Systems Thinking

INCOSE-LA Tutorial

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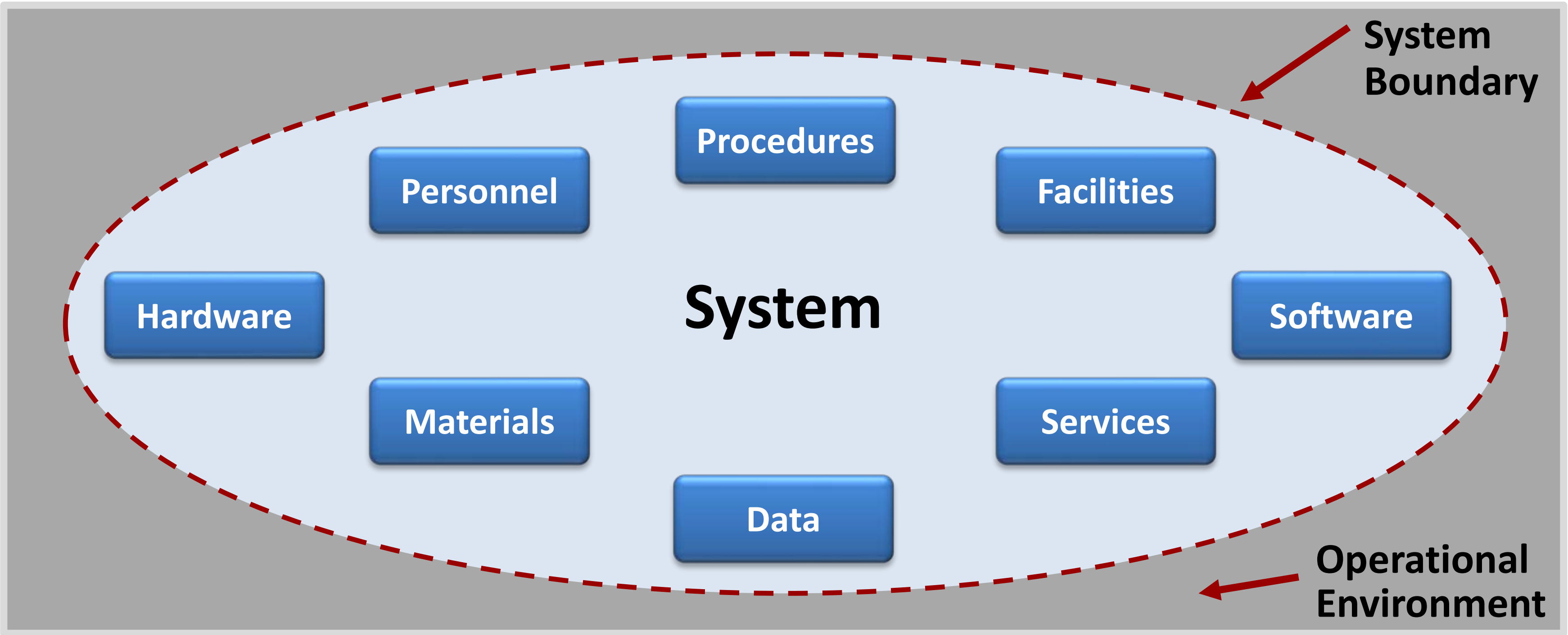
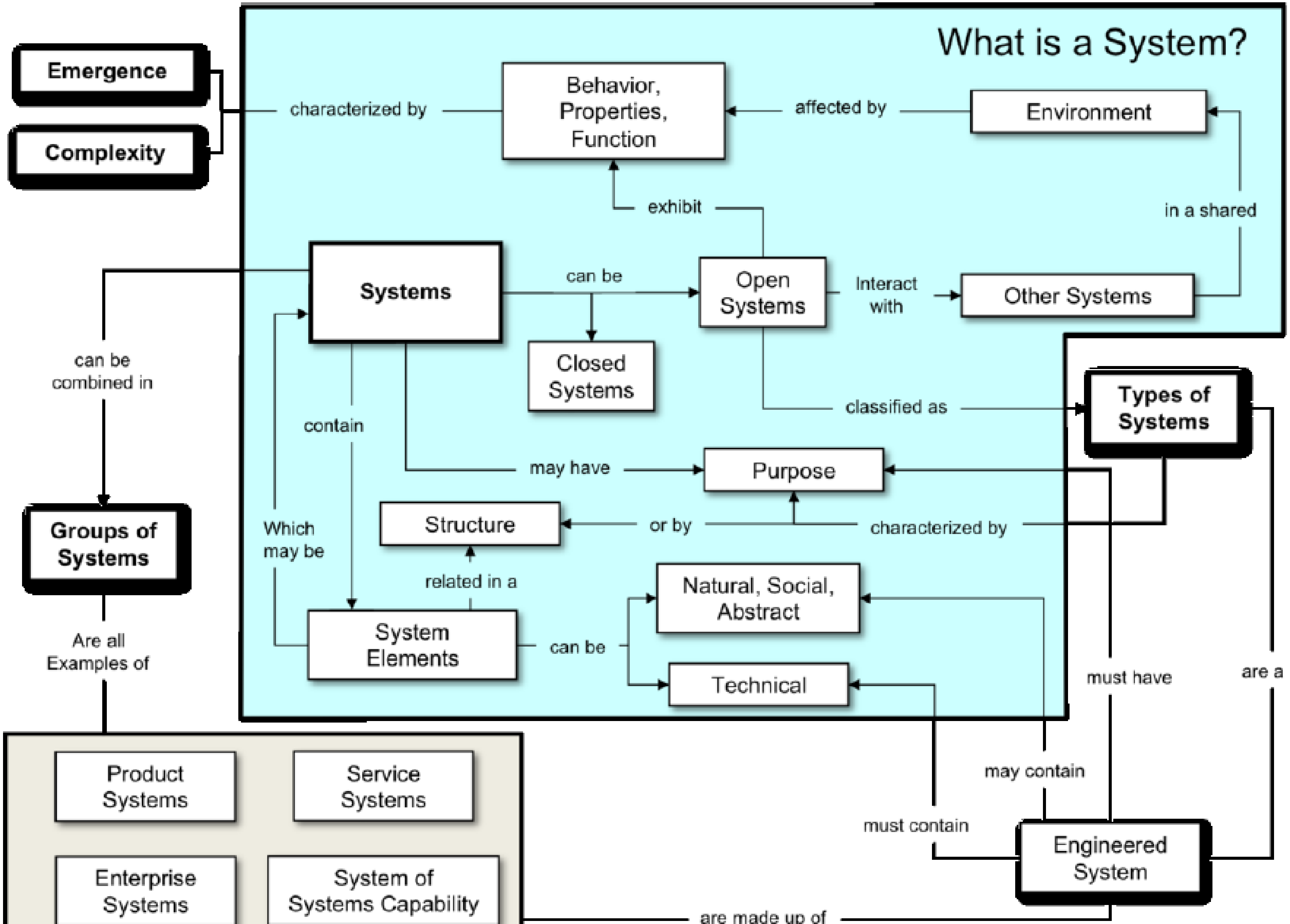
What is a System?

An integrated set of elements, subsystems, or assemblies that accomplish a defined purpose; these elements include products hardware, software and firmware), processes, people, information, techniques, facilities, services and other support elements [INCOSE Systems Engineering Handbook]





INCOSE Systems Engineering Handbook

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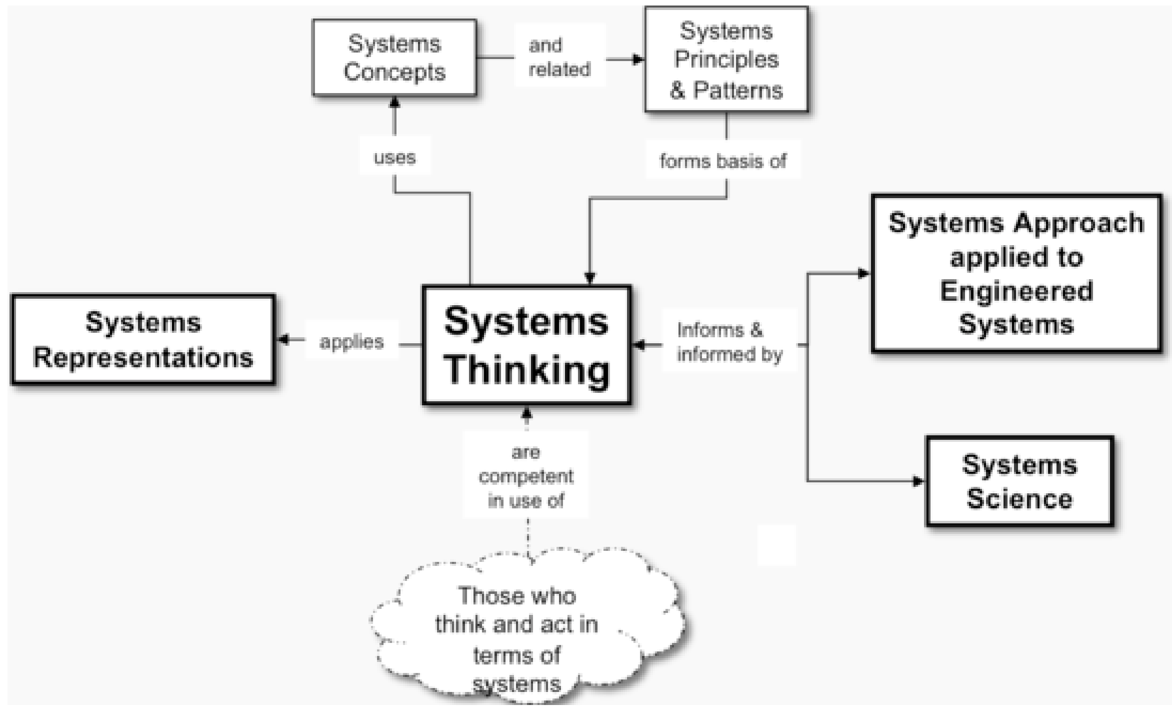
Systems Thinking

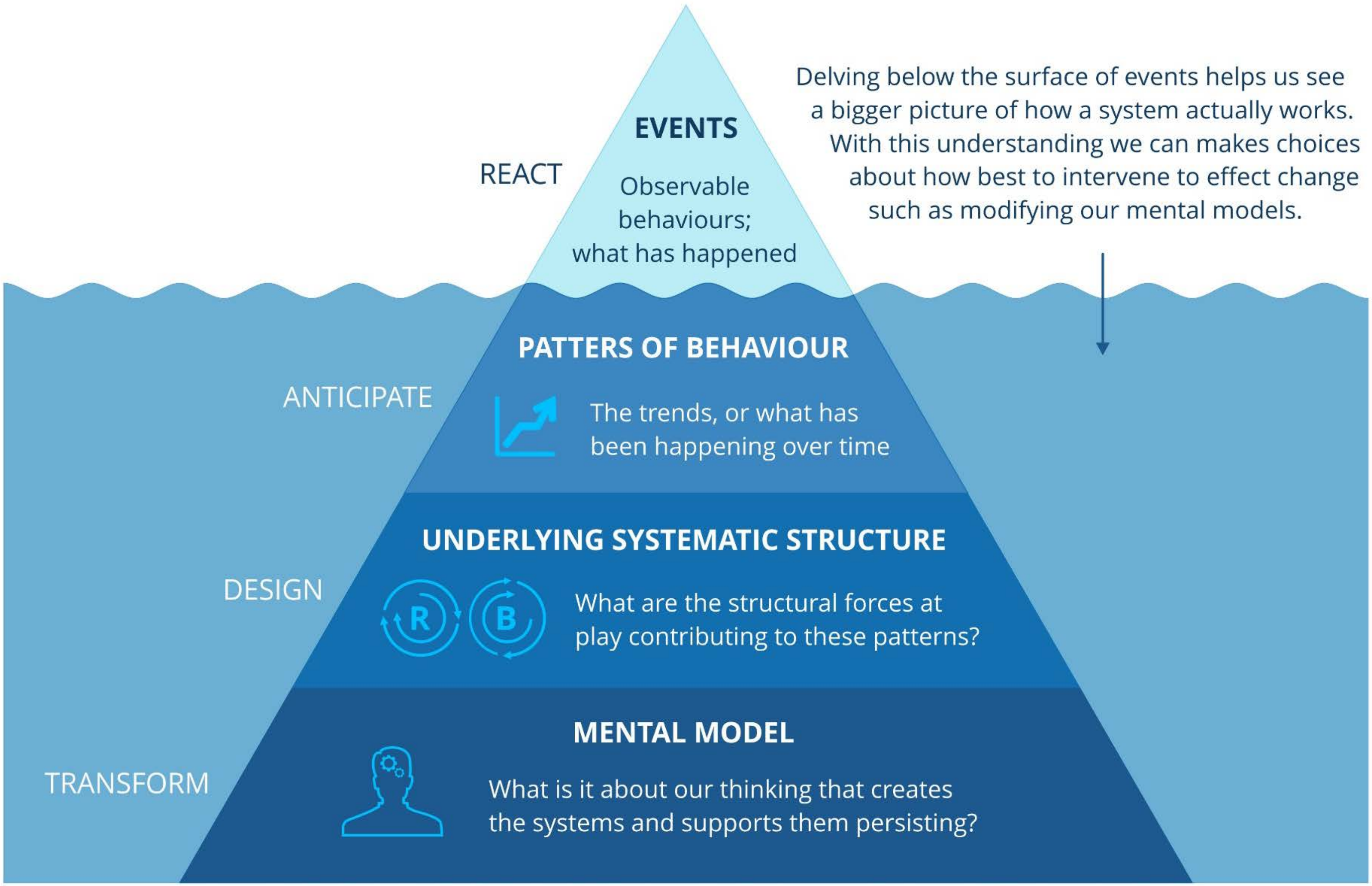
Systems thinking is concerned with understanding or intervening in problem situations, based on the principles and concepts of the systems paradigm [INCOSE SE Body of Knowledge – sebokwiki.org]

Systems thinking considers the similarities between systems from different domains in terms of a set of common systems concepts, principles and patterns



INCOSE Systems Engineering Handbook

Systems Thinking Iceberg



Systems Principles (1 of 2)

INCOSE SE Body of Knowledge – sebokwiki.org

Abstraction	A focus on essential characteristics is important in problem solving because it allows problem solvers to ignore the nonessential, thus simplifying the problem. (Sci-Tech Encyclopedia 2009; SearchCIO 2012; Pearce 2012)
Boundary	A boundary or membrane separates the system from the external world. It serves to concentrate interactions inside the system while allowing exchange with external systems. (Hoagland, Dodson, and Mauck 2001)
Change	Change is necessary for growth and adaptation, and should be accepted and planned for as part of the natural order of things rather than something to be ignored, avoided, or prohibited (Bertalanffy 1968; Hybertson 2009).
Dualism	Recognize dualities and consider how they are, or can be, harmonized in the context of a larger whole (Hybertson 2009)
Encapsulation	Hide internal parts and their interactions from the external environment. (Klerer 1993; IEEE 1990)
Equifinality	In open systems, the same final state may be reached from different initial conditions and in different ways (Bertalanffy 1968). This principle can be exploited, especially in systems of purposeful agents.
Holism	A system should be considered as a single entity, a whole, not just as a set of parts. (Ackoff 1979; Klir 2001)
Interaction	The properties, capabilities, and behavior of a system are derived from its parts, from interactions between those parts, and from interactions with other systems. (Hitchins 2009 p. 60)
Layer Hierarchy	The evolution of complex systems is facilitated by their hierarchical structure (including stable intermediate forms) and the understanding of complex systems is facilitated by their hierarchical description. (Pattee 1973; Bertalanffy 1968; Simon 1996)
Leverage	Achieve maximum leverage (Hybertson 2009). Because of the power versus generality tradeoff, leverage can be achieved by a complete solution (power) for a narrow class of problems, or by a partial solution for a broad class of problems (generality).
Modularity	Unrelated parts of the system should be separated, and related parts of the system should be grouped together. (Griswold 1995; Wikipedia 2012a)
Network	The network is a fundamental topology for systems that forms the basis of togetherness, connection, and dynamic interaction of parts that yield the behavior of complex systems (Lawson 2010; Martin et al. 2004; Sillitto 2010)

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Systems Principles (2 of 2)

INCOSE SE Body of Knowledge – sebokwiki.org

Parsimony	One should choose the simplest explanation of a phenomenon, the one that requires the fewest assumptions (Cybernetics 2012). This applies not only to choosing a design, but also to operations and requirements.
Regularity	Systems science should find and capture regularities in systems, because those regularities promote systems understanding and facilitate systems practice. (Bertalanffy 1968)
Relations	A system is characterized by its relations: the interconnections between the elements. Feedback is a type of relation. The set of relations defines the network of the system. (Odum 1994)
Separation of Concerns	A larger problem is more effectively solved when decomposed into a set of smaller problems or concerns. (Erl 2012; Greer 2008)
Similarity/ Difference	Both the similarities and differences in systems should be recognized and accepted for what they are. (Bertalanffy 1975 p. 75; Hybertson 2009). Avoid forcing one size fits all, and avoid treating everything as entirely unique.
Stability/ Change	Things change at different rates, and entities or concepts at the stable end of the spectrum can and should be used to provide a guiding context for rapidly changing entities at the volatile end of the spectrum (Hybertson 2009). The study of complex adaptive systems can give guidance to system behavior and design in changing environments (Holland 1992).
Synthesis	Systems can be created by choosing (conceiving, designing, selecting) the right parts, bringing them together to interact in the right way, and in orchestrating those interactions to create requisite properties of the whole, such that it performs with optimum effectiveness in its operational environment, so solving the problem that prompted its creation" (Hitchins 2008: 120).
View	Multiple views, each based on a system aspect or concern, are essential to understand a complex system or problem situation. One critical view is how concern relates to properties of the whole. (Edson 2008; Hybertson 2009)

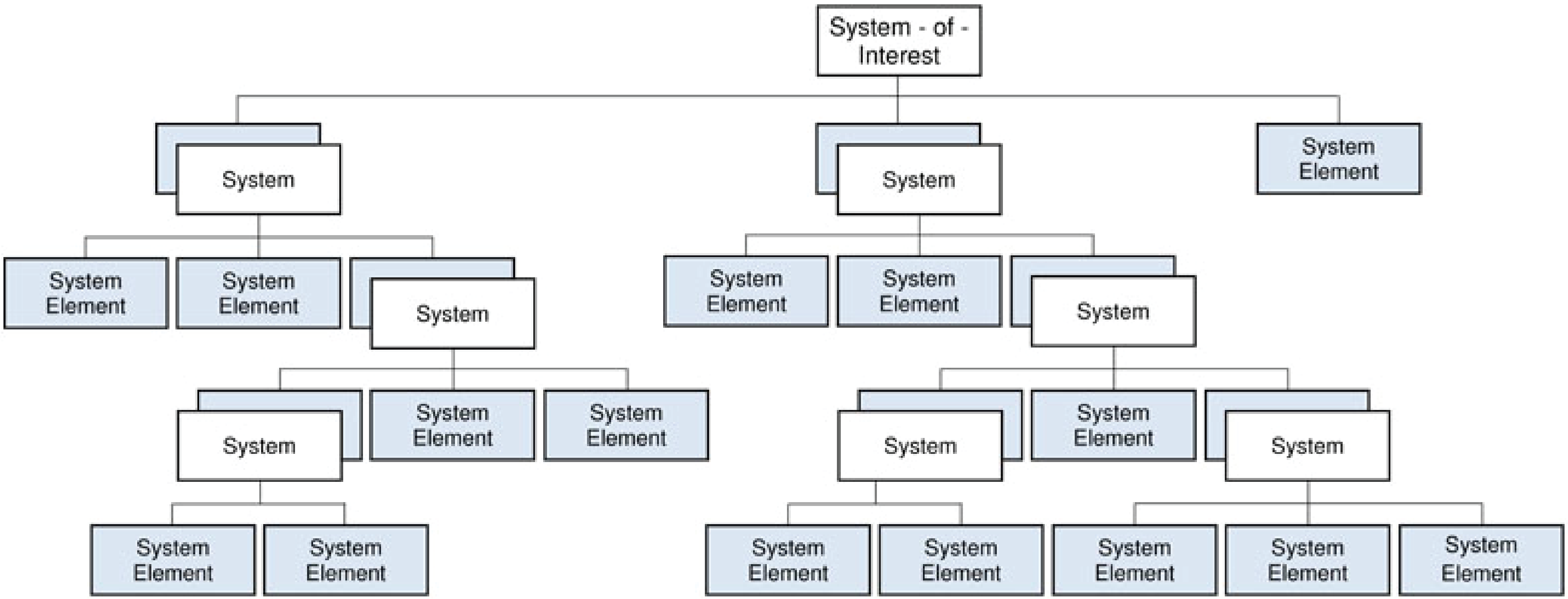
Systems Thinking

A holistic approach to analysis that focuses on the way that a system's **constituent parts interrelate** and how systems **work over time** and **within the context of larger systems**

Key concepts:

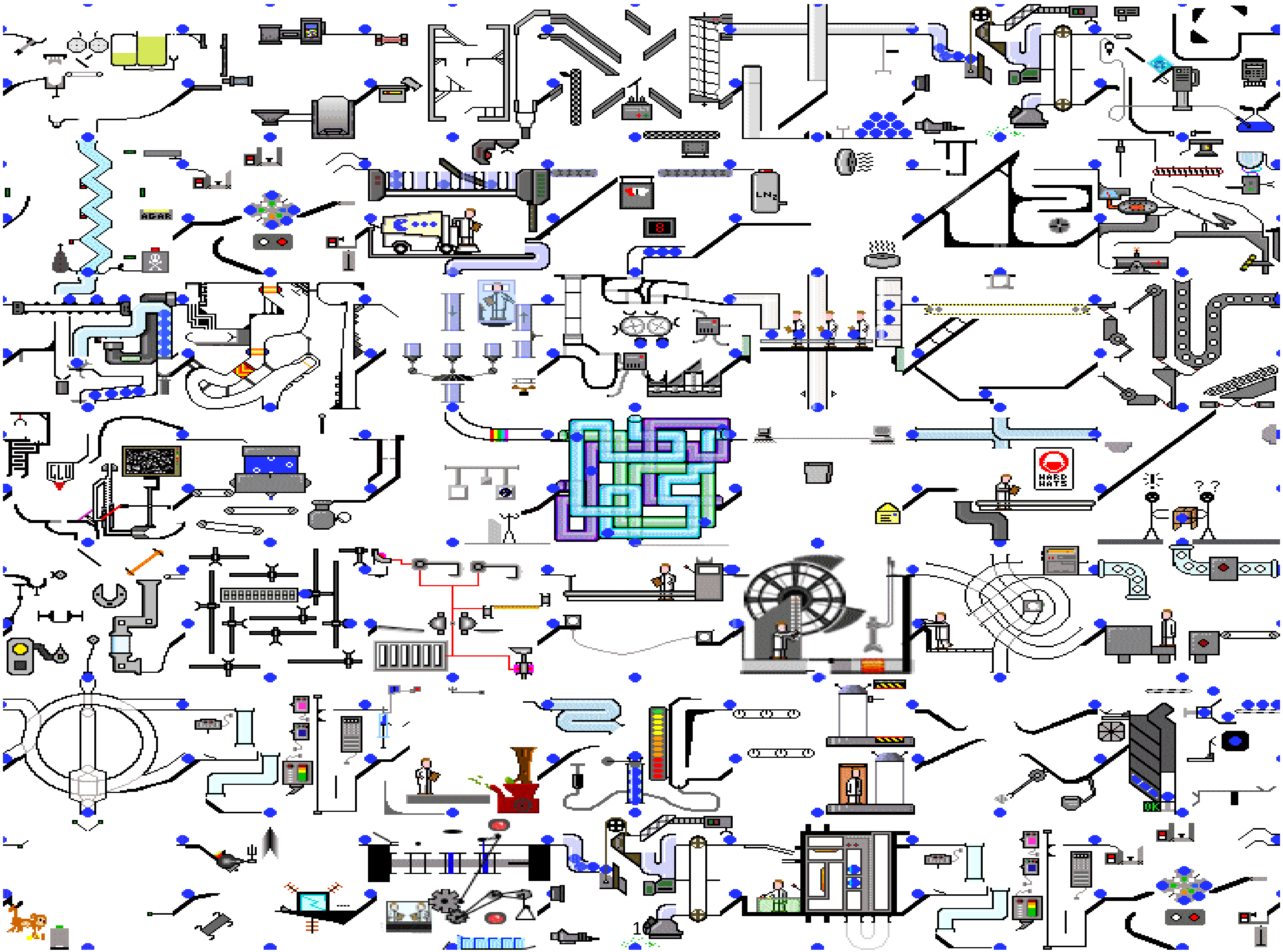
- **Hierarchy** – Systems are composed of smaller subsystems
- **Complexity** – Creates unknown (and sometimes undesirable) emergent behavior
- **Emergent behavior** – Properties of the system result from the both the components and their interactions

Hierarchy - System-of-Interest, System Element



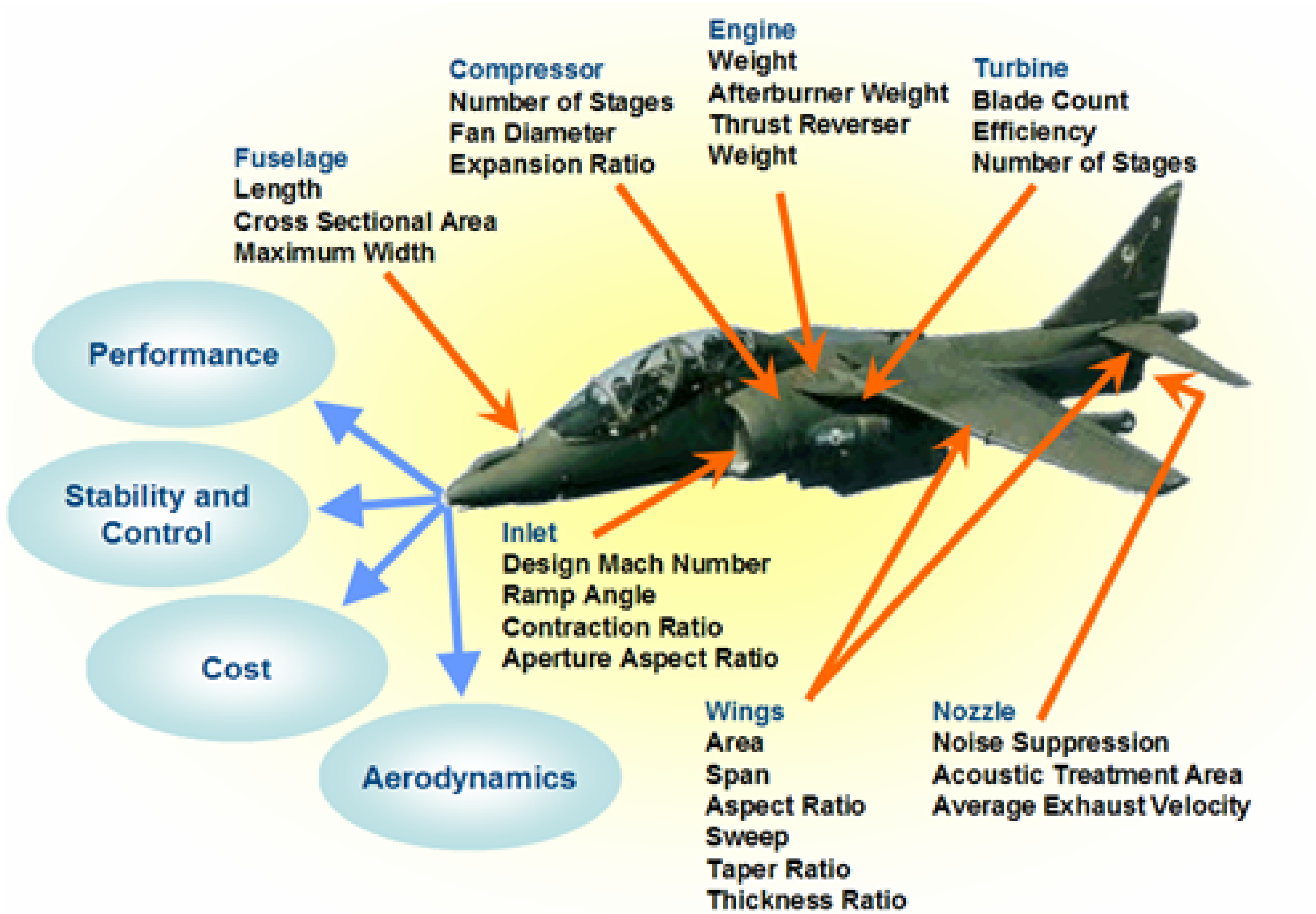
ISO/IEC/IEEE 15288

Complexity - What makes this system complex?



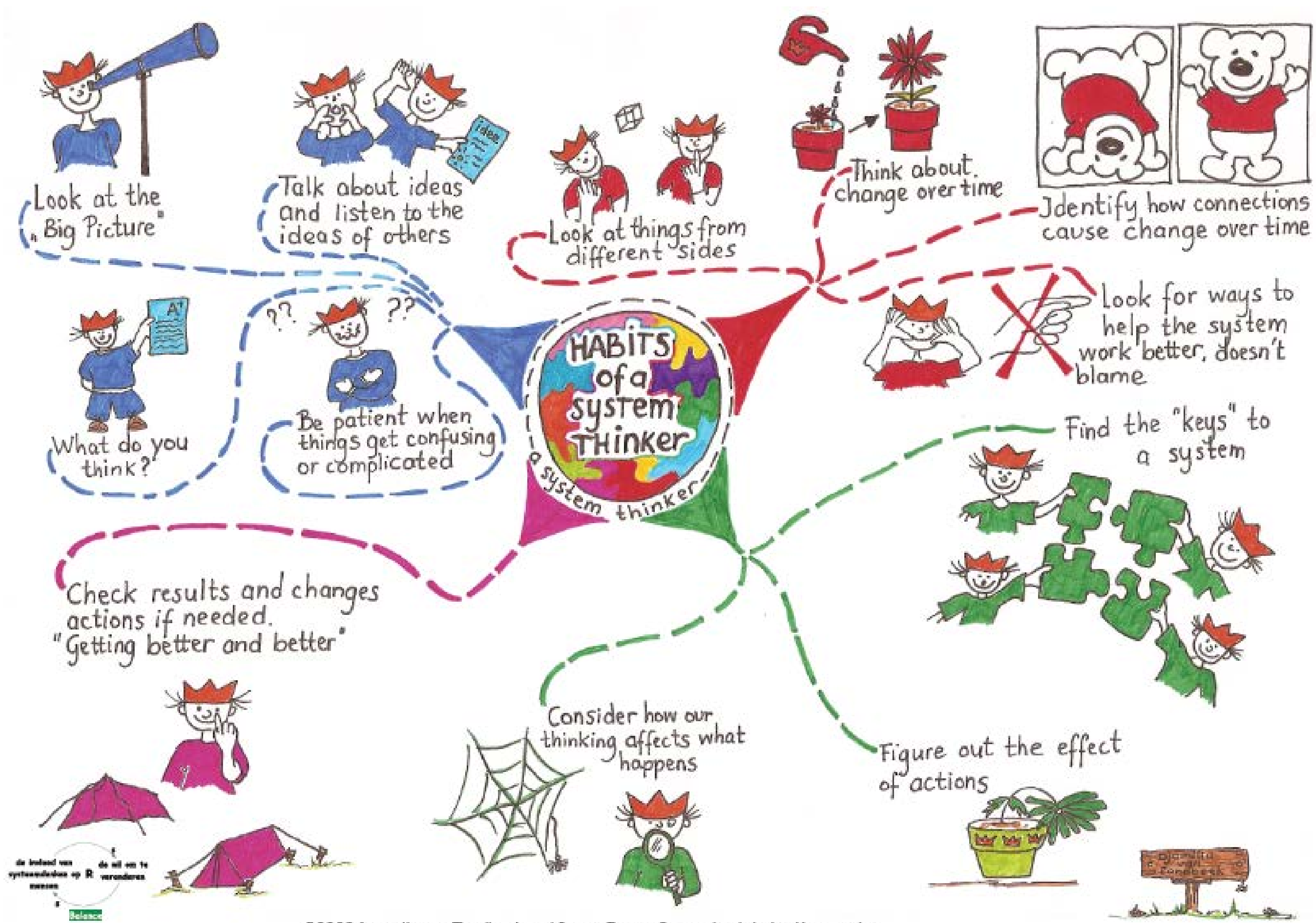
Emergent Behavior

Properties of the system result from both the components and their interactions



Discussion – System Example

- What is the hierarchy of systems?
- What makes the system-of-interest complex?
- What emergent behaviors (positive and negative) might we try to influence in the system design process?



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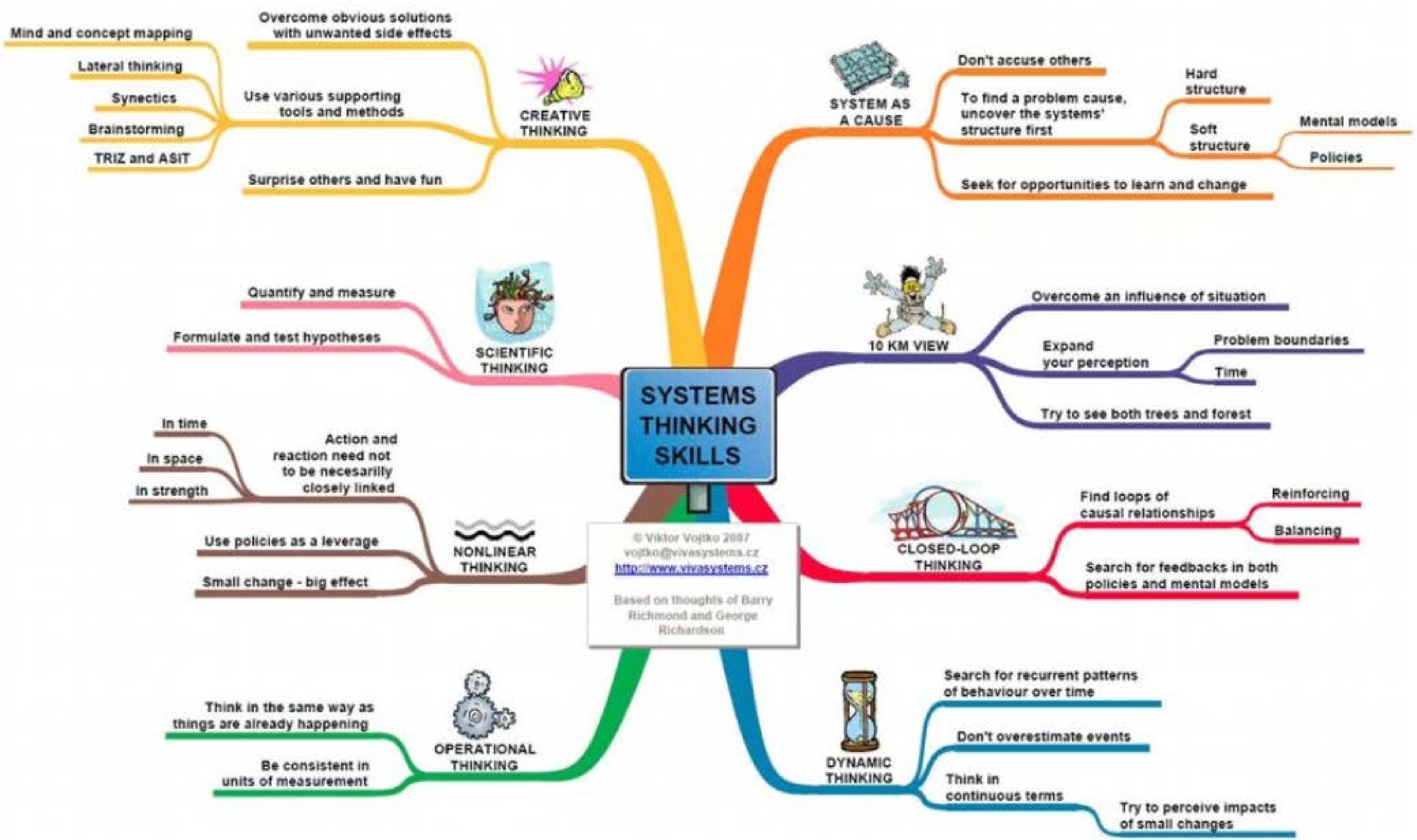
https://insightmaker.com/insight/597/Habits-of-a-Systems-Thinker

Systems Thinking Skills



https://bradhurstia.com/2015/07/09/scientific-literacy-is-key-to-understanding-systems-thinking/

Benefits of Systems Thinking

Provides a rigorous way of:

- Integrating people, purpose, process and performance
- Relating systems to their environment
- Understanding complex problem situations
- Maximizing the outcomes achieved
- Avoiding or minimizing the impact of unintended consequences
- Aligning teams, disciplines, specialisms and interest groups
- Managing uncertainty, risk and opportunity

How Systems Thinking Contributes to Systems Engineering, INCOSE UK

Systems Engineering

- An **interdisciplinary** approach encompassing the entire technical development effort to **evolve and verify** an integrated and **life-cycle balanced** set of system, people, product and process solutions that satisfy customer needs

Systems engineering encompasses:

- **Technical efforts** related to the development, manufacturing, verification, deployment, operations, support, disposal of and user training for, system products and processes
- Definition and management of the **system configuration**
- Translation of the system definition into **work breakdown structures**
- Development of information for management **decision making**

EIA 632, Systems Engineering

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System Engineering Process

INCOSE Handbook and ISO/IEC/IEEE 15288

AGREEMENT PROCESSES

- Acquisition
- Supply

TECHNICAL MANAGEMENT PROCESSES

- Project Planning
- Project Assessment and Control
- Decision Management
- Risk Management
- Configuration Management
- Information Management
- Measurement
- Quality Assurance

ORGANIZATION PROJECT-ENABLING PROCESSES

- Life Cycle Model Management
- Infrastructure Management
- Human Resource Management
- Quality Management
- Knowledge Management

TECHNICAL PROCESSES

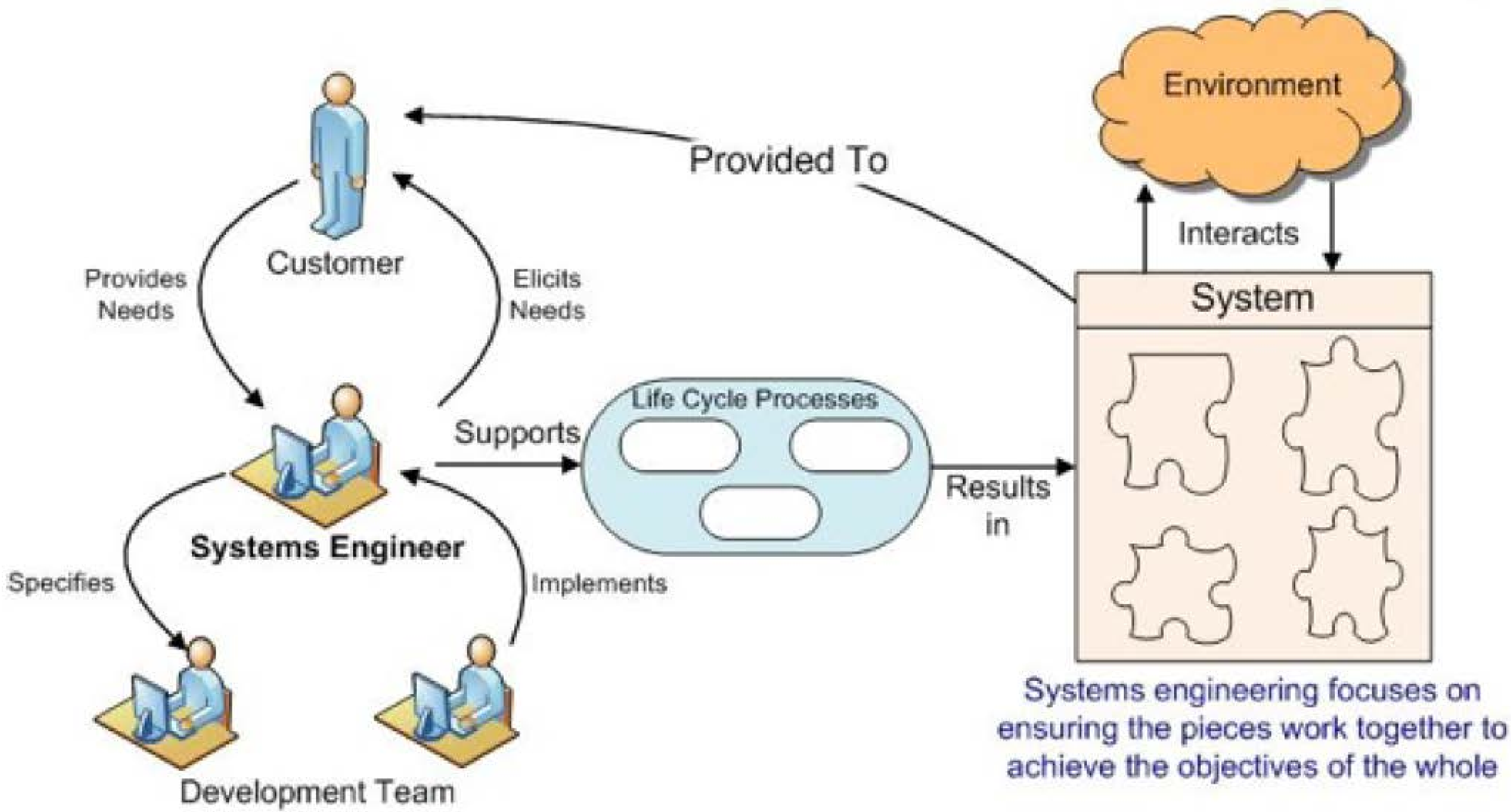
- Systems Analysis
- Business or Mission Analysis
- Stakeholder Needs & Requirements Definition
- System Requirements Definition
- Architecture Definition
- Design Definition
- Implementation
- Integration
- Verification
- Validation
- Operation
- Maintenance
- Transition
- Disposal

Systems Thinking Principles Applied to Systems Engineering

A. **The Systems Approach** - SE is applied to a system-of-interest (SoI) in a wider systems context
B. **Synthesis** - SE must bring together a collection of parts to create whole system solutions
C. **Holism** - Always consider the consequences on the wider system when making decisions about the system elements
D. **Organismic Analogy** - Always consider systems as having dynamic "living" behavior in their environment
E. **Adaptive Optimizing** - Solve problems progressively over time
F. **Progressive Entropy Reduction** - Continue to make systems work over time, through maintenance, sustainment, upgrade activities
G. **Adaptive Satisfying** - A system will succeed only if it makes winners of its success-critical stakeholders, so the lifecycle of a system must be driven by how well its outputs contribute to stakeholder purpose"

Hitchins, D., "What are the General Principles Applicable to Systems?"

Classic Role of a Systems Engineer



Systems Engineering Body of Knowledge (SEBoK)

Discussion – Systems Thinking

How would becoming more of a system thinker affect your job?

References

- What is Systems Thinking?, INCOSE SEBOK
- Basic principles of systems thinking as applied to management and leadership, The Institute of Systemic Leadership
- What are the General Principles Applicable to Systems?, D. Hitchins
- How Systems Thinking Contributes to Systems Engineering, INCOSE UK