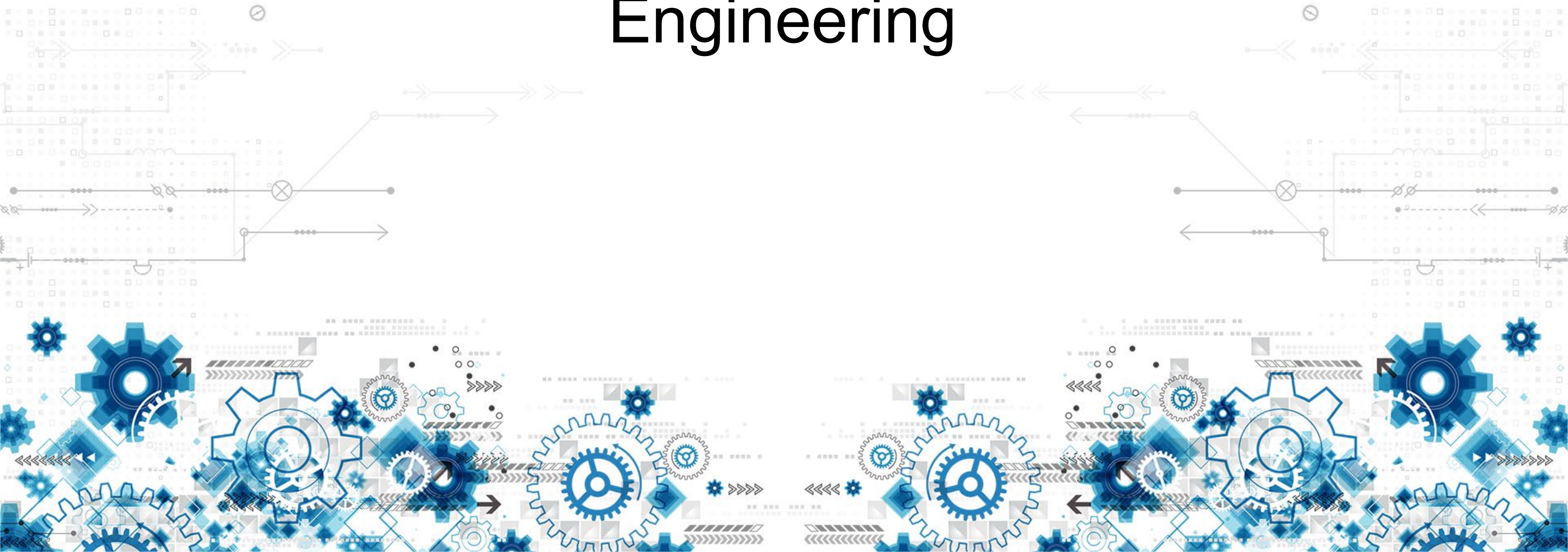


Introduction to System of Systems Engineering



Objectives

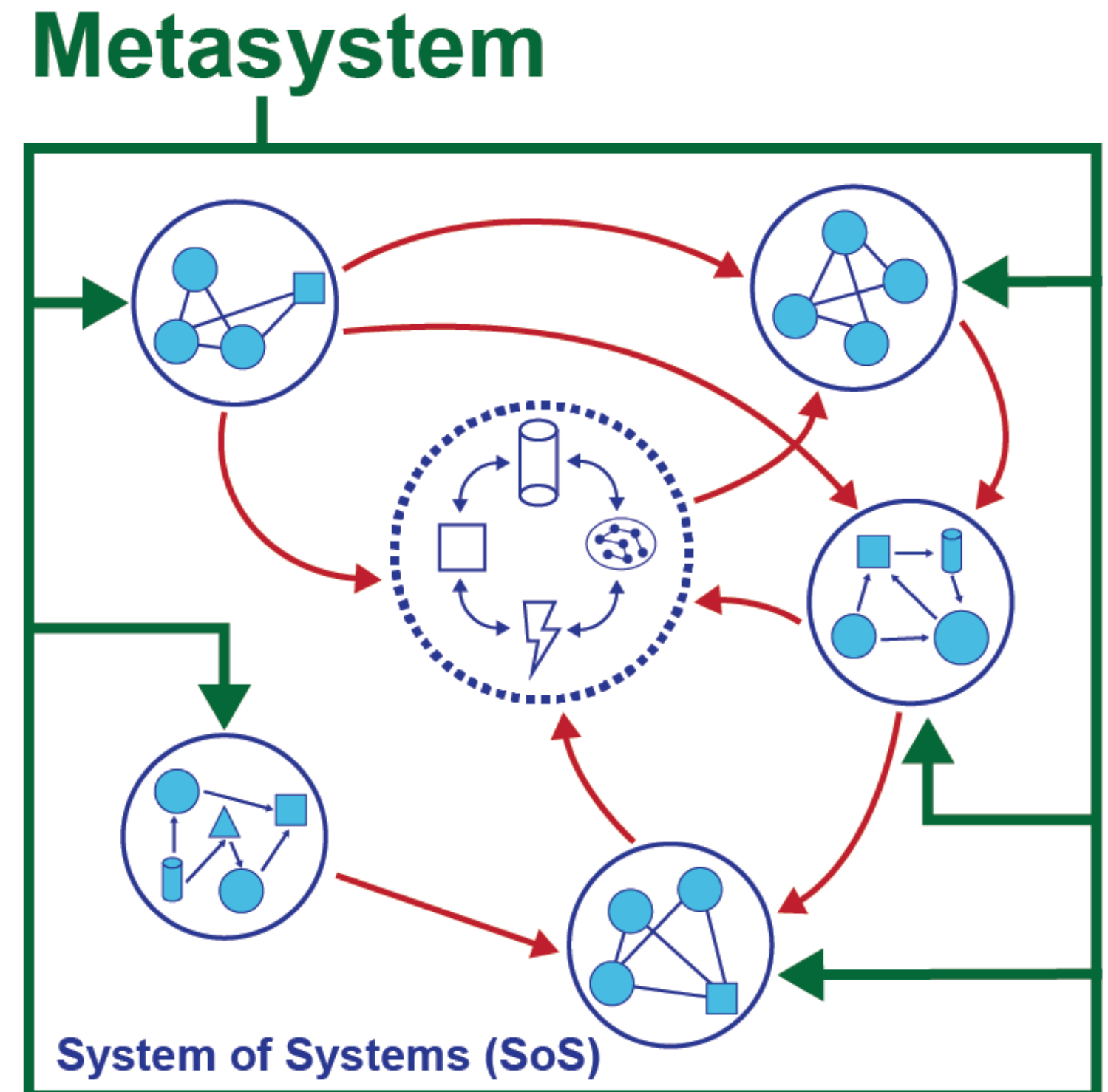
- ⚙ Understand the fundamentals of System of Systems Engineering (SoSE) by correctly classifying something as a System of System (SoS)
- ⚙ Appreciate a System of Systems Engineering Methodology by discussing the pros and cons of application
- ⚙ Demonstrate understand of SoSE utility by describing the range of applicability

Fundamentals of System of Systems Engineering

What is System of Systems Engineering?

“ The design, deployment, operation, and transformation of higher-level metasecosystems that must function as an integrated complex system to produce desirable results. ”

Keating, C. B., Rogers, R., Unal, R., Dryer, D., Sousa-Poza, A., Safford, R., et al. (2003). System of Systems Engineering. Engineering Management Journal, 15(3), 36-45.



Seven Characteristics of a SoS



Maier, M. W. (1999). Architecting Principles for Systems-of-Systems. *Systems Engineering*, 1(4), 267-284.

Sage, A. & Cuppan, C. (2001). On the Systems Engineering and Management of Systems of Systems and Federations of Systems. *Information, Knowledge, Systems Management*, 2(4), 325-345.

Systems Engineering vs. SoSE Problem Domain

Attribute	SoSE (System of Systems Engineering) Problems	Traditional Systems Engineering Problems
<i>Objective</i>	Understanding/Improvement	Solution/Resolution
➡ Interpretation	Subjective	Objective
<i>Environment</i>	Turbulent	Static
➡ Boundaries	Ambiguous/Shifting	Defined/Stable
<i>Structure</i>	Relationships	Elements
<i>Behaviour</i>	Uncertain/non-linear	Deterministic/linear
<i>Preferred Representation</i>	Interpretative (relationships/diagram/approximate)	Symbolic (mathematical/model/precision)
<i>Quantification</i>	Limited	Comprehensive
<i>Understanding</i>	Holistic/Irreducible	Part/Reducible
➡ Solution Form	Satisficing	Optimal
<i>Viewpoints</i>	Pluralist (many/potentially irrational)	Unitary (singular/rational)
<i>Approach</i>	Unique-Not Replicable-Methodology	Standardized-Replicable-Method
<i>Dynamic Nature</i>	Assured-Emergent	Minimal-Controlled
➡ Knowledge	Emergent	Absolute
➡ Emphasis	Sociotechnical	Technical
➡ Relationships	Power/Politics/Systems	Defined/Apolitical/Elements
<i>Definition</i>	Ambiguous/evolving	Clear
<i>Complexity</i>	Complex	Simple

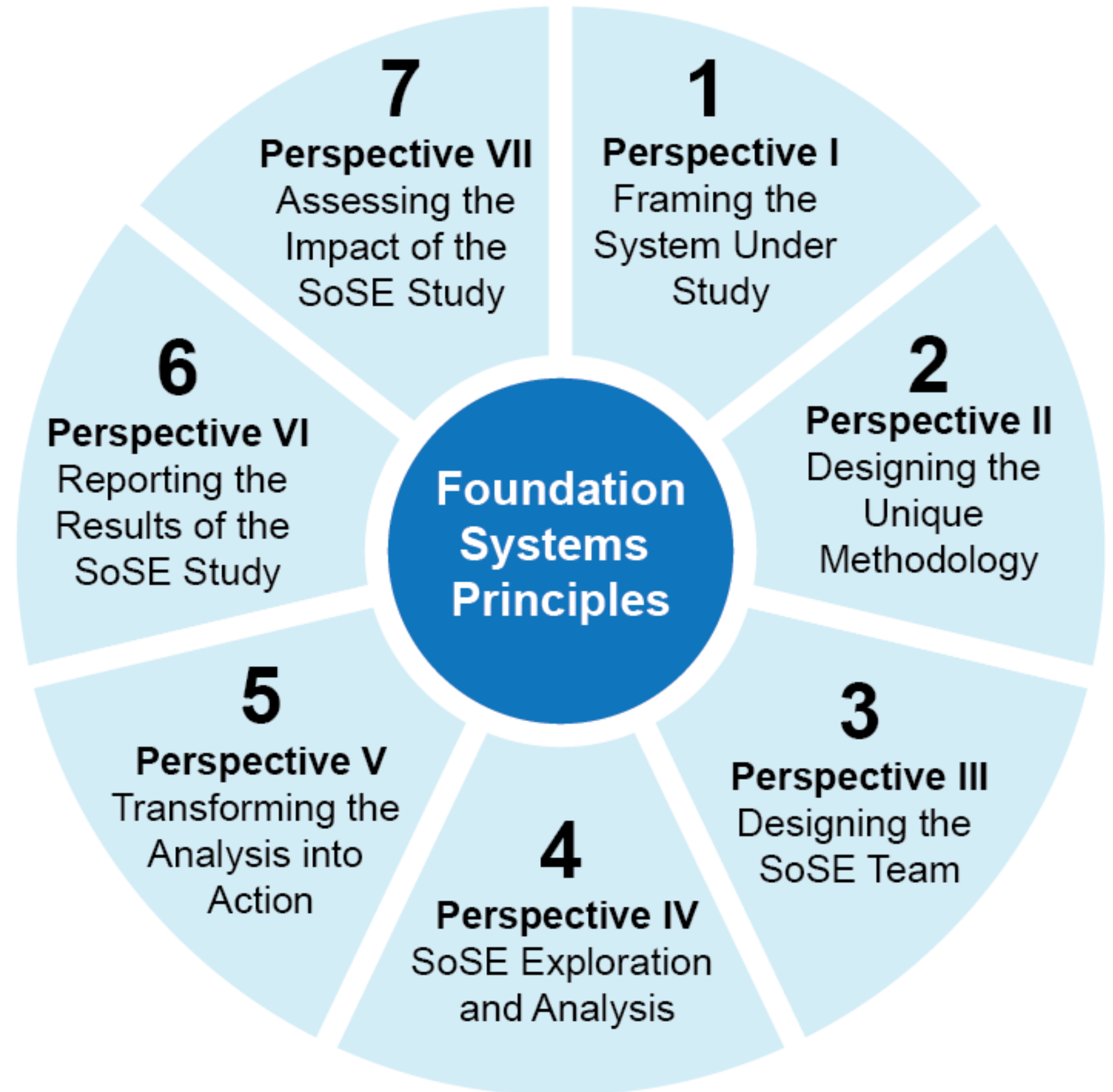
Keating, C. B., Pyne, J. C., & Bradley, J. M. (2015). Advancing enquiry for system of systems engineering: paradox, critical thinking, and critical systems enquiry. *International Journal of System of Systems Engineering*, 6(4), 327-354.

SoS Examples

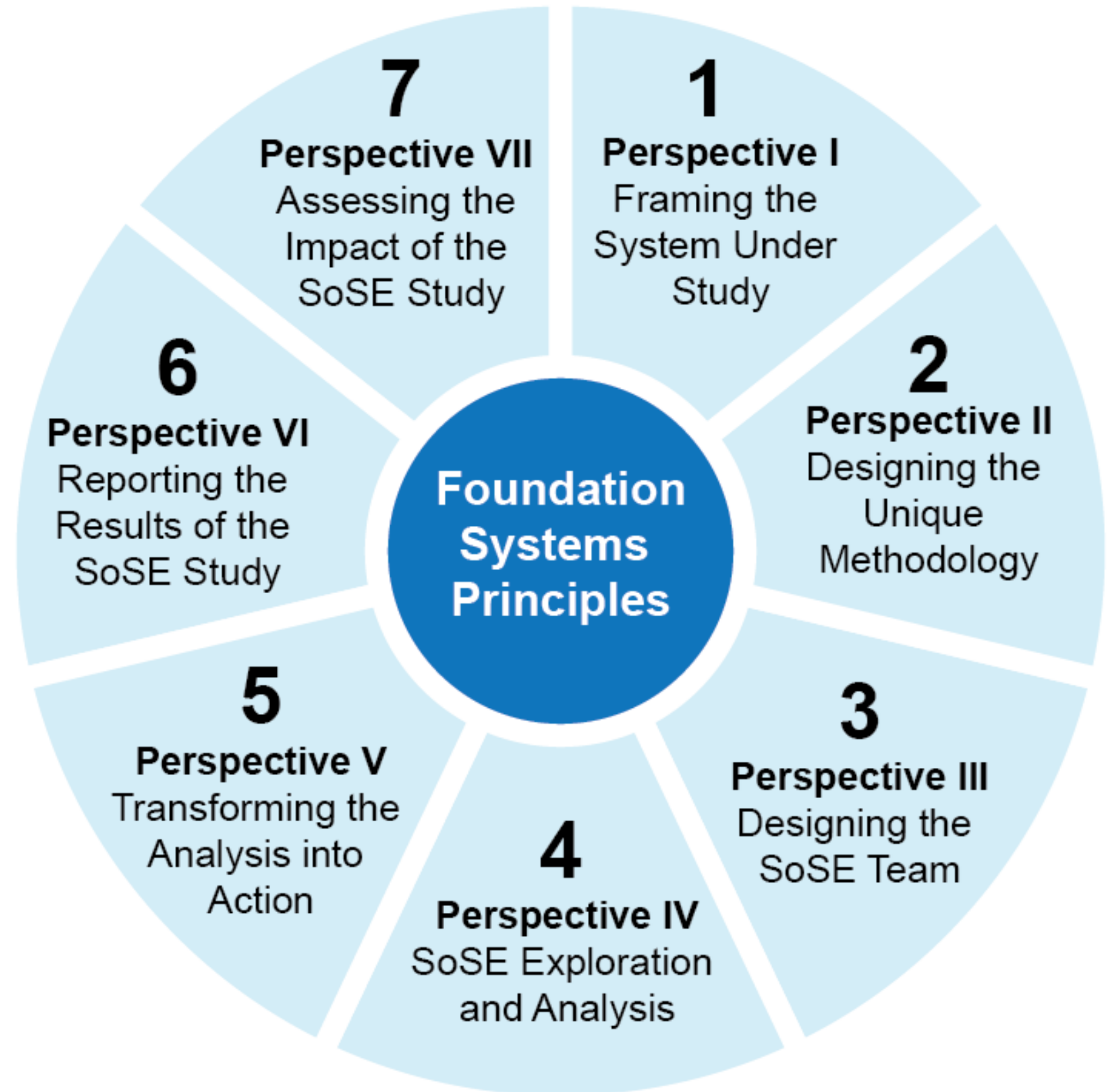
Are these systems a System of Systems?

System	SoS?	Explanation
Boeing 787	No	None of the components perform useful operations independently, no geographic separation
Computer	No	Few if any of the components perform useful operations independently, no geographic separation
Integrated Healthcare System	Yes	Many independently useful systems, acquired & managed independently, wide geographic separation
Distributed Computer Network	Yes	Many independently useful systems, acquired & managed independently, wide geographic separation, emergent behaviors

“A” System of Systems Engineering Methodology



SoSE Methodology Framework Summary

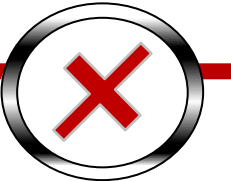


SoSE Methodology Application

Some Pros and Cons for Consideration

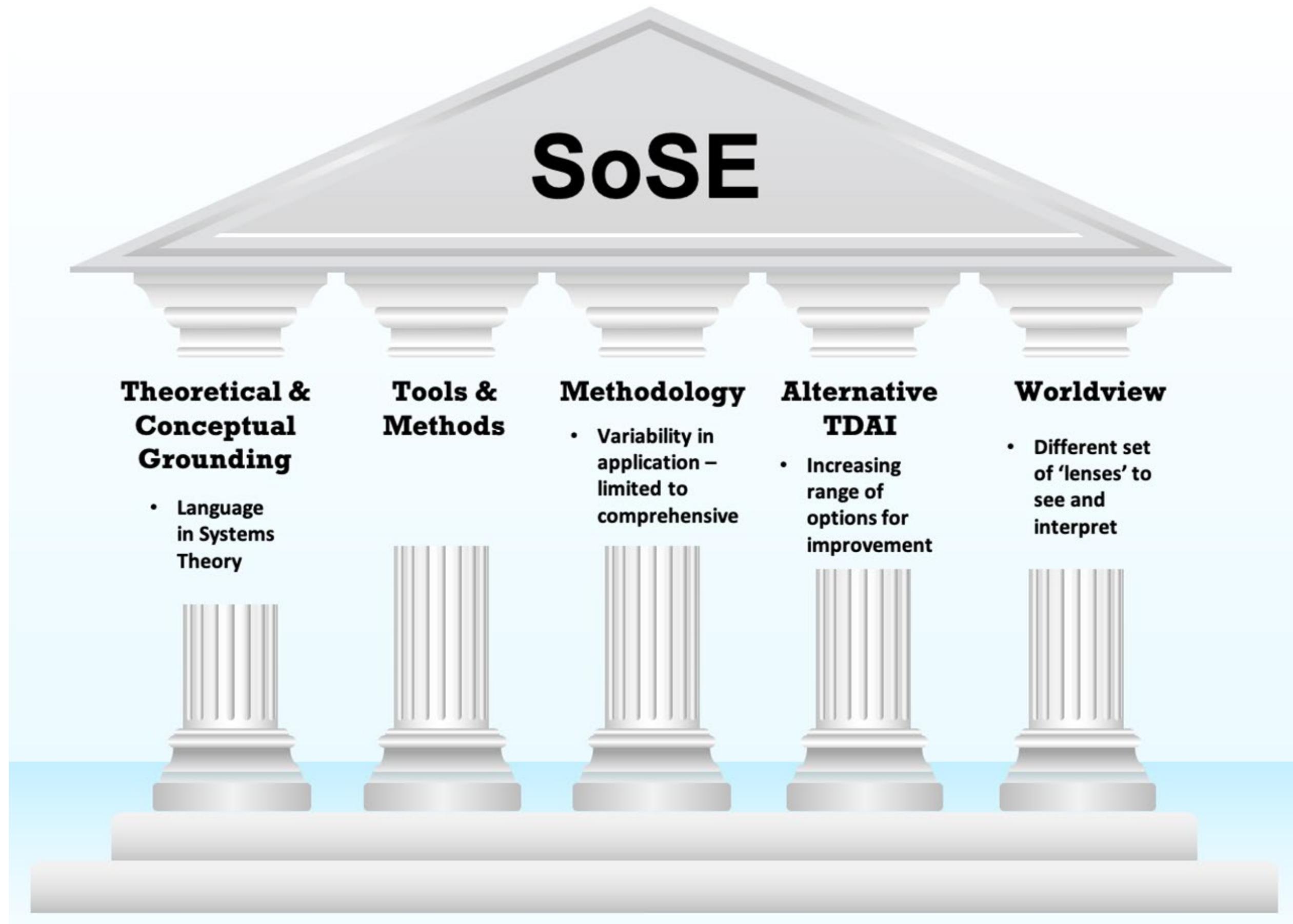


- ⚙️ Grounded in a solid theoretical framework (Systems Theory)
- ⚙️ Holistic appreciation of a 'wicked problem domain' in the 'front end'
- ⚙️ Appreciates uniqueness of every problem and context
- ⚙️ Generates 'deep' understanding of systemic issues
- ⚙️ Engages spectrum of technical, human, social, organizational, managerial, information, policy, and political dimensions
- ⚙️ Identifies feasible paths forward



- ⚙️ Requires sophistication in level of systems worldview
- ⚙️ Unsatisfying for 'solution' based expectations
- ⚙️ Incompatible with 'reductionist' mindset
- ⚙️ Lack of sophisticated methods, tools, and techniques to deploy approach
- ⚙️ Requires high level of 'systems' expertise to engage
- ⚙️ Compatibility of support infrastructure necessary

Utility of System of Systems Engineering SoSE Utility – Not a Binary 0 - 1



Example: Carrier Strike Group Information Exchange

Carrier strike groups are created and dissolved as required, with the aircraft carrier the focal point of the group. Besides the carrier, a typical strike group might be made up of five to seven of the ships shown.

The Tomahawk missiles on **Ticonderoga-class cruisers** provide long-range strike capability.

The air wing on a **nuclear-powered (CVN) or conventional-powered (CV) aircraft carrier** attacks targets on land, sea and air. Most of the current carriers belong to the Nimitz class.

A **replenishment ship** provides continuous resupply capability for ammunition, fuel and other supplies. Theater-based ships provide additional assistance by keeping the strike group resupplied.

