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David Rousseau BEng PhD FRSA

President, International Society of the Systems Sciences

Director, Centre for Systems Philosophy (UK)

A Framework for Understanding Systems Principles and Methods

www.incose.org/symp2018

SE's interest in systems principles

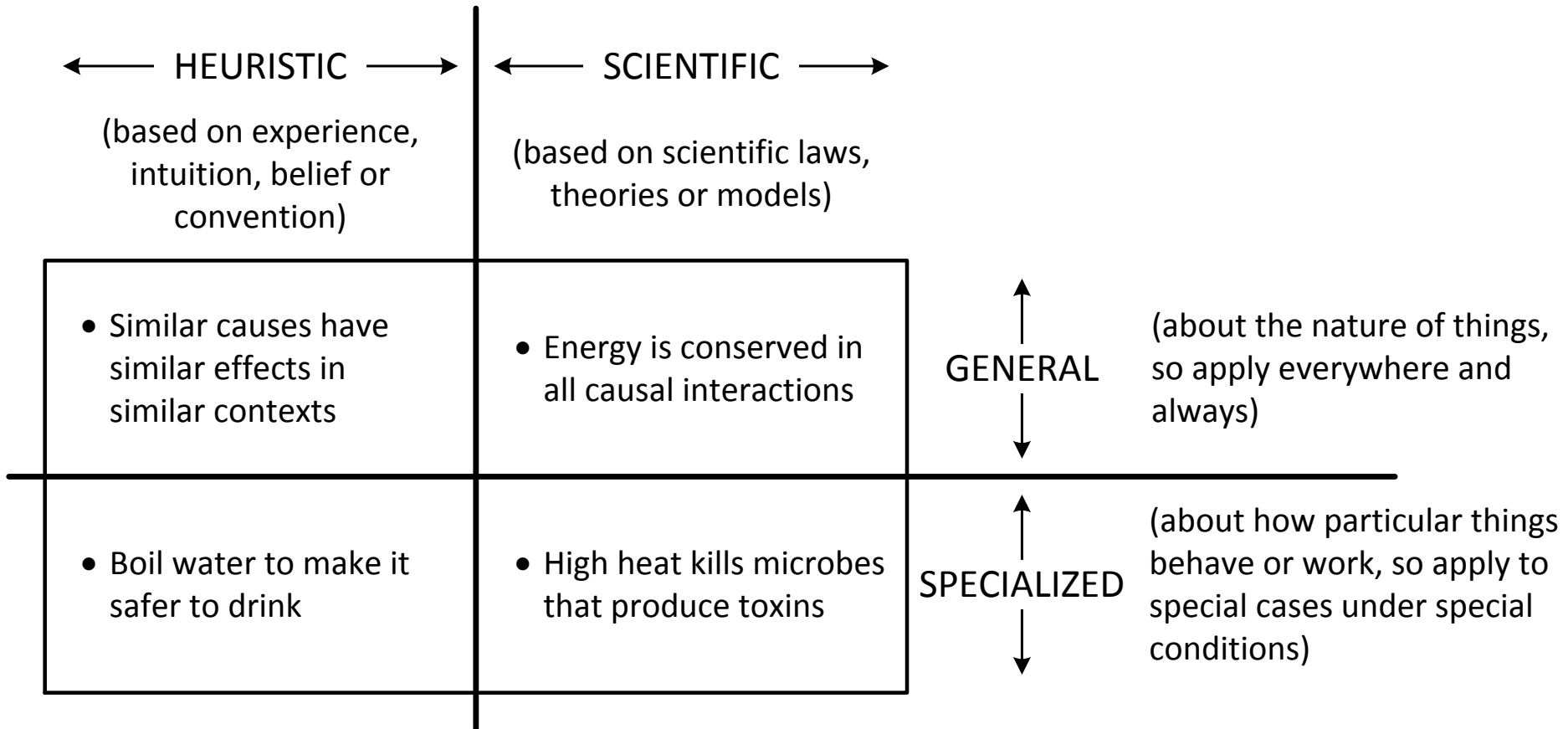"It is important to develop a scientific foundation that helps us to understand … the emergent properties of the whole. This reflects a shift in emphasis from reductionism to holism. Systems Science seeks to provide a common vocabulary (ontology), and general principles explaining the nature of complex systems"

INCOSE Vision 2025
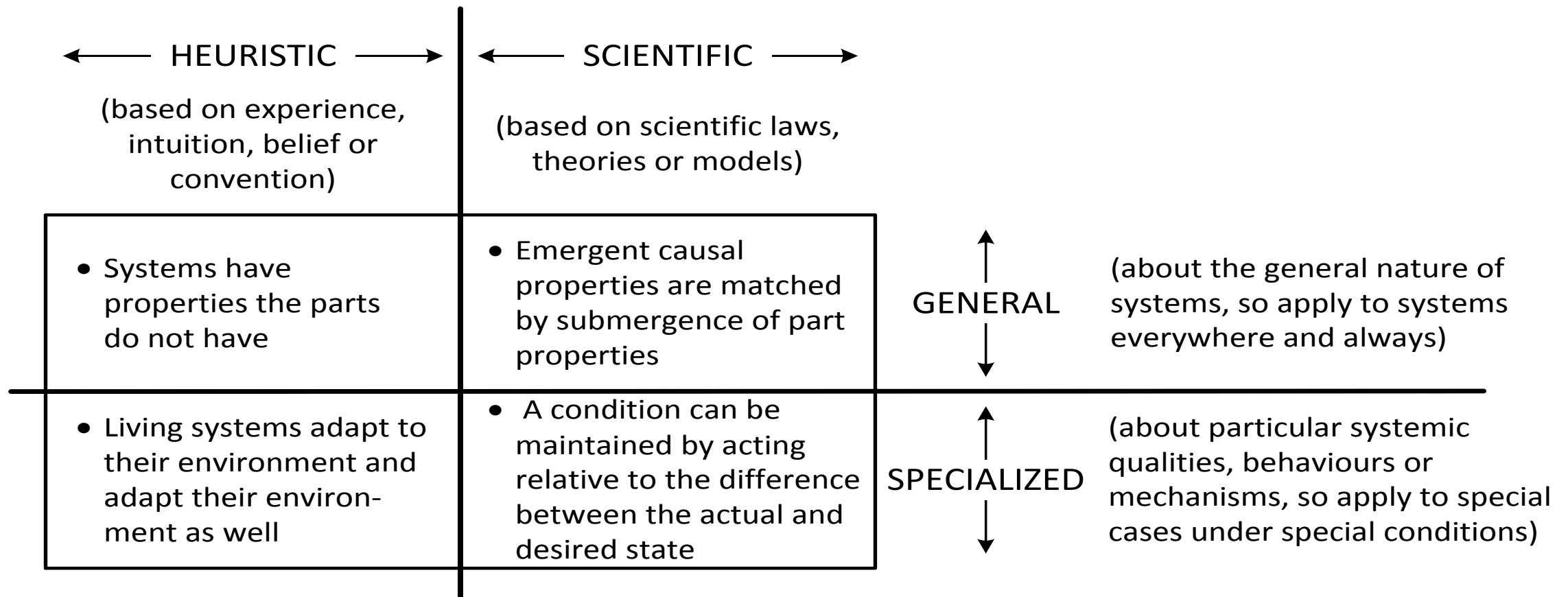
What are principles?

- A principle is a rule that provides guidance for making a judgement or taking action
- It represents the take-away or bottom line distilled from theories, experience or intuition
- They come in four types:

	← HEURISTIC →	← SCIENTIFIC →	
	(based on experience, intuition, belief or convention)	(based on scientific laws, theories or models)	
GENERAL	• Similar causes have similar effects in similar contexts	• Energy is conserved in all causal interactions	(about the nature of things, so apply everywhere and always)
SPECIALIZED	• Boil water to make it safer to drink	• High heat kills microbes that produce toxins	(about how particular things behave or work, so apply to special cases under special conditions)

What are *systems* principles?

- A *systems* principle is a rule that provides guidance for judgement or action in systemic contexts e.g. system design or systemic intervention
- It represents the take-away distilled from theories, experience or intuition re *systems*

← HEURISTIC →	← SCIENTIFIC →		
(based on experience, intuition, belief or convention)	(based on scientific laws, theories or models)		
• Systems have properties the parts do not have	• Emergent causal properties are matched by submergence of part properties	GENERAL	(about the general nature of systems, so apply to systems everywhere and always)
• Living systems adapt to their environment and adapt their environment as well	• A condition can be maintained by acting relative to the difference between the actual and desired state	SPECIALIZED	(about particular systemic qualities, behaviours or mechanisms, so apply to special cases under special conditions)

Principles guide us through the stages of any scientific endeavor

Activity Stages of a Scientific Endeavour

Principles guide us through the stages of any scientific endeavor

Activity Stages of a Scientific Endeavour

1   2   3   4

Challenge Concern Opportunity Interest

Reflection Conceptualization Problem structuring etc.

Research Exploration Experimentation Explanation Prediction etc.
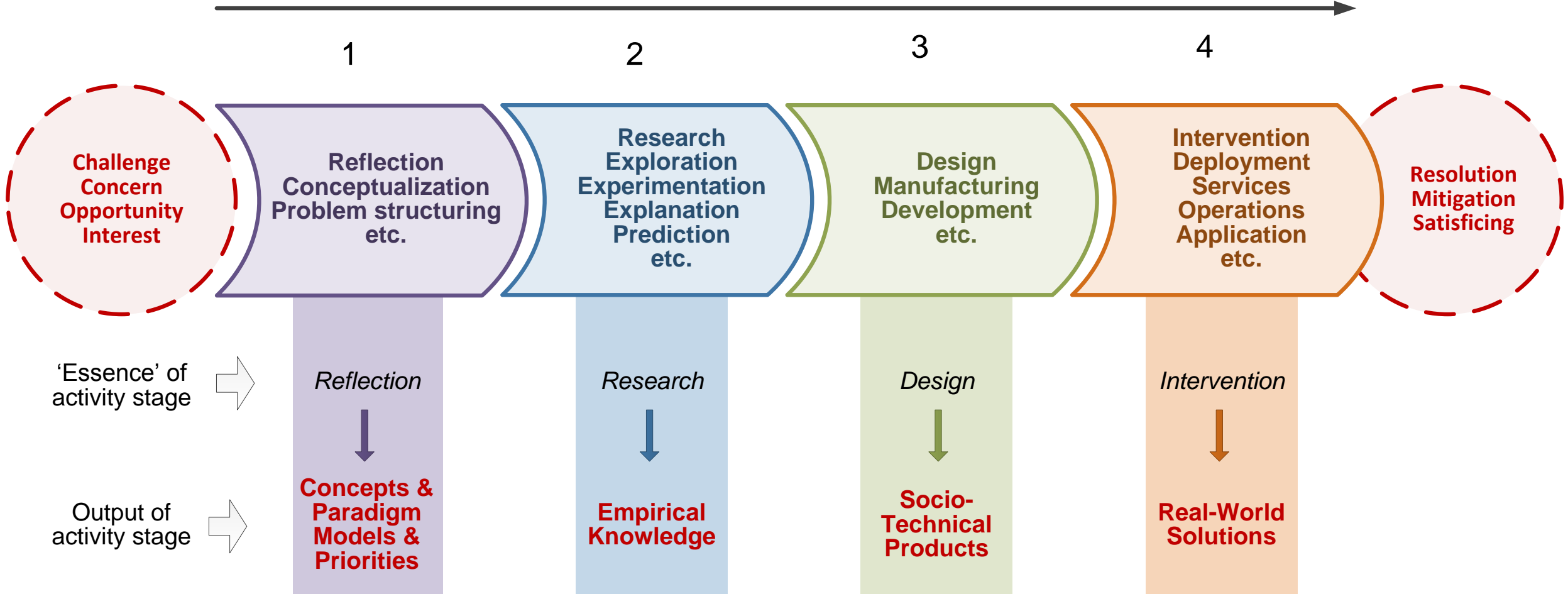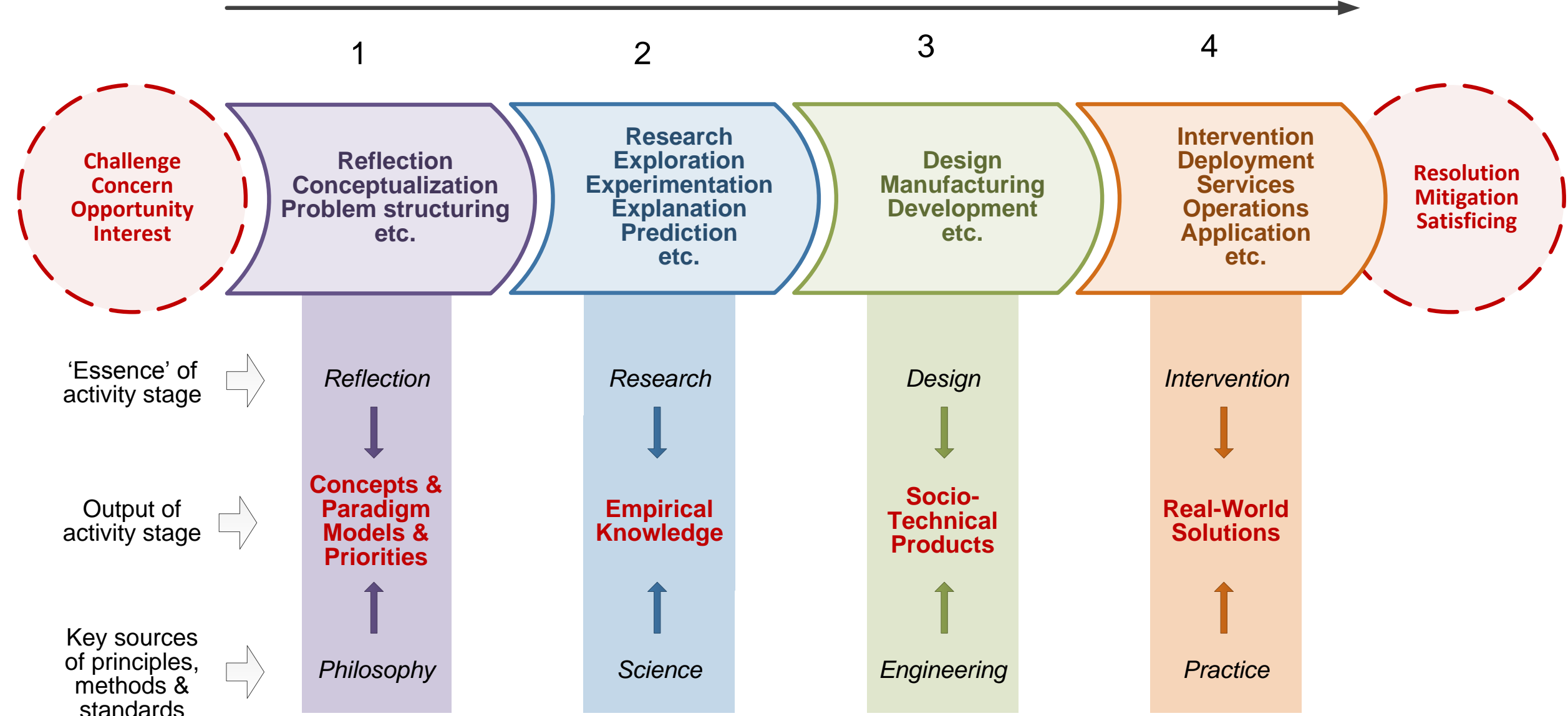
Design Manufacturing Development etc.

Intervention Deployment Services Operations Application etc.

Resolution Mitigation Satisficing

'Essence' of activity stage ⇨

Reflection   *Research*   *Design*   *Intervention*

Output of activity stage ⇨

Concepts & Paradigm Models & Priorities   **Empirical Knowledge**   **Socio-Technical Products**   **Real-World Solutions**

Principles guide us through the stages of any scientific endeavor

Disciplinary Activity Levels per Field Dimension
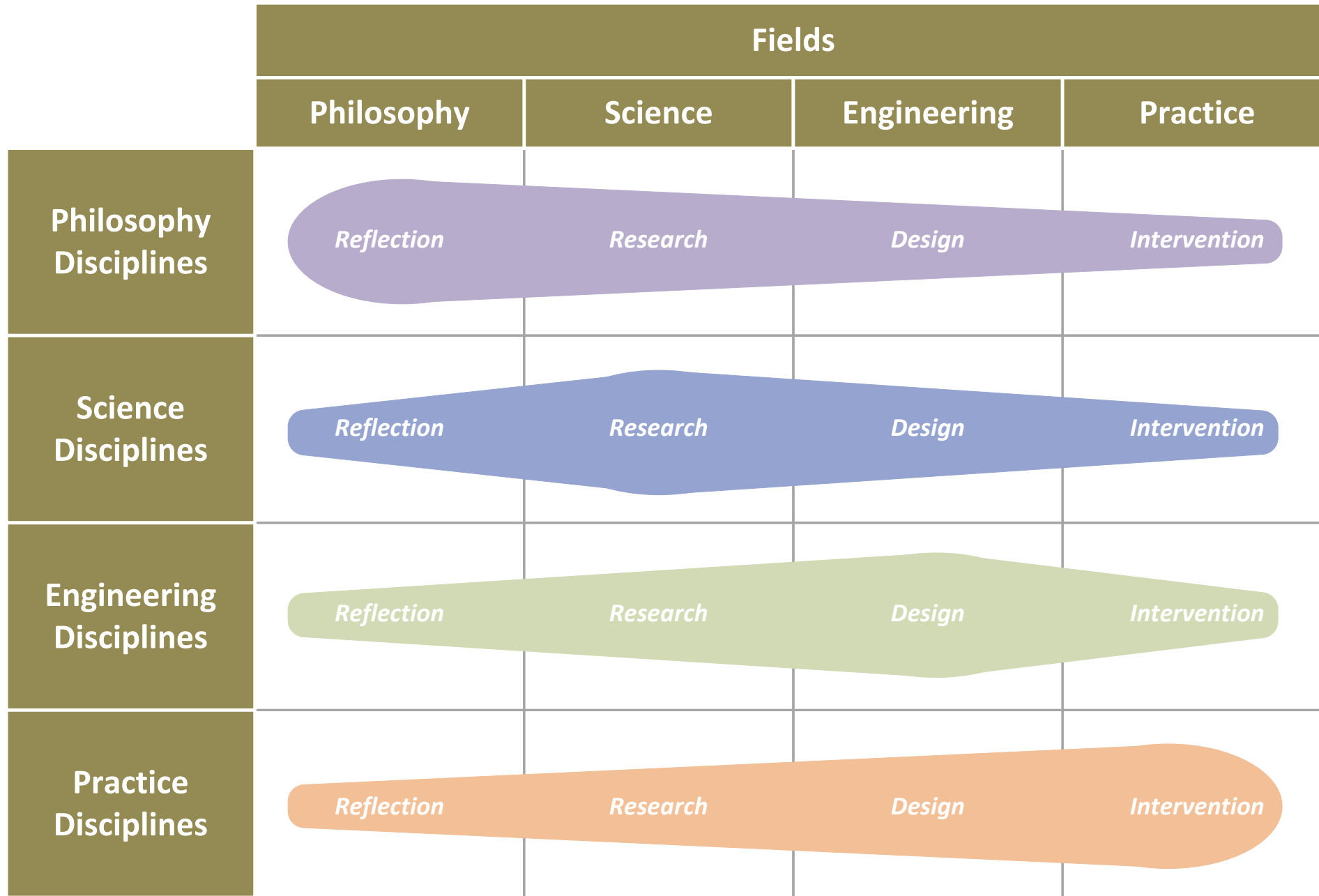
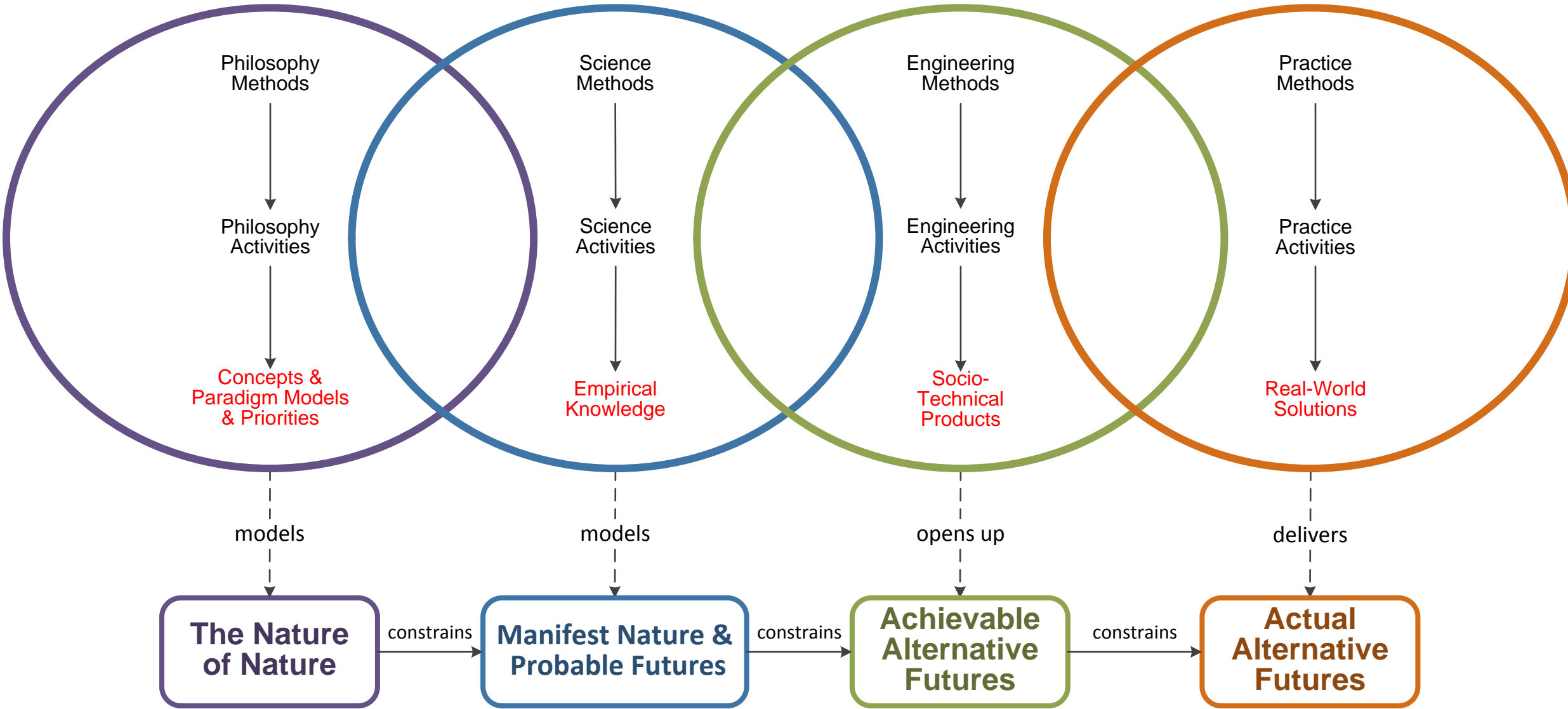# Every Stage has Questions, and Principles to Help Address Them

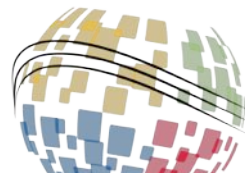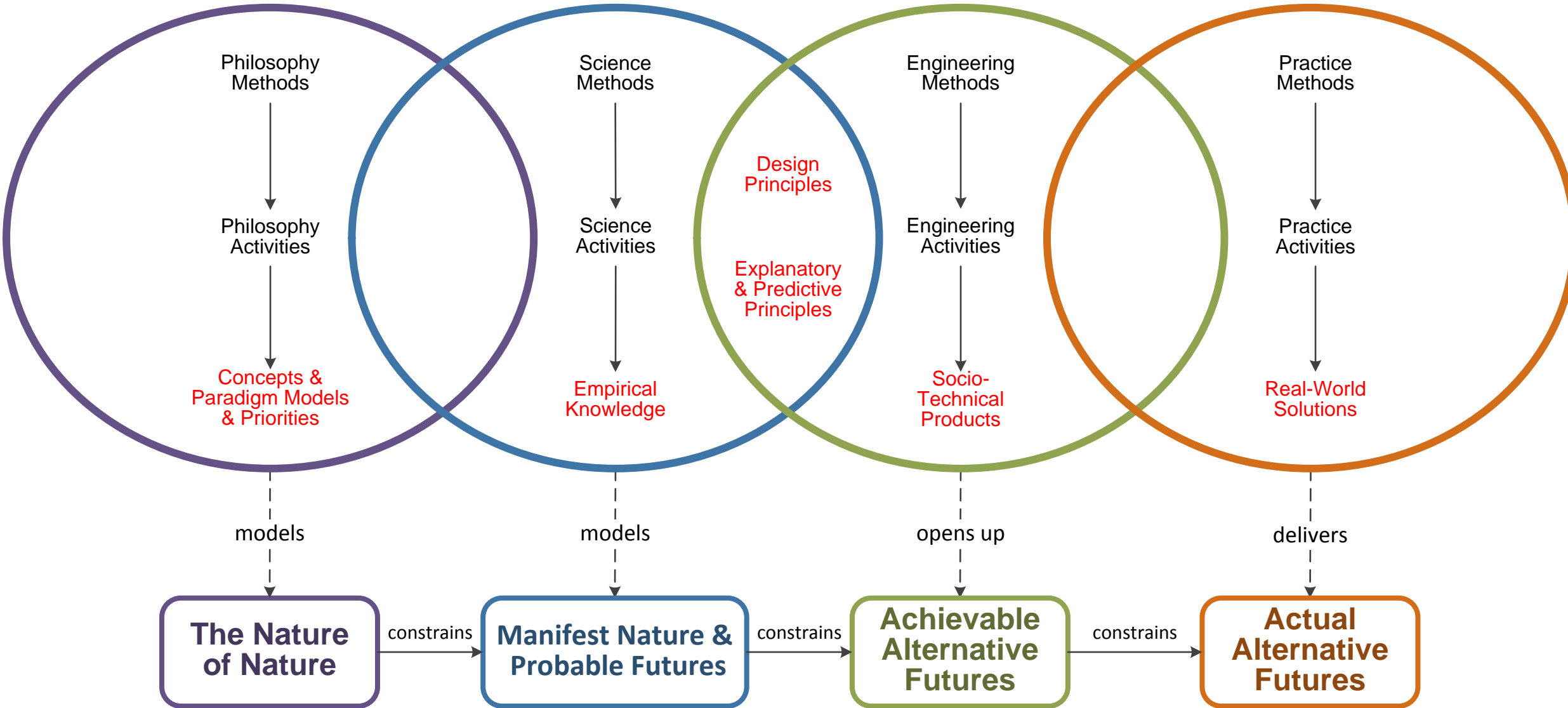| Stage	Key Questions	Subtypes of Principles	Examples of Systems Principles
Reflection	What is the issue?	Focus Principles	estabish clear boundaries
	What is the context?	Perspective Principles	systems are conditioned by systemic relationships
	What might happen?	Exploration Principles	systems change in a network balancing way
	Why does this matter?	Evaluation Principles	systemic changes have causes and consequences
	What are the risks/uncertainti	Confidence Principles	we can only influence the systems we recognize
	What can/should we do?	Actioning Principles	dance with the systems; respect the stakeholders
Design	What should it be like?	Conceptualization Ps	hierarchical organization provides robustness
	How could it work?	Functional Design Ps	stability via setpoint and negative feedback
	Why should it work this way?	Design Optimization Ps	minimise resource use, maximize effectiveness
	How can we provide it?	Manufacturing Ps	integrate simpler systems to make complex ones
	Is there a better way to do thi	Innovation Ps	open systems create integration opportunities
	How can we sustain it?	Maintenance Ps	maintenance and repair depend on systems too

Structure and Role of Disciplinary Fields

Structure and Role of Disciplinary Fields

Example for the Science / Engineering Connection

Science Activity Drivers: Research Questions		Science Output: Explanatory Principles		Engineering Input: Design Principles
What is it? What is it like (how it looks/behaves, what it does)	➡	Classification Principles	➡	Design Conceptualization Principles
How does it work?	➡	Functionality Principles	➡	Functional Design Principles
Why does it work this way?	➡	Optimality Principles	➡	Design Optimization Principles
How did it get like this (how do instances originate and develop)?	➡	Developmental Principles	➡	Manufacturing/Production Principles
How did it emerge (how did the kind arise as a new form in evolutionary history)?	➡	Emergence/Evolutionary Principles	➡	Innovation Principles

Structure and Role of Disciplinary Fields
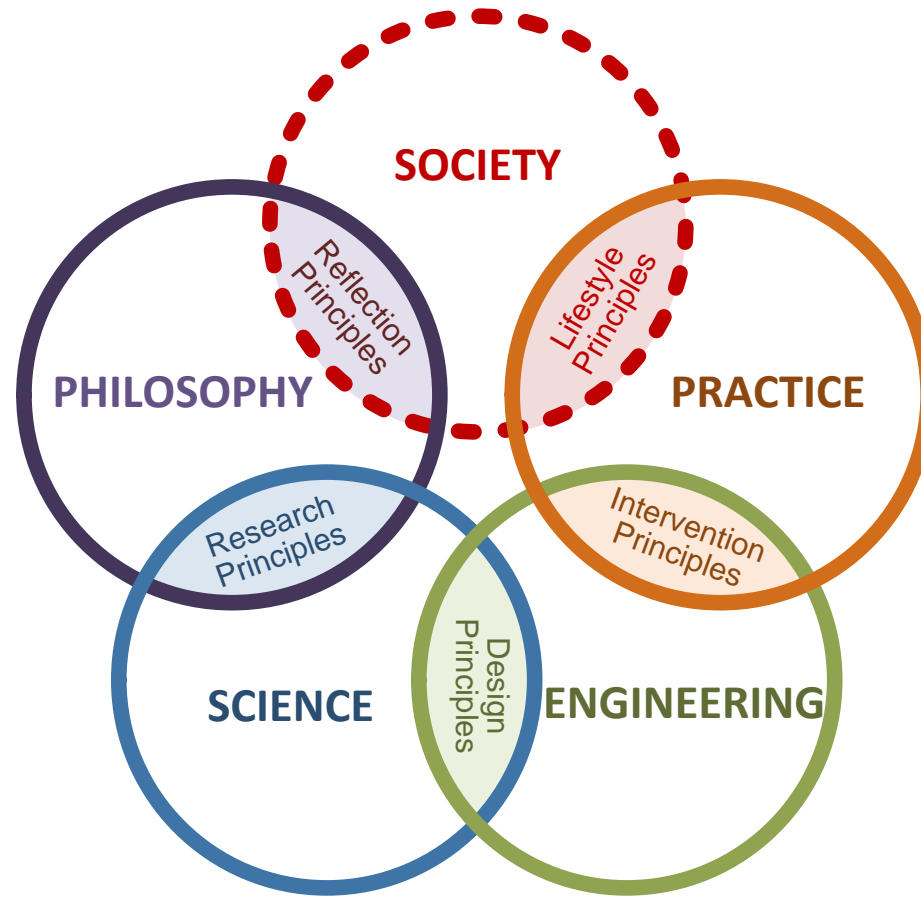
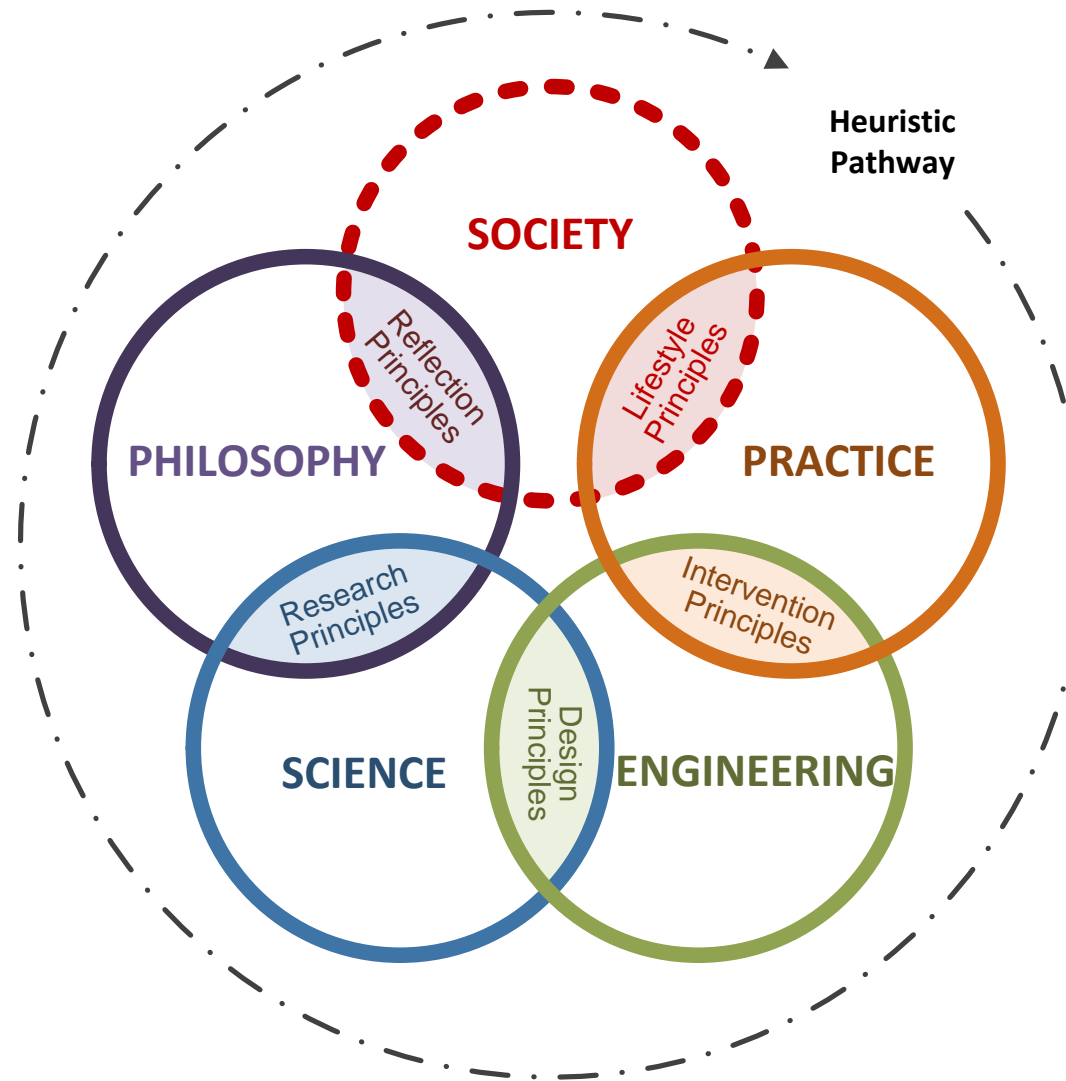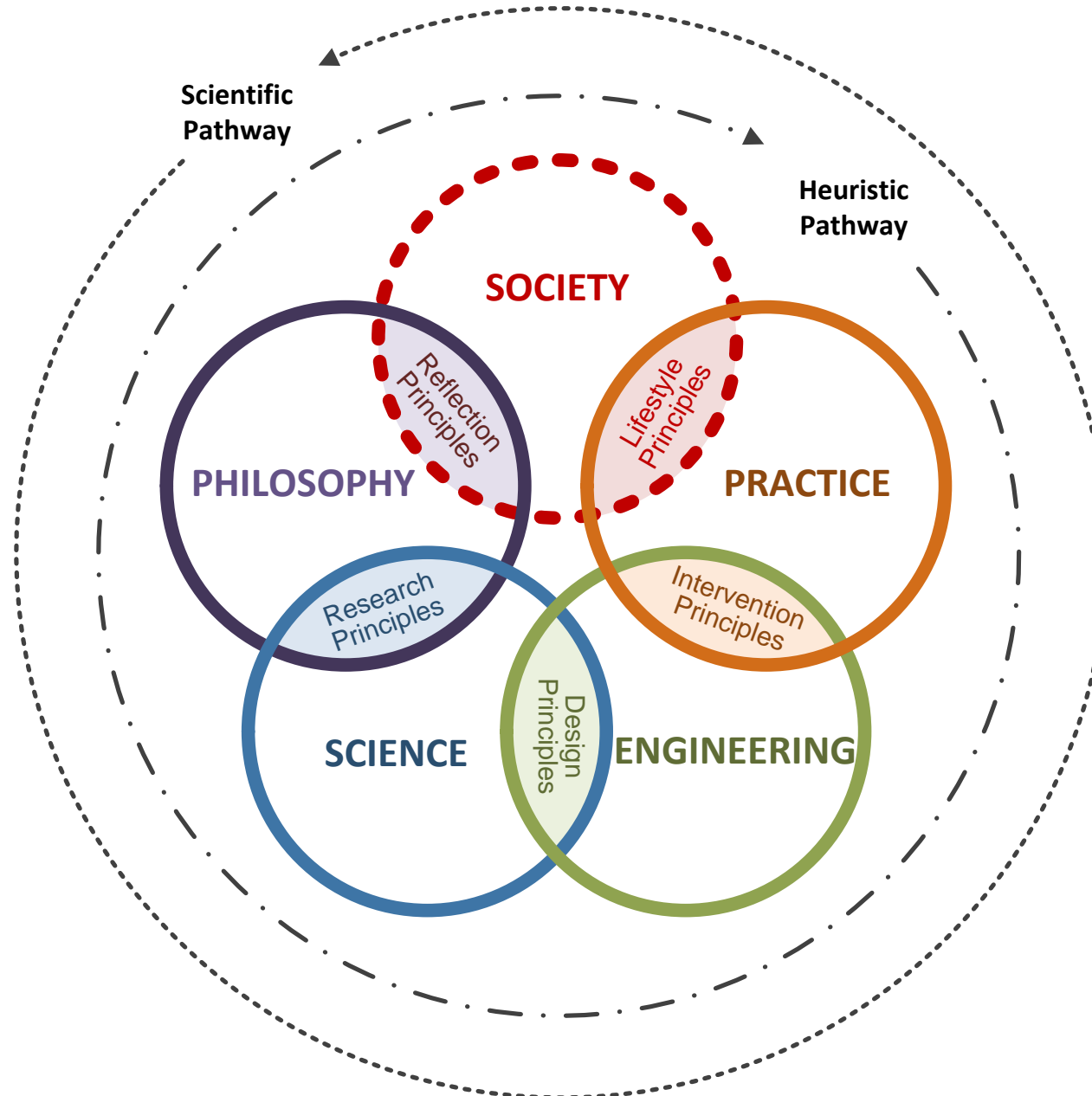# Scientific Development of Principles Across Fields
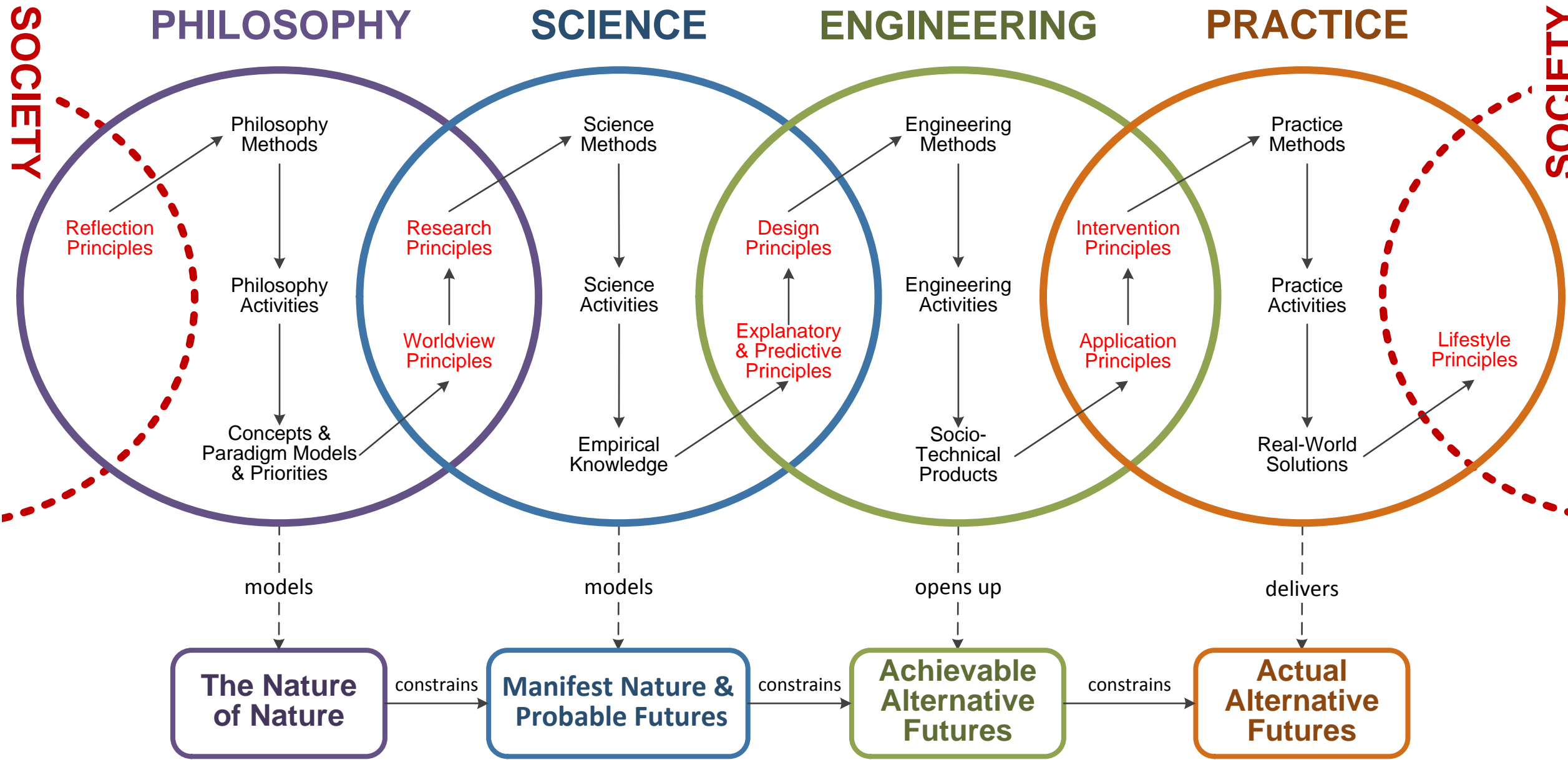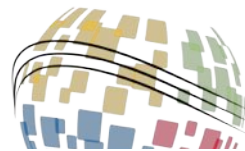
Interplay of Scientific and Heuristic Principles Across Fields
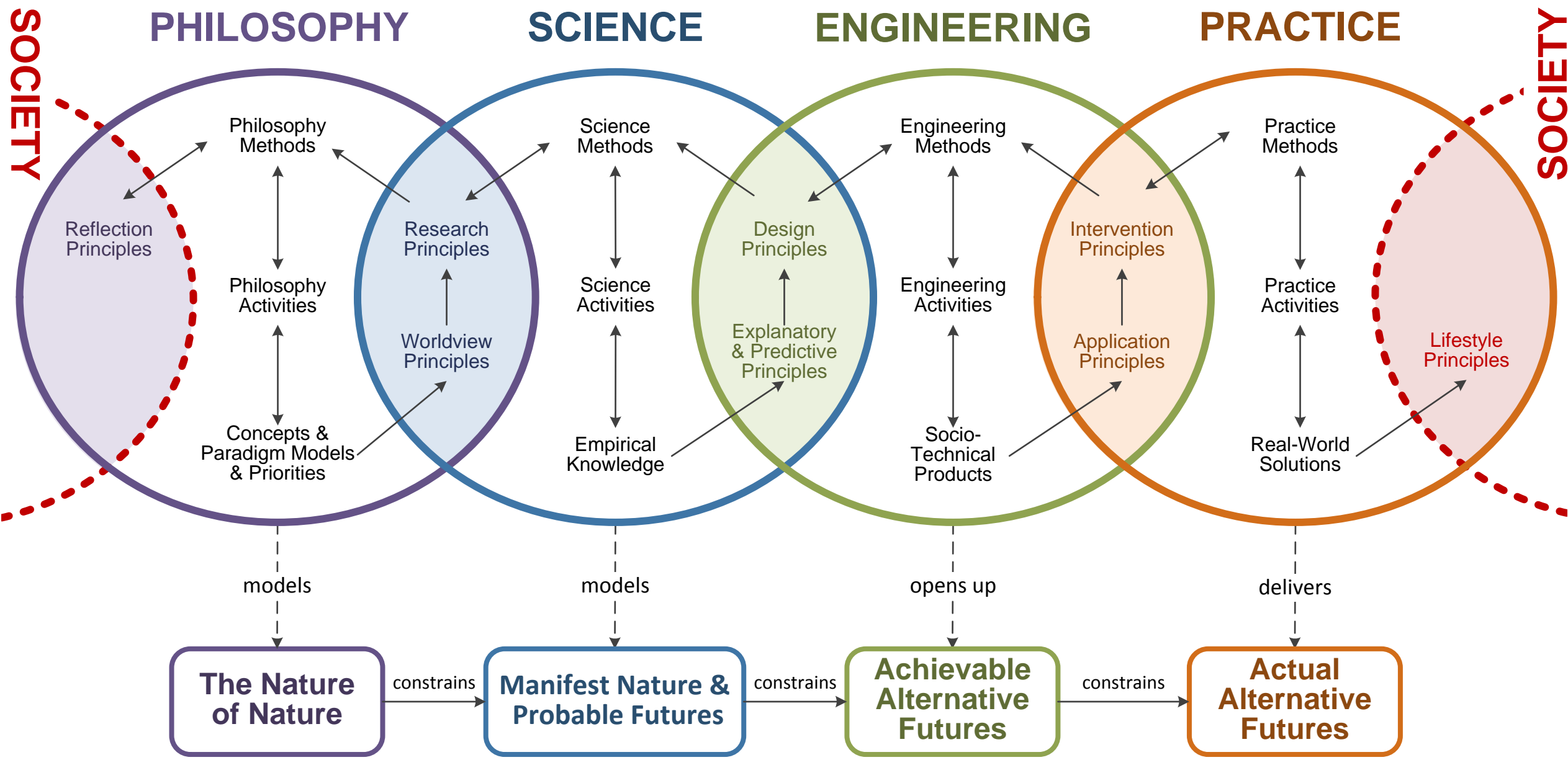
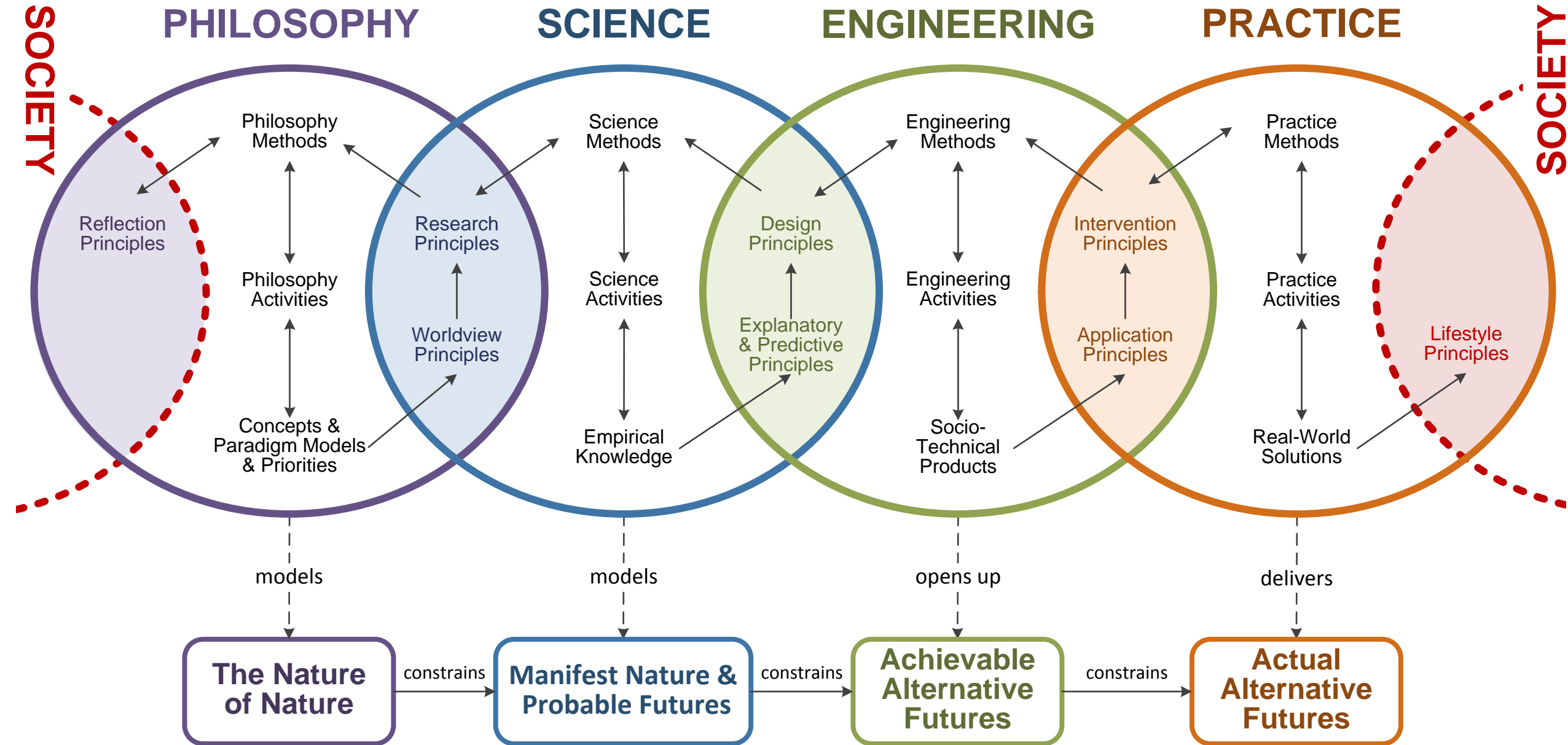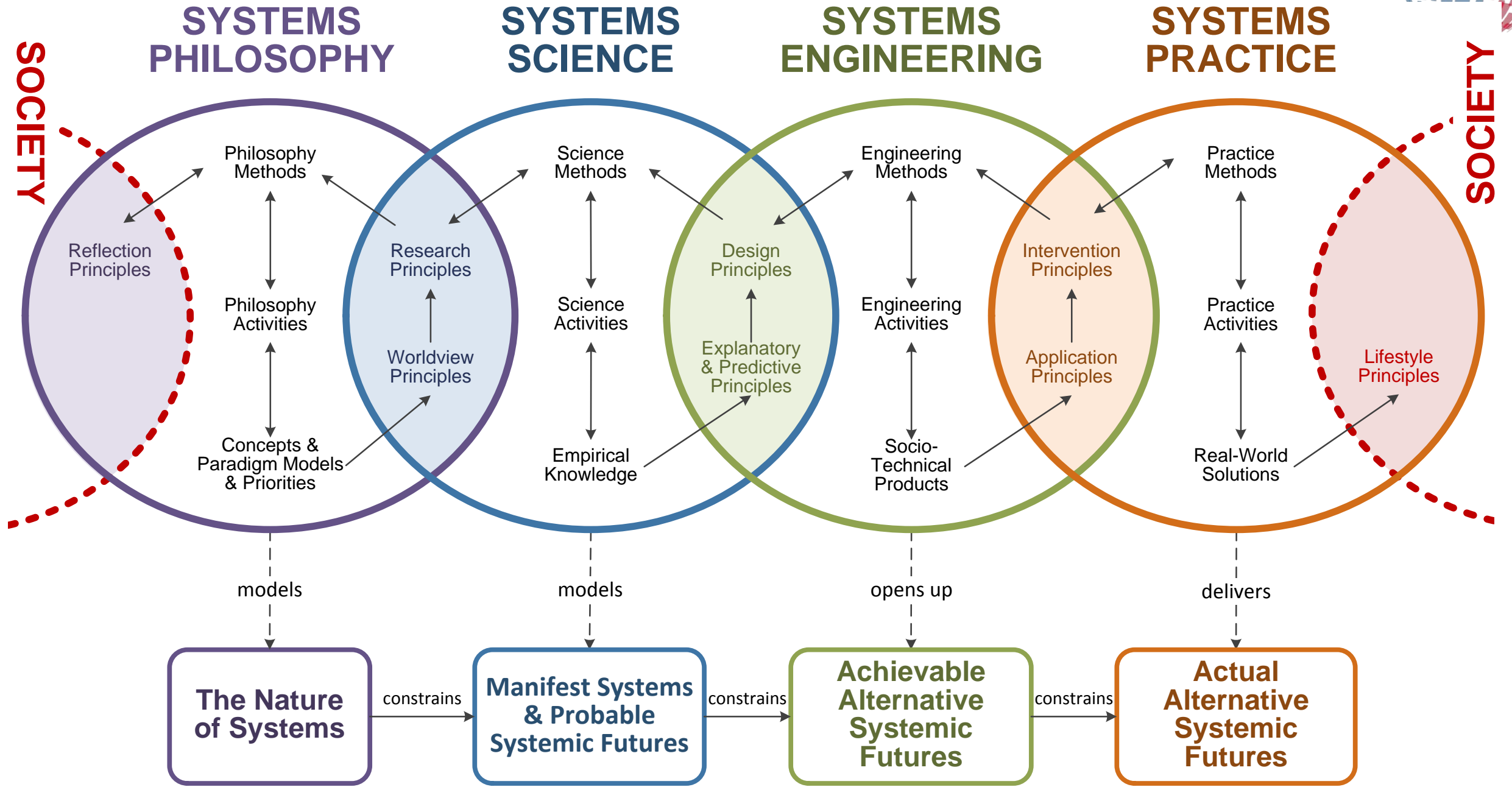# Interplay of Scientific and Heuristic Principles Across Fields

Interplay of Scientific and Heuristic Principles Across Fields

Interplay of Scientific and Heuristic Principles Across Fields

The Architecture of Disciplinary Fields

The Architecture of Systemology

A Typology of Systems Principles

Stage	Key Questions	Subtypes of Principles	Examples of Systems Principles
Reflection	What is the issue?	Focus Principles	estabish clear boundaries
	What is the context?	Perspective Principles	systems are conditioned by systemic relationships
	What might happen?	Exploration Principles	systems change in a network balancing way
	Why does this matter?	Evaluation Principles	systemic changes have causes and consequences
	What are the risks/uncertainties?	Confidence Principles	we can only influence the systems we recognize
	What can/should we do?	Actioning Principles	dance with the systems; respect the stakeholders
Research	What is it? What is it like?	Classification Ps	systems, boundaries, relationships
	Where does it occur?	Ecological Ps	almost everything is part of a greater system
	How does it work?	Functionality Ps	emergent properties entail submergence
	Why does it work this way?	Optimization Ps	explore emergence/submergence interplay
	How did it get like this?	Developmental Ps	systems emerge from stable relationships
	How did it arise?	Evolutionary Ps	balance technical and social needs
Design	What should it be like?	Conceptualization Ps	hierarchical organization provides robustness
	How could it work?	Functional Design Ps	stability via setpoint and negative feedback
	Why should it work this way?	Design Optimization Ps	minimise resource use, maximize effectiveness
	How can we provide it?	Manufacturing Ps	integrate simpler systems to make complex ones
	Is there a better way to do this?	Innovation Ps	open systems create integration opportunities
	How can we sustain it?	Maintenance Ps	maintenance and repair depend on systems too
Intervention	Can we preserve it?	Prevention Ps	protect the hyper-nodes
	Can we change it back/recover it?	Restoration Ps	restore its structure and relationships
	Can we make it grow/multiply?	Expansion Ps	protect the systems it depends on
	Can we change it?	Transformation Ps	adjust the internal and/or external relationships
	Can we get hold of it?	Establishment PS	leverage relationship: supply - demand systems
	Can we get rid of it?	Dismantling Ps	cut at the joints in the hierarchical structure

Value to SE and Next Steps

- By understanding the relationships between kinds of principles, we can:
    - find strategies for developing scientific principles from heuristic ones
    - develop scientific principles for design and intervention from known philosophical and scientific research ones
- Strengthen the methods of SE by grounding them in scientific principles
- Develop new methods for SE by operationalising principles transposed from adjacent fields
- Classify principles we already have to identify gaps, overlaps and opportunities to make them more scientific

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