add value

- How do we add value?

→ By creating or improving artifacts

- SE & Design are transformation processes
  - Primarily a process of information transformation — we compile information specifying a plan for how to add value

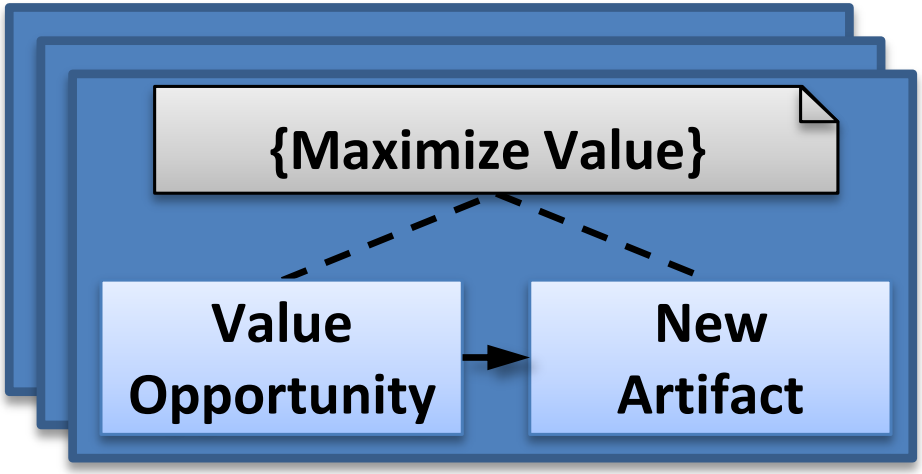
→ Planning before executing adds value

What do we Mean by Value?

Value is an Expression of the Preferences of the Designer

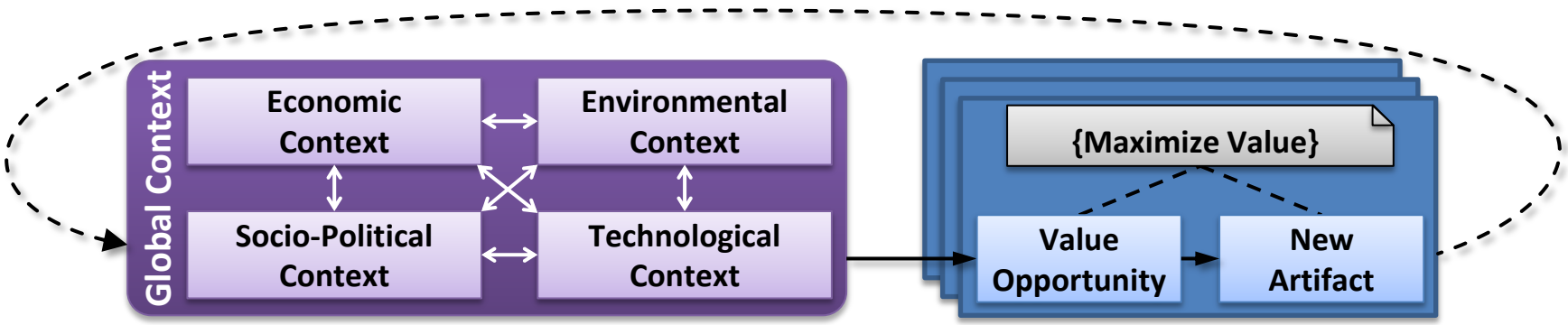
- Value is an expression of preference – the more an outcome is preferred, the higher the value assigned to it
  - A philanthropist may assign high value to an alternative that significantly increases well-being even if it cannot be produced at a profit
  - An environmentalist may assign high value to environmentally friendly, sustainable alternatives
  - A publicly traded company may assign high value to profitable alternatives
- Value is often expressed in monetary terms
  - If a designer prefers outcome A over outcome B then he/she is willing to pay an amount of $\Delta v = v_A - v_B$ to exchange B for A
  - No loss of generality

SE & Design: Maximizing Value



SE & Design: Maximizing Value

Value Opportunities in a Global Context



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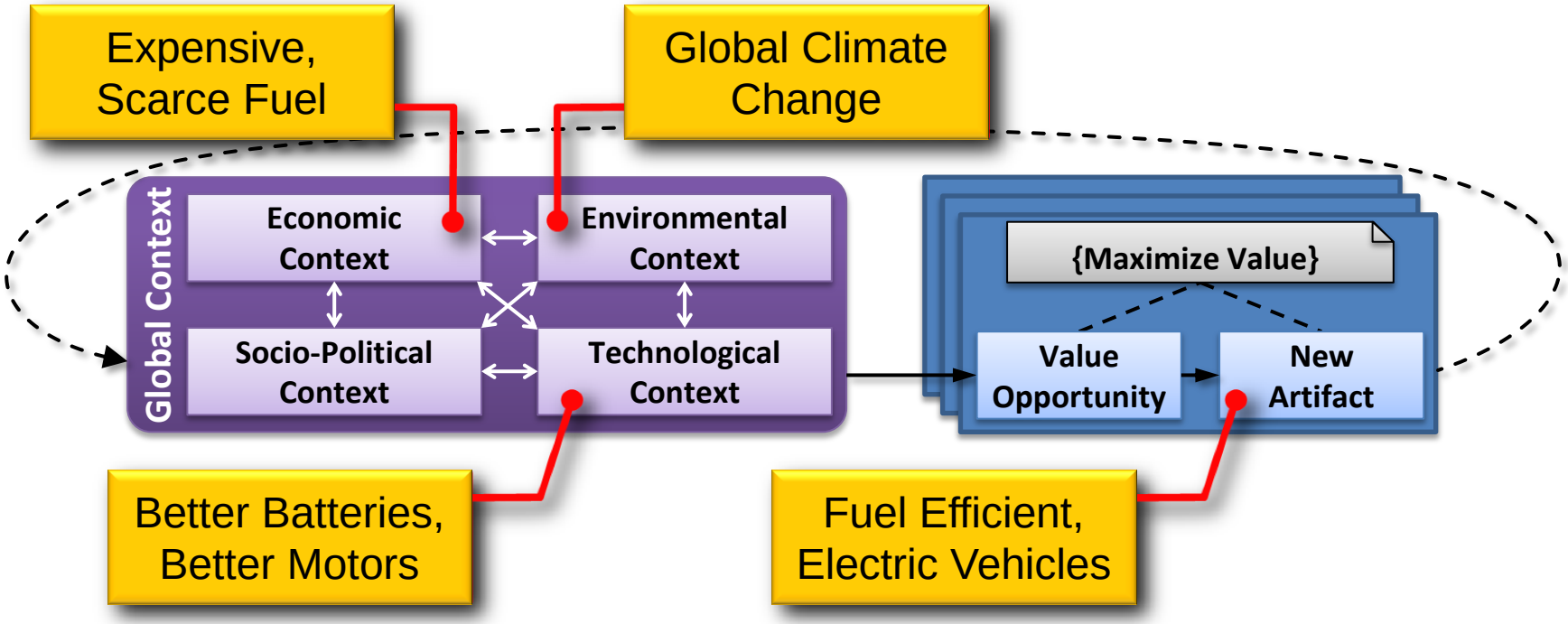
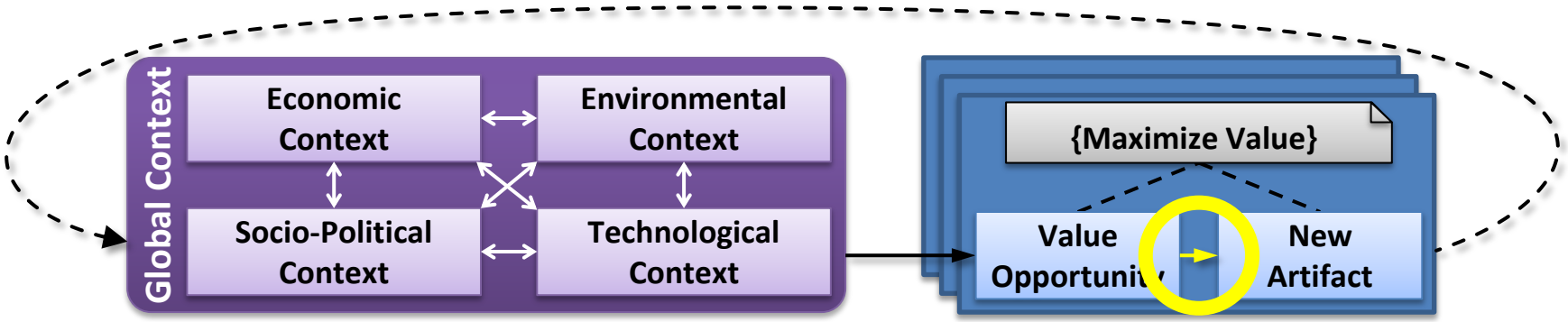


SE & Design: Maximizing Value

Value Opportunities are Restricted by SE&D Capabilities



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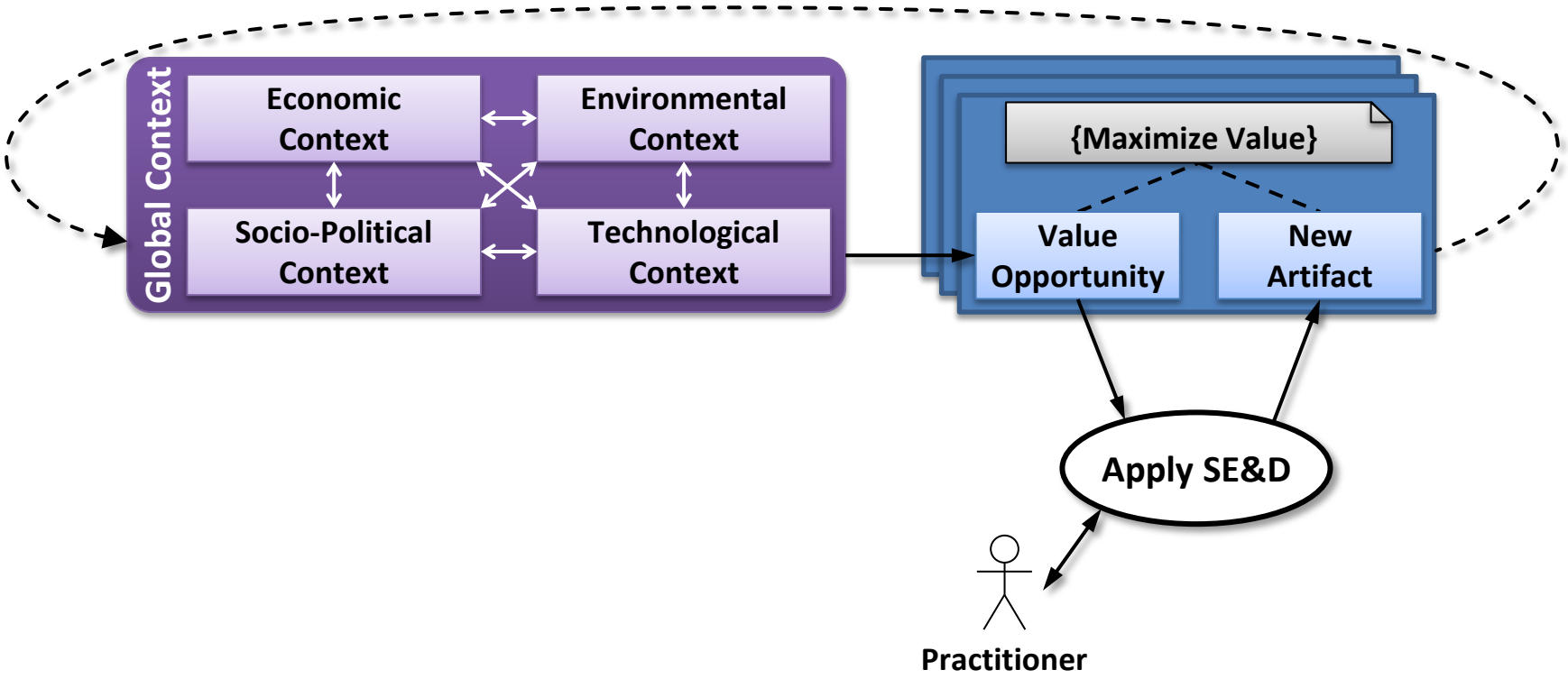
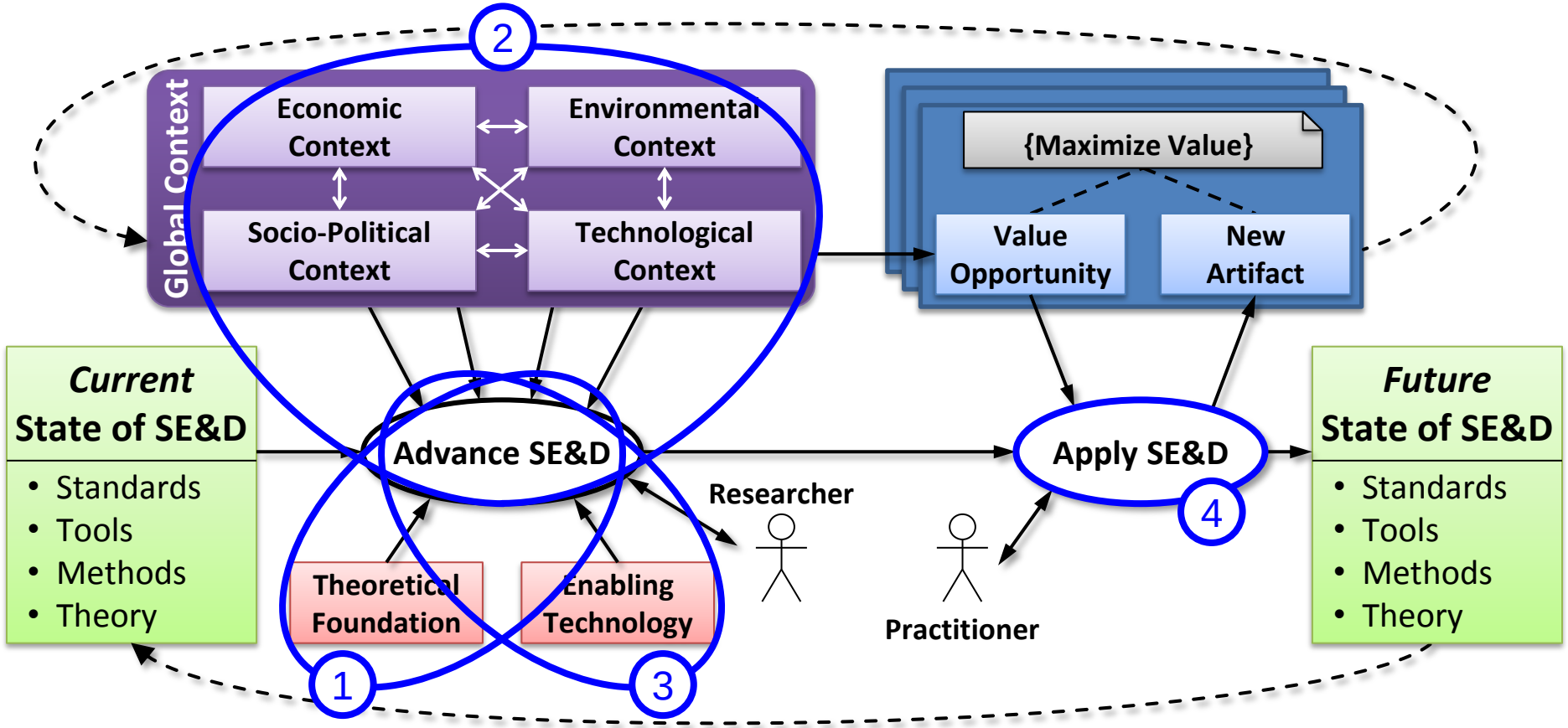


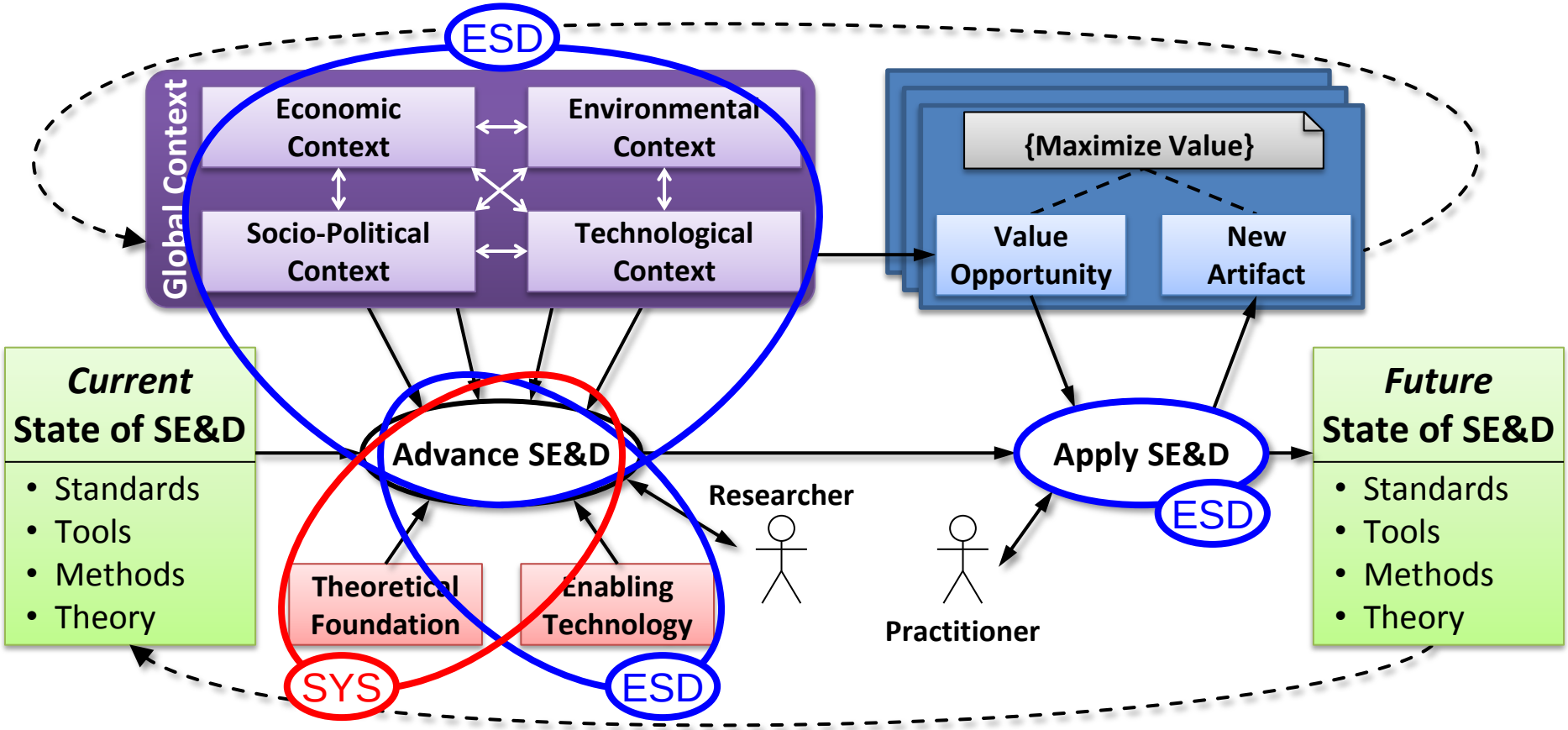
SE & Design: Maximizing Value

Value Maximization Drives Advances in SE&D



Where do SYS and ESD fit in?

Value Maximization Drives Advances in SE&D



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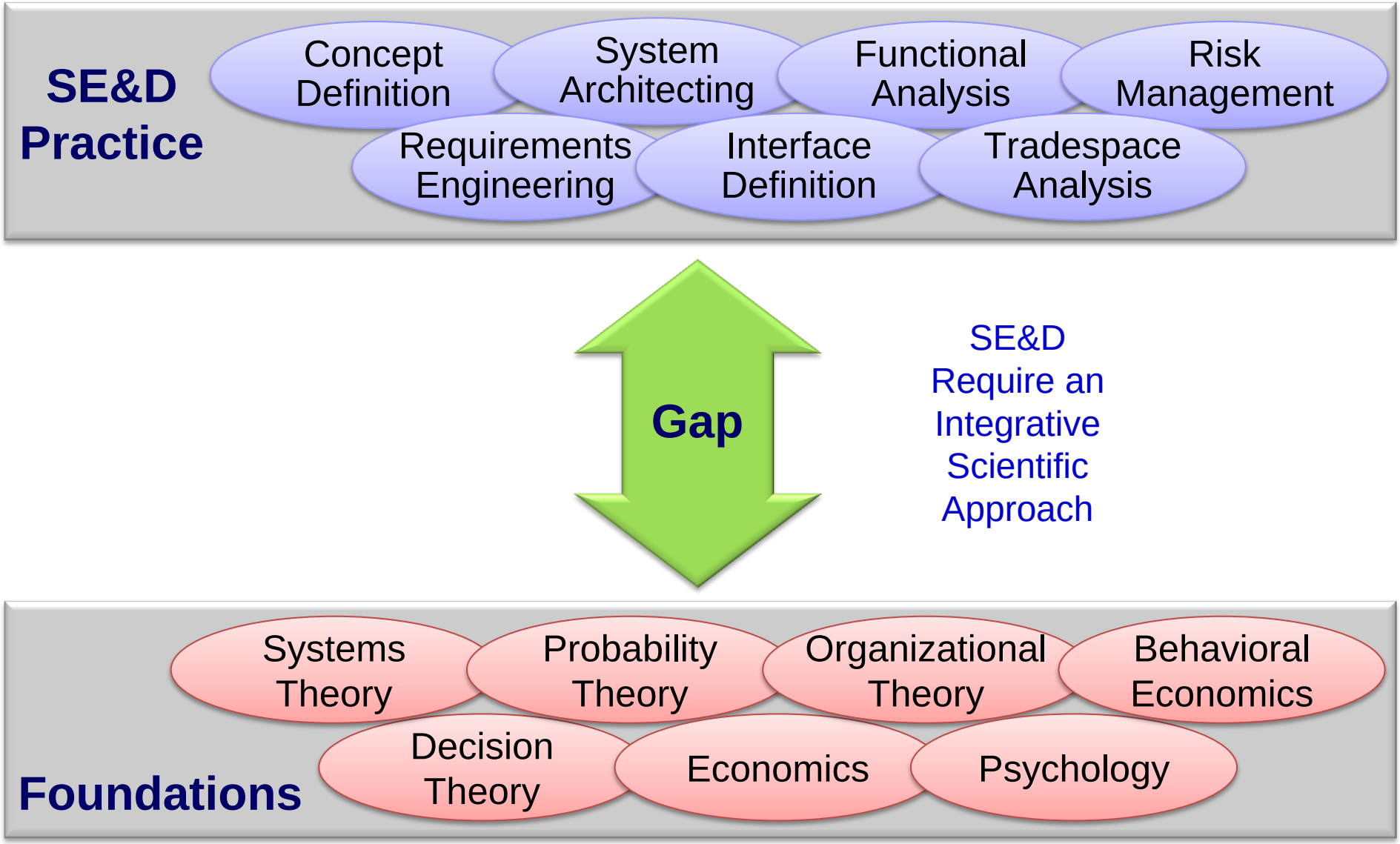
Systems Science (SYS)

Theoretical Foundation for SE & Design



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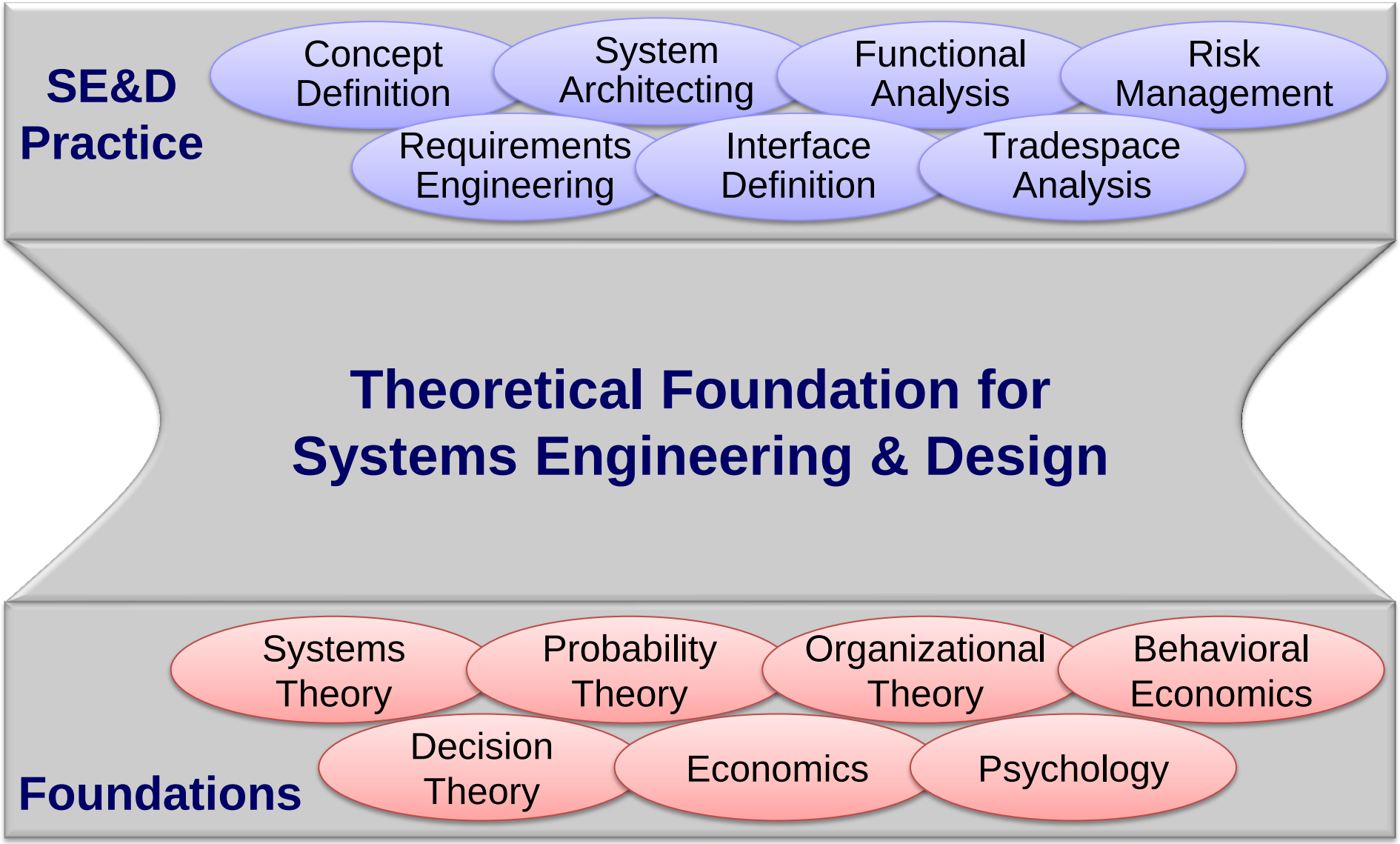

Systems Science (SYS)

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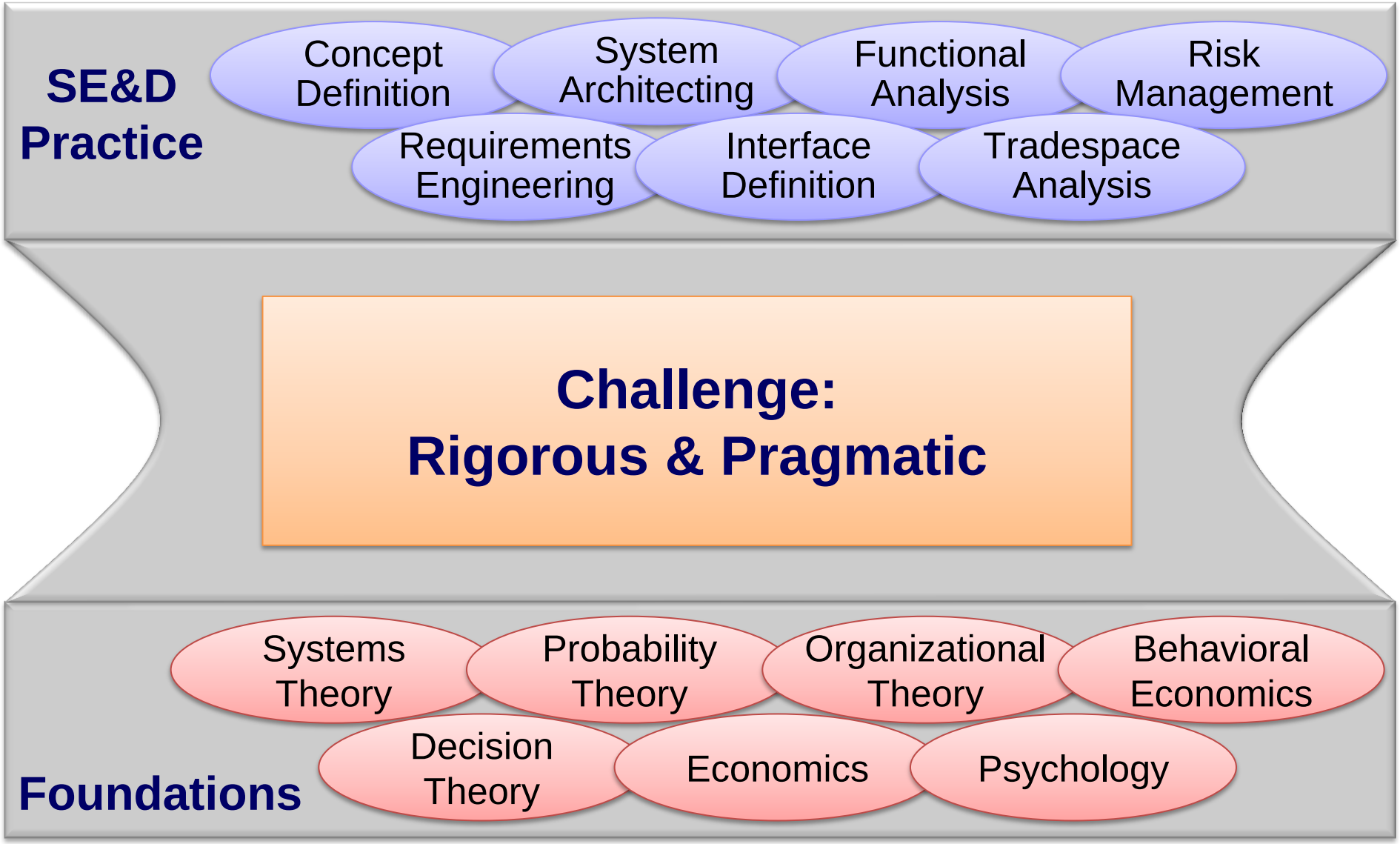


Systems Science (SYS)

Program Overview

- Role of Program
  - Leadership in grounding systems engineering and design practice on a rigorous theoretical foundation
- Focus
  - Theoretical foundation of systems engineering & design
  - Application domain independent
  - Special emphasis on Complex Engineered Systems
  - Draw on or extend established theory in mathematics, economics, organizational theory, social psychology, and other relevant fields
  - Empirical research is in scope when characterizing a theoretical model

→ An integrative scientific approach to support the development of complex engineered systems

Systems Science (SYS)

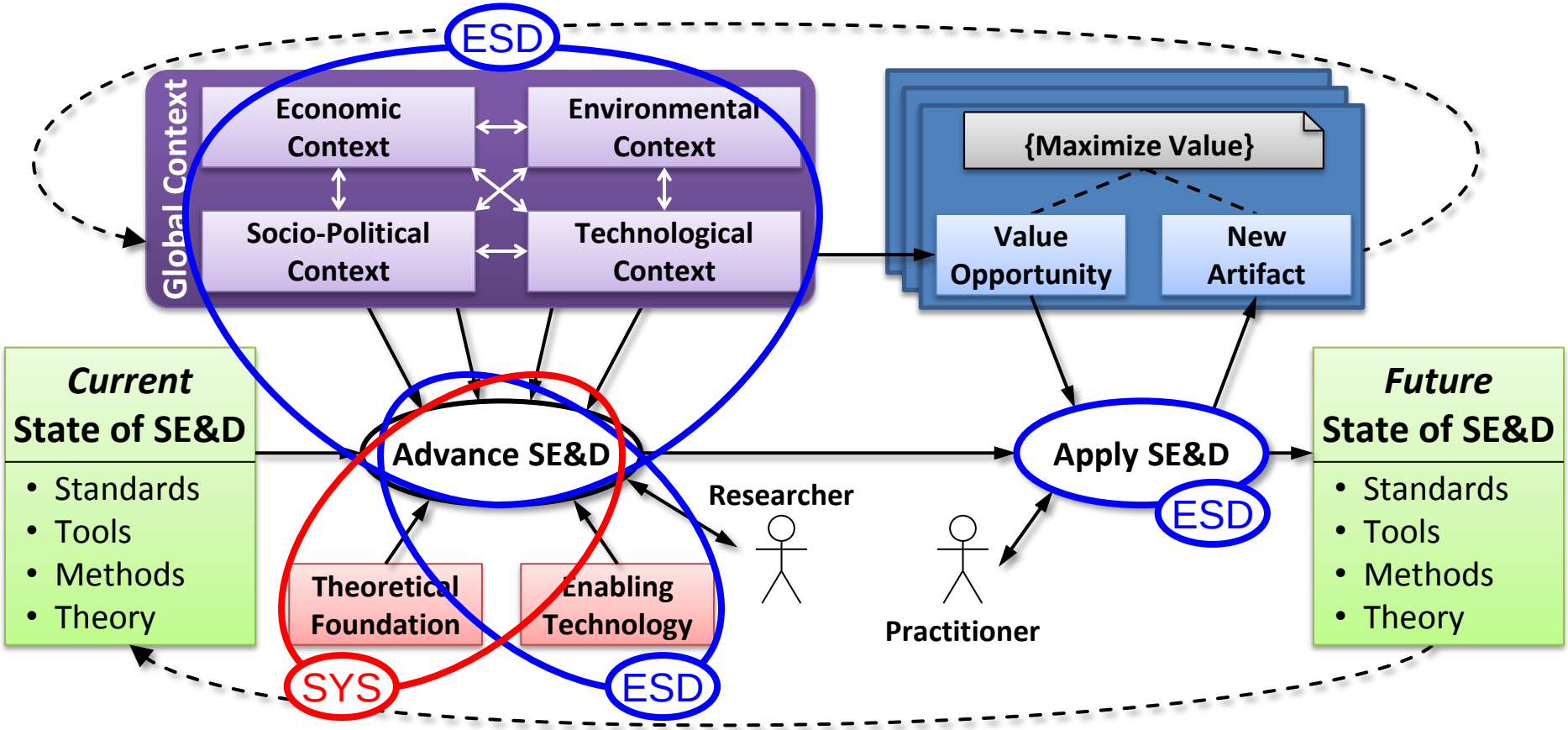
Research Directions

- Processes: Search Strategy, Guidance and Control
  - Design as a search process → What are good search strategies? Appropriate abstractions? Metrics for process control? Influence of uncertainty?
- Organizations: Decomposition, Communication and Incentivisation
  - How to decompose problems and delegate the decomposed parts? Impact of incentive structures? How to facilitate communication between experts with disparate backgrounds towards ideation and analysis in design?
- Modeling: Creation, Use and Assessment of Models
  - Which modeling formalisms are most appropriate when? What are the cognitive models of modeling? How best to teach modeling? How to facilitate reuse and sharing? How to assess and characterize the accuracy and applicability of models?
- Research Methodology
  - We want to "improve" design, but we don't agree on what "good" means or how to assess "goodness"

  → Given that the theoretical foundations need to be operationalized into pragmatic, domain-specific methods and tools that are based on approximations of the foundations, how can we efficiently and effectively derive such methods and tools, and characterize their performance and applicability?

Where do SYS and ESD fit in?

Value Maximization Drives Advances in SE&D



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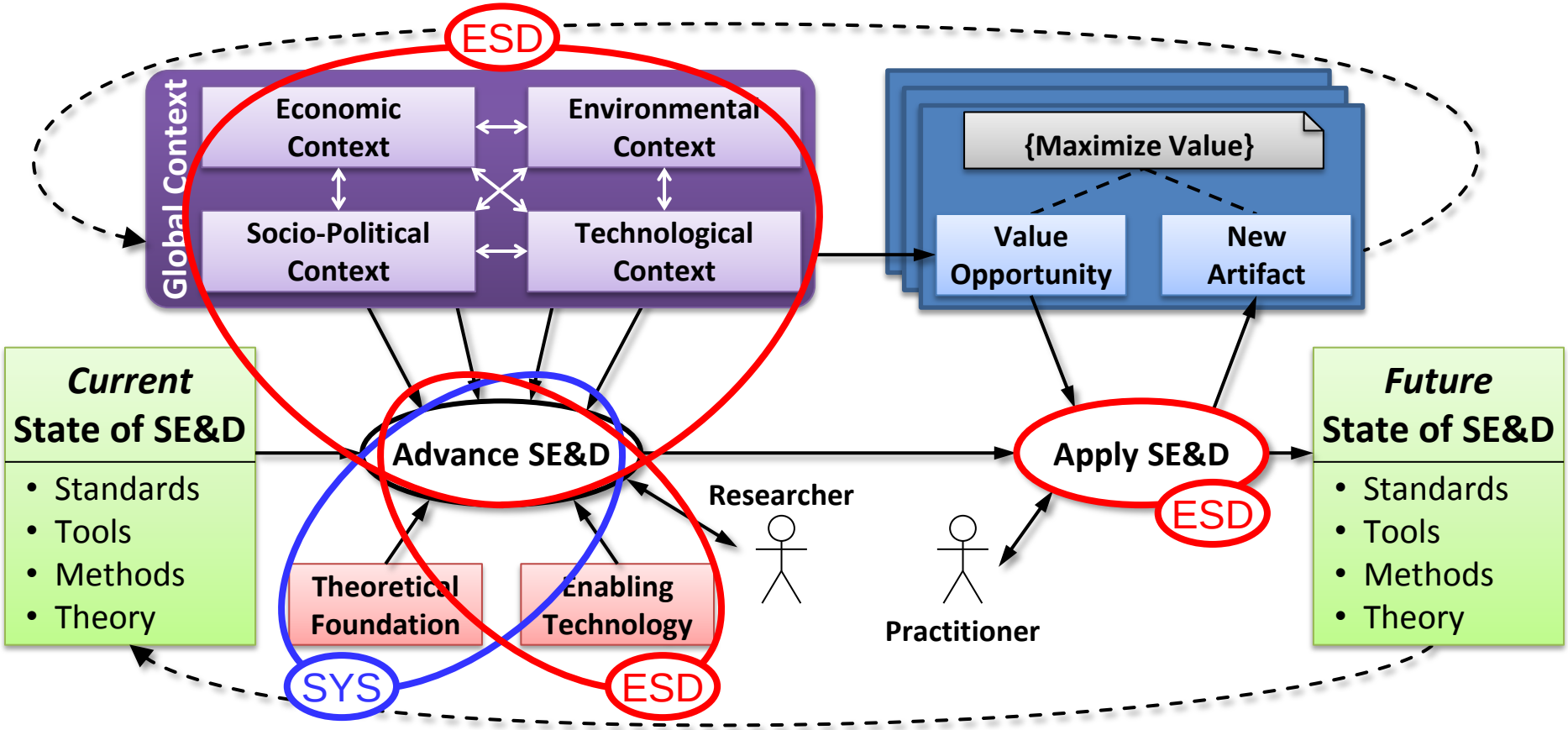

Engineering & Systems Design (ESD)

Building on the Theoretical Foundation

SE&D Practice

- Concept Definition
- System Architecting
- Functional Analysis
- Risk Management
- Requirements Engineering
- Interface Definition
- Tradespace Analysis

Challenge:
Rigorous & Pragmatic
→ Context-Specific Approximations

Foundations

- Systems Theory
- Probability Theory
- Organizational Sociology
- Behavioral Economics
- Decision Theory
- Economics
- Psychology

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Engineering & Systems Design (ESD)

SE&D Methods & Tools for a Specific Context

- As the context changes, SE&D must adapt…

…by operationalizing the theoretical foundation for each specific context

- Increasing complexity
- Shorter lifecycle times
- Decentralization
- Systems of Systems
- Mass-customization
- Human-centered

- Cloud-based high-performance computing
- Big data
- Immersive data visualization
- Net-enabled collaboration

Engineering & Systems Design (ESD)

SE&D Methods & Tools for a Specific Context

- As the context changes, SE&D must adapt…

…by operationalizing the theoretical foundation for each specific context

A new context implies new approximations:

- Synthesis heuristics — which architecture patterns?
- Analysis idealizations — which formalisms, fidelity?
- SE&D process heuristics — when to do what?
- Organizational structure — who does what?

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- D
- Systems of Systems
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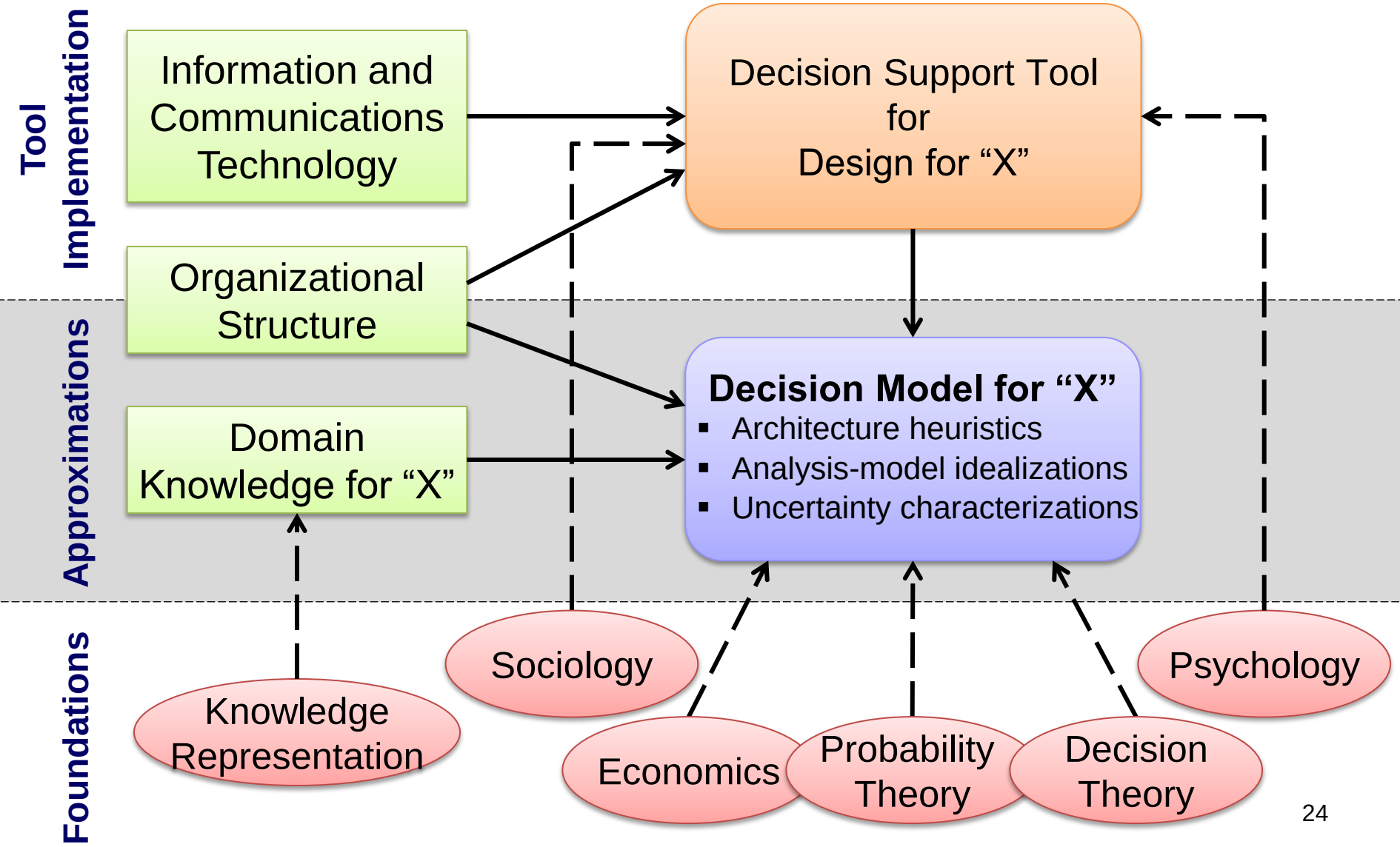
Engineering & Systems Design (ESD)

An Illustrative Example



Engineering & Systems Design (ESD)

Program Overview

- Role of Program
  - Leadership in advancing engineering and systems design practices for current and future global contexts, by combining rigor and pragmatism
- Program Focus
  - Operationalizing the theoretical foundation in specific contexts
    - » Develop pragmatic methods to apply the theory efficiently and effectively in a specific economic, socio-political, environmental and technological context
  - Rigorously characterizing current and novel methods
    - » In which context and under which assumptions is a method effective?
    - » Rigorously gather theoretical and empirical evidence, regarding current and improved practices
  - Education
    - » Develop effective teaching strategies rigorously based on cognitive models

Engineering & Systems Design (ESD)

Research Directions

- Design for X
  - *X = Specific Application Domain* — energy systems, consumer products, additive mfg,…
  - *X = Specific Concern* — resilience, sustainability, usability, manufacturability, …
- Novel Information and Communication Technologies in SE&D
  - immersive visualization and human-computer interaction, social networking and net-enabled collaboration, modeling frameworks and languages, data mining and analytics, high-performance computing and cloud-computing
- Novel Modeling Formalisms & Algorithms
  - Formalisms and algorithms for representing and manipulating form, function and behavior; algorithms for analysis, simulation, optimization, or reasoning; algorithms for prediction, uncertainty quantification and propagation
- Novel Integrated Frameworks for SE&D
  - Frameworks combining concept generation, gradual specification refinement, models at different abstractions, uncertainty characterization, optimization, human input, HPC, visualization, … to achieve efficient and effective search.

→ We Need to Rigorously Characterize and Assess Domain-Specific Methods

How to get Research Funding from NSF?

Start a Conversation with NSF

- Volunteer to be a review panelist
  - E-mail a 1-page description of your background & interests to the program director
- Request feedback on your proposal ideas
  - E-mail a 1-page project summary: What is the idea? Intellectual merit? Broader impact?
  - PD will typically follow in writing or over the phone
- Approach program directors at meetings/conferences
- Be informed – subscribe to NSF News
  - https://www.nsf.gov/news/ (e-mail subscription possible)

Program Opportunities & Logistics

What you need to know to submit your proposal?

- Unsolicited proposals submission windows
  - Fall: September 1-15
  - Spring: February 1-15
- Typical scope of proposals:
  1-2 PIs, 1-2 PhD students, 3 years
- CAREER proposals (only for assistant professors)
  - Deadline: July 22, 2015
  - Solicitation number: NSF 15-555
  - Budget: $500,000

Related Programs

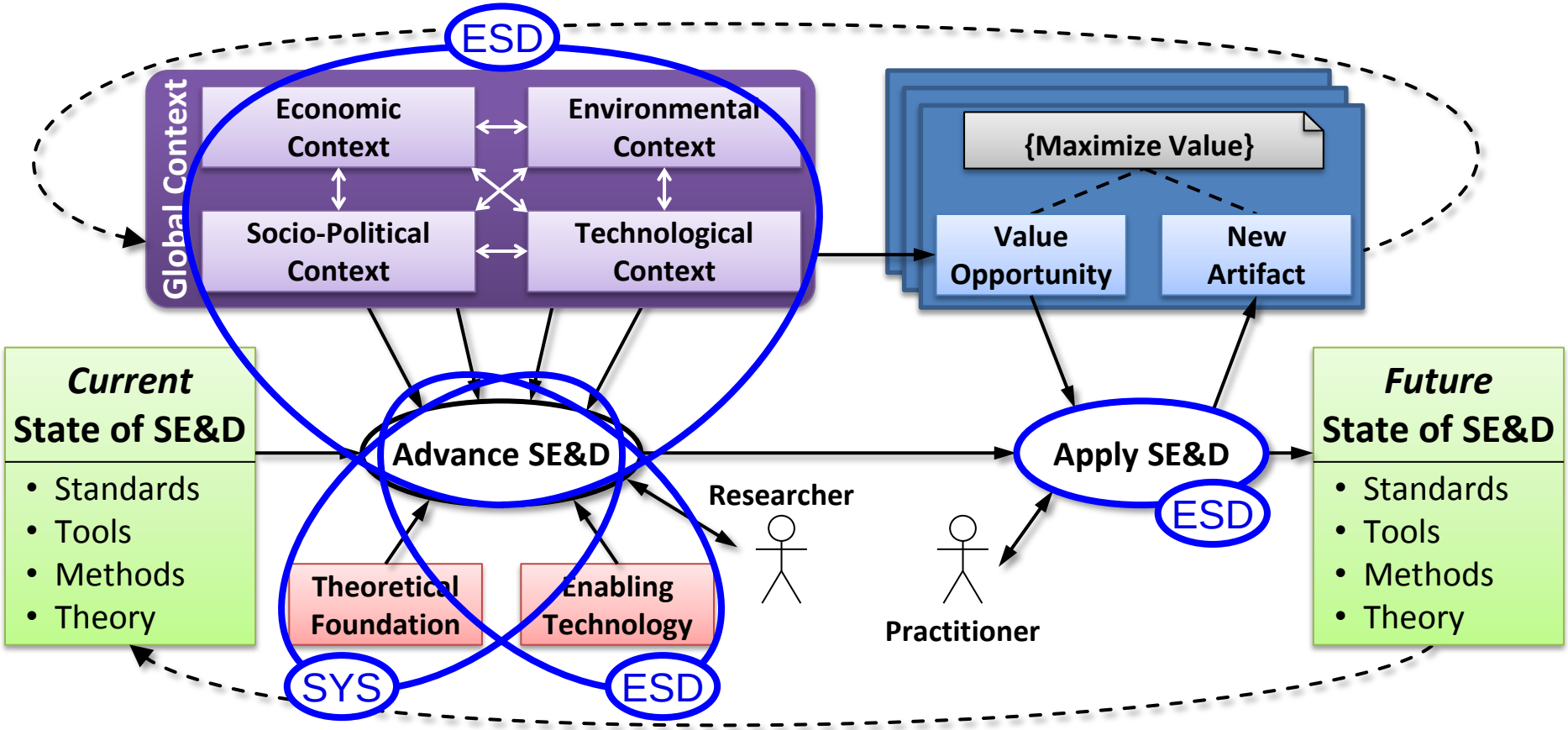
How can you expand your funding base?

- GOALI: Grant Opportunities for Academic Liaison with Industry
- DEMS: Design of Engineering Material Systems
- RSB: Decision Frameworks for Multi-Hazard Resilient and Sustainable Buildings
- CPS: Cyber-Physical Systems
- ACI: Advanced Cyberinfrastructure
- CDS&E: Computational and Data-Enabled Science and Engineering
- INSPIRE: see NSF 14-106. We will specifically consider proposals that tie SE&D to organizational sociology or cognitive science — other interdisciplinary topics will be considered also.

- Additional opportunities will follow… Subscribe to NSF News

Summary

Advancing the State of Knowledge in Systems Engineering and Design



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