NATURAL SYSTEMS WORKING GROUP

Overview of the Natural Systems Working Group

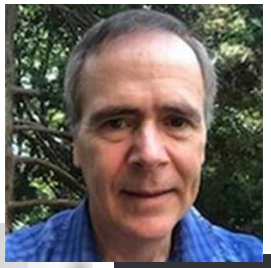
The Natural Systems Engineering Working Group is established to improve System Engineering processes and practices with the application of natural systems knowledge and approaches.

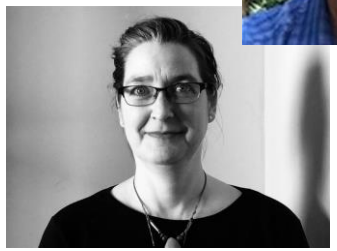
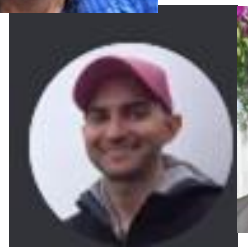

Co-chairs: Dennis Tuckowski, Allison Lyle


Founders: George Studor, Curt McNamara

Core members




NSWG Activities

- **Monthly Meetings**
  - 3rd Thursday of each month

- **2024 Sessions:**
  - *INCOSE IW 2024 (Jan)*
  - *IW 2024 Recap and 2024 Planning (Feb)*
  - *NSWG 10 year anniversary & Networking (March)*
  - *Digital Gaia (April)*
  - *Natural Artificial Intelligence (April)*
  - *Smart Cities Modeling (May)*
  - *Working Session - SE Processes (June)*
  - *INCOSE IS - AI BID (July)*
  - *Think Like an Ecosystem (August)*
  - *Working Session - IW 2025 topics (Sept)*
  - *Biomimetic AI (Oct)*
  - *IW 2025 Planning (Nov)*
  - *IW 2025 Prep (Dec)*

Workstreams / Products

1. Natural Systems Primer
2. Entry in SE Handbook v5
3. Library of presentations from SMEs in Natural Systems
4. NASA BIDARA AI tool
5. SEBoK entry (additions planned for fall 2025)
6. Application Roadmap (planned)
7. NASA/ Biomimicry Institute Biocene conference (planned)

NSWG Objectives

- Connect SE Practitioners with subject matter experts in NS: Help with answering “How can Nature help me solve this problem?”
- Build a Community of Practice: Identify, create, share tools, processes and resources to support
- Drive development practices to consider and leverage intelligence from Natural Systems throughout the entire product development lifecycle

Natural Systems - What are they?

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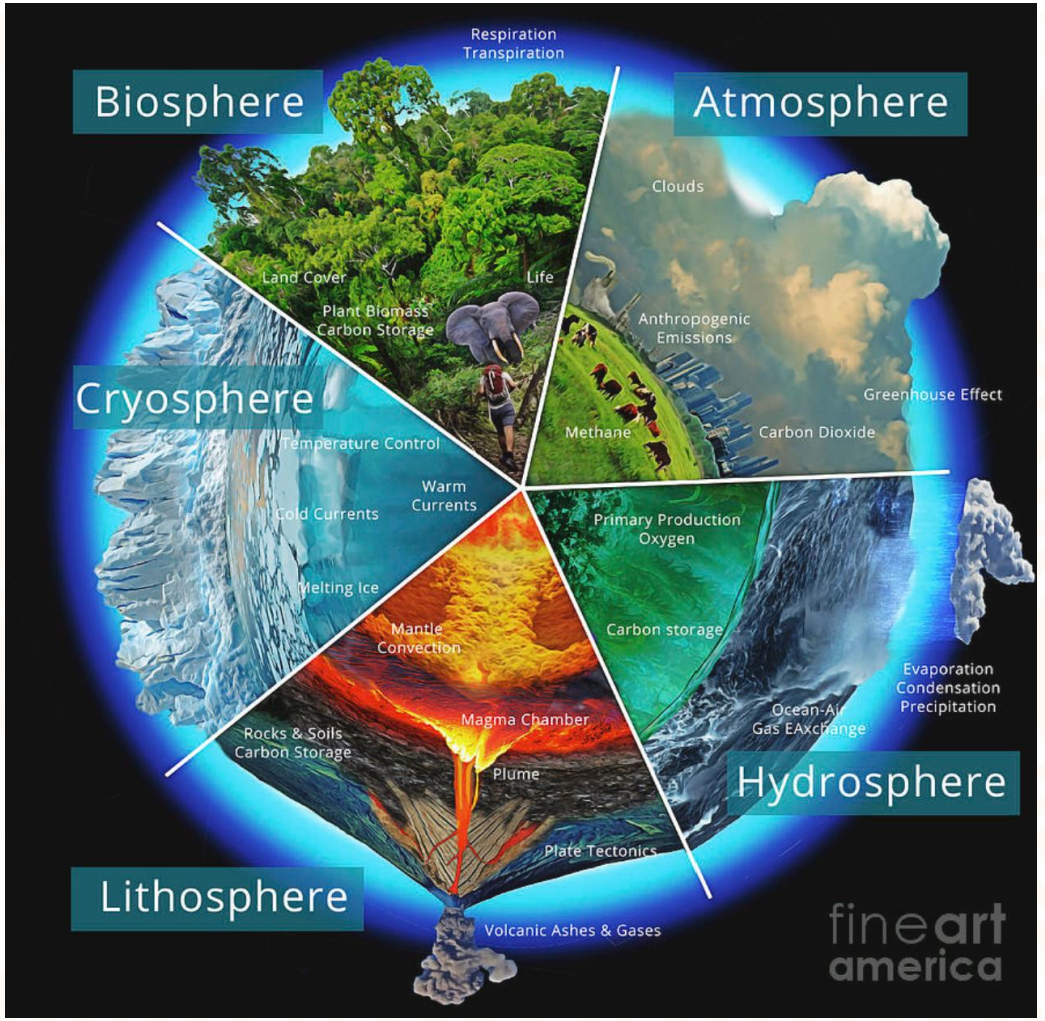
"An open system whose elements, boundary, and relationships exist independently of human control. "

- SEBoK

A system of planetary features, forces and processes, existing and operating independently of humans, governed by physical laws and limits.

- compiled from Cambridge, Wikipedia and Oxford dictionaries.



Earth's Climate System
sciencephotogallery.com

Biomimicry

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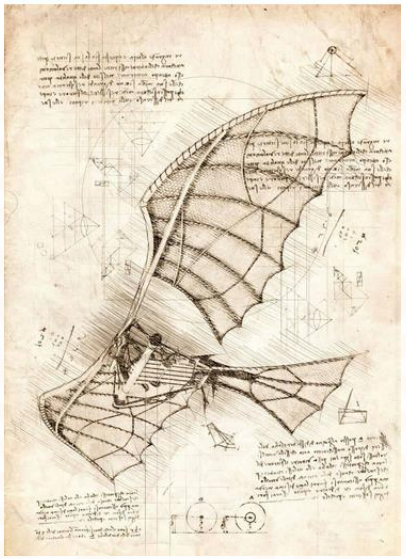
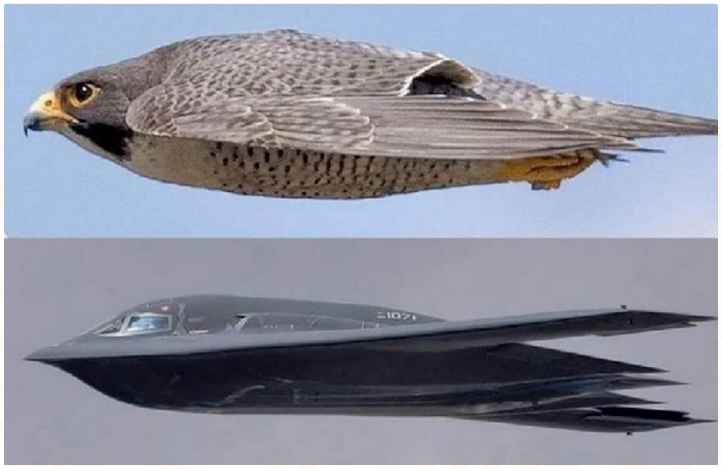
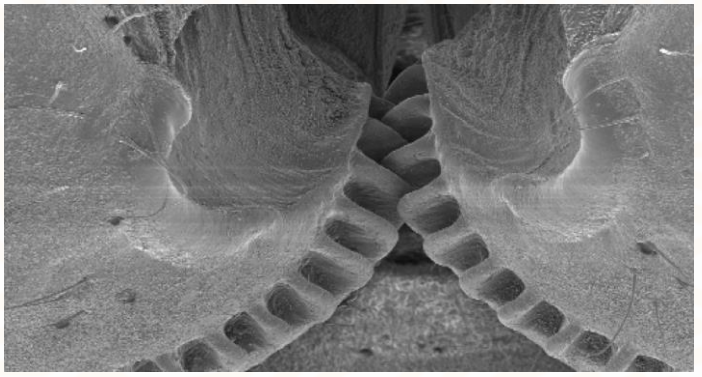






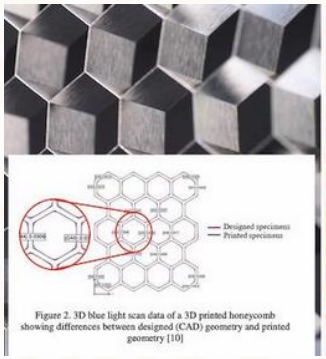
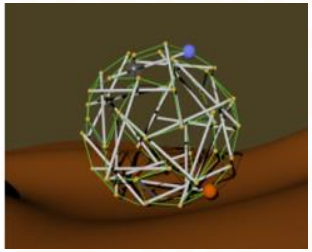
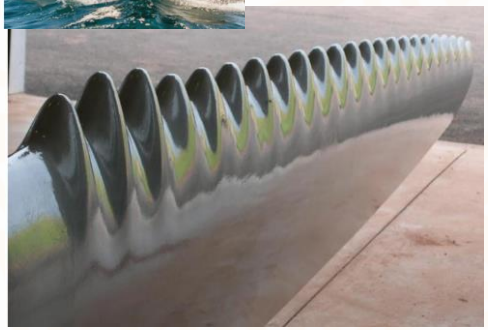


Figure 2. 3D blue light scan data of a 3D printed honeycomb showing differences between designed (CAD) geometry and printed geometry [10]





Biomimicry

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Image by Matthew Grocoff comparing emergent, bottom-up design of Venice, Italy with organic structure of a leaf showing similar branching patterns.

Thermal maps (right) superimposed on this termite mound show contrasting temperature profiles for night (left half) and day (right half).
Photographs courtesy of Hunter King and Sam Ocko

Ecosystem-mimicry

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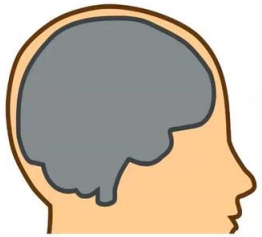
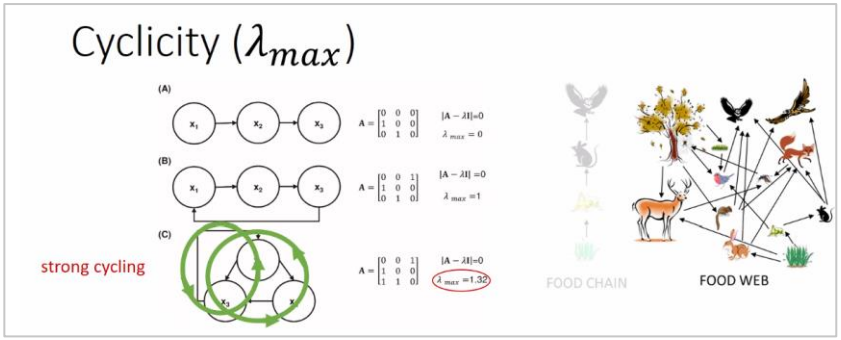


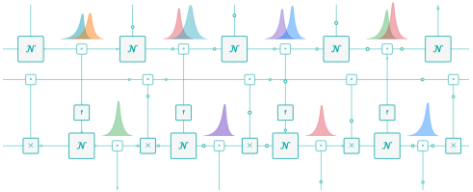
- Size: $>10^{14}$ (100 trillion) synapses
- Sensing: ~10^{7} (10 million) bits/sec
- Power: <20 Watts
- Latency: msec (real-time)

- Frontier Supercomputer (~ 1 exaflops*)
- 40 Mega-Watts

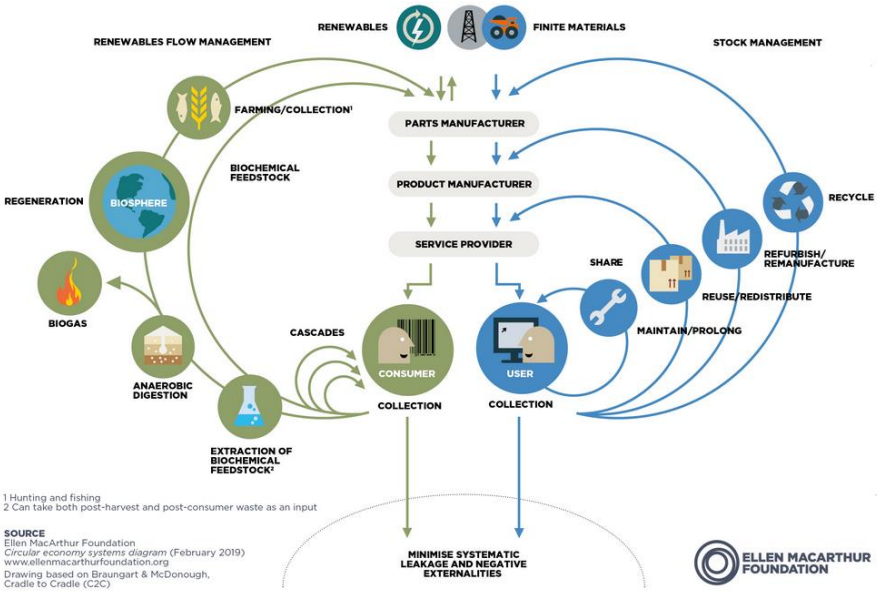
Consumes about 1 million times more power for similar computational load.

*: at least 10^{18} IEEE-754 Double Precision operations per second





B Commoner The Closing Circle: Nature, Man, and Technology (1971)



Principles of Natural Systems

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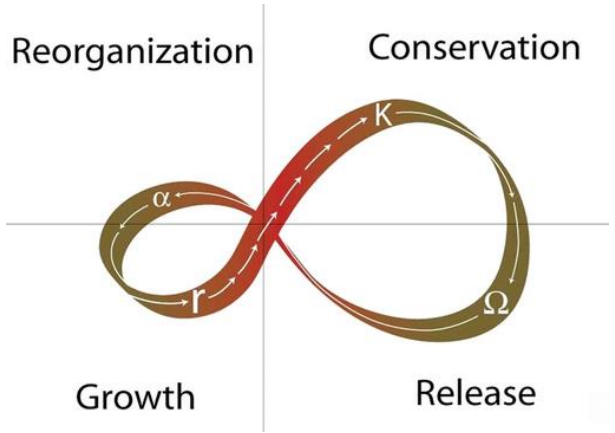
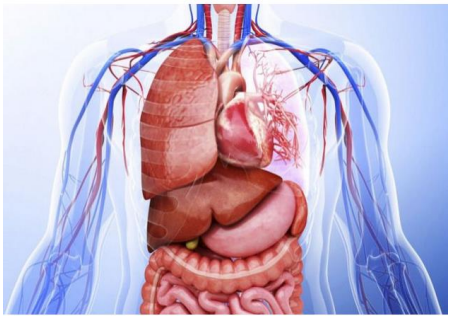
- Decentralized / Distributed
- Have evolved to function with low energy requirements
- Have high cycling rates (energy and material)
- Operate on closed cycling loops (energy and material)
- Exhibit patterns (in form, function and behavior)
- Adapt to their environment and operating context



The Adaptive Cycle



Source: Eye of Science/Science

Why leverage Natural Systems in system design?

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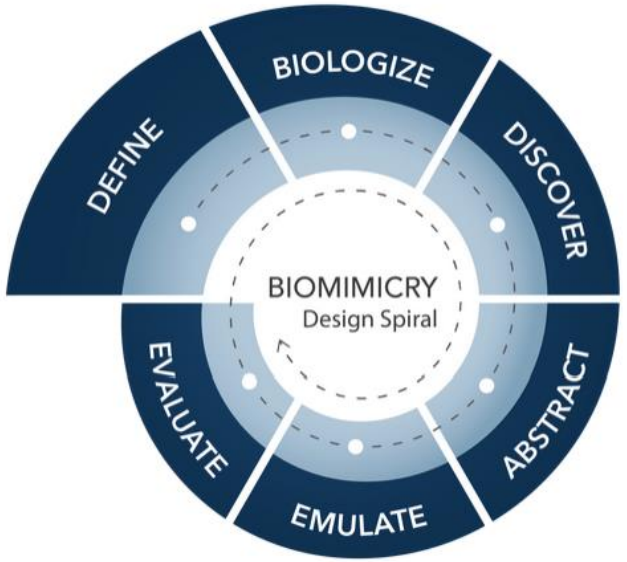
"Nature plays a harsh game of survivor, brutally winnowing out the weakest ideas from trillions of experiments. It's the best-funded, longest-lasting R&D lab in history."

- Andrew Winston

Natural systems have expertise in:

- Effectiveness
- Efficiency
- Waste / Reuse
- Energy Storage
- Resilience
- Growth strategies
- Symbiotic relationships



The Biomimicry Design Spiral
BiomimicryInstitute.org

Integration of Natural Systems with Human-Design Systems

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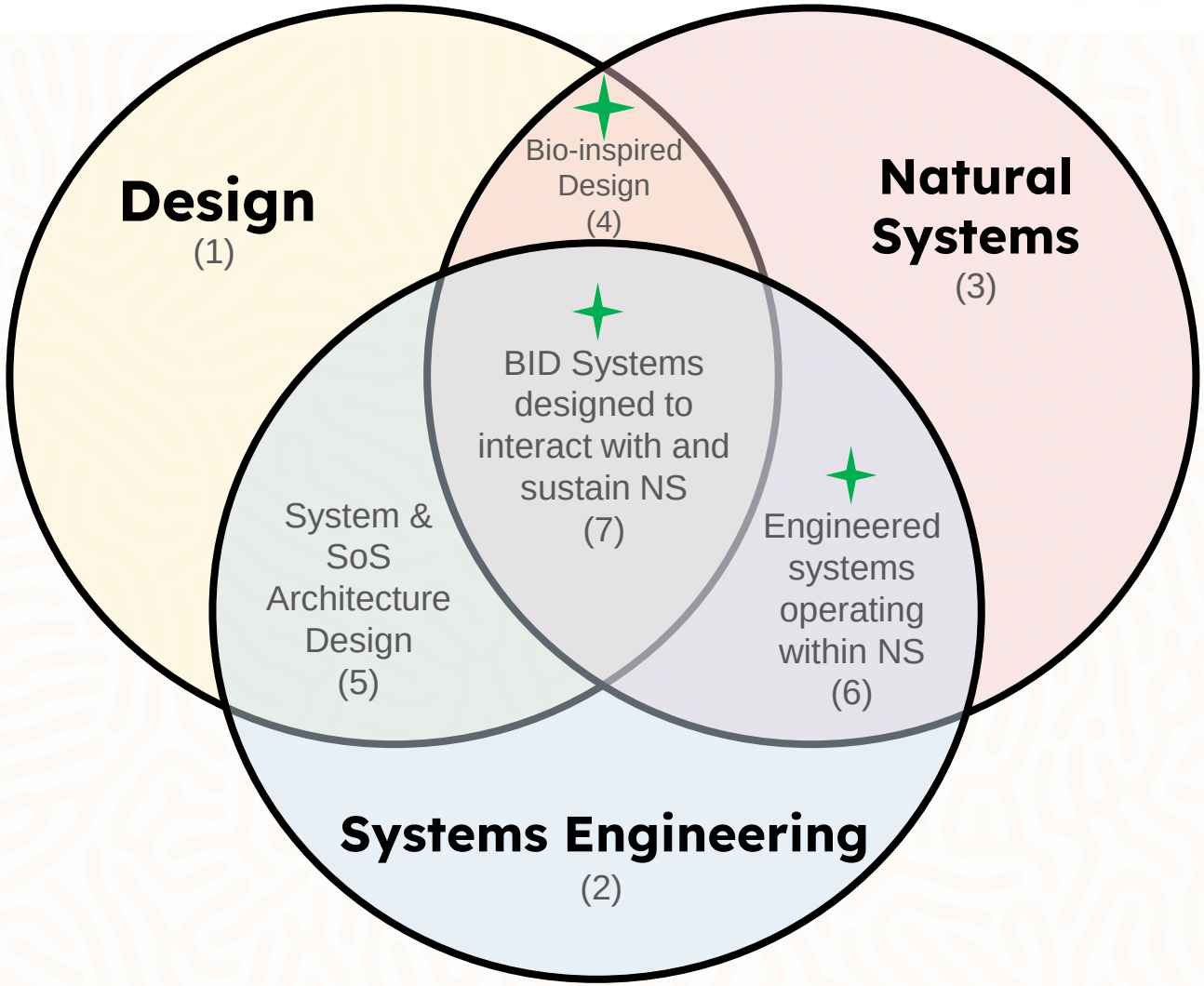

Natural Systems Integration into System Development Cycle

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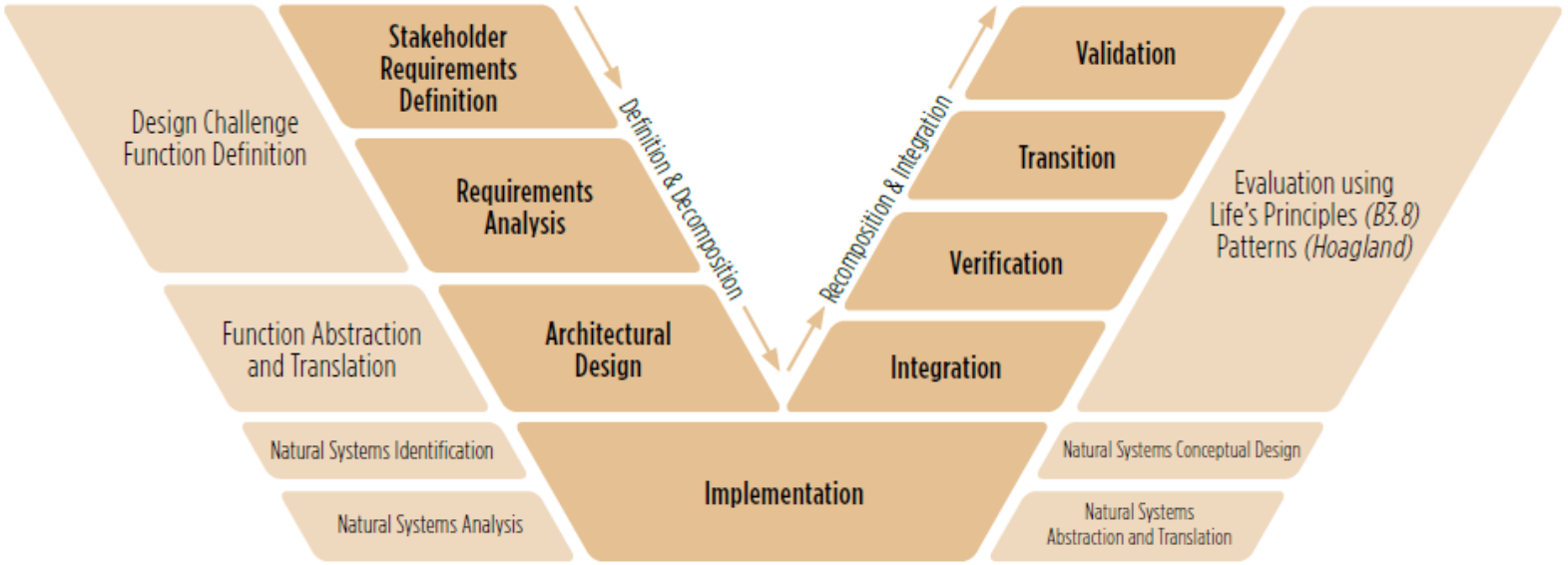
Systems Engineering vee diagram with Natural Systems inspiration process connections V2

Note: Assuming that both processes start with an understanding of the problem.



Natural Systems and SE process overlay (Nagel)
(from INCOSE Natural Systems Primer)

Natural Systems can be leveraged at every step of the system life-cycle

Natural Systems Integration into System Development Cycle

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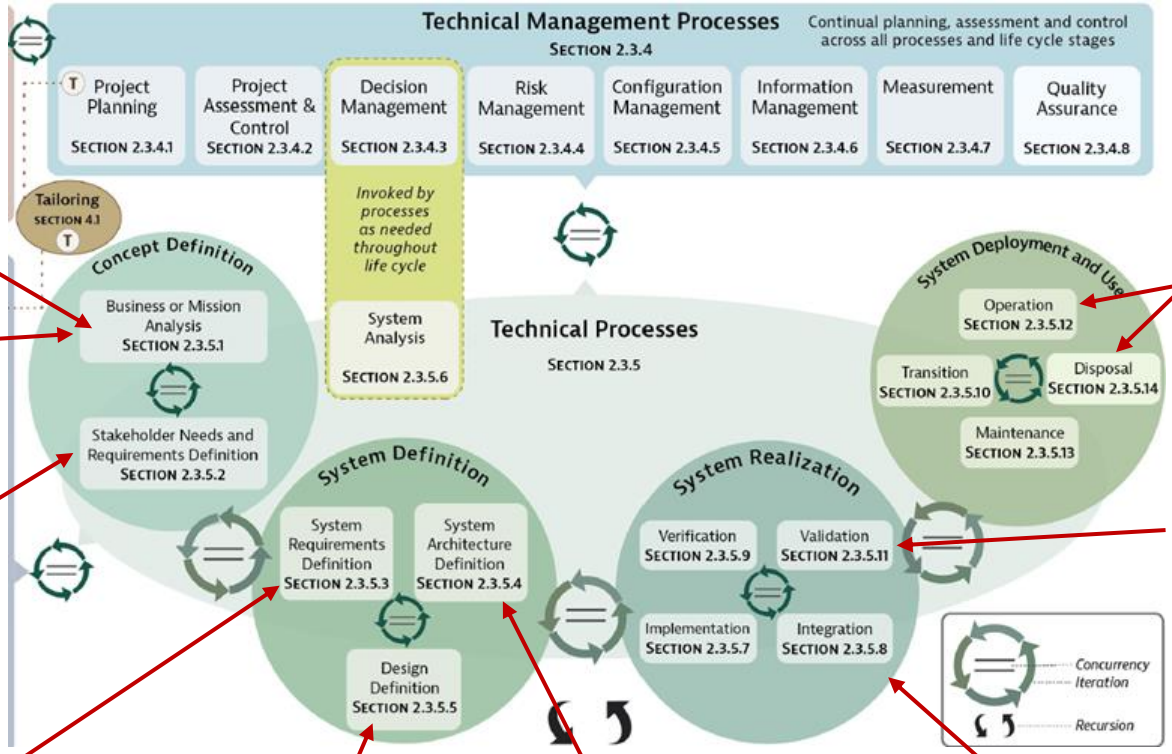
- Analysis of NS for SOI operating environment
- Consideration of material, energy sources & sinks (I/O), risks

Natural Systems as a stakeholder



Consideration of NS-SOI interfaces, sources & sinks

Bio-inspired evaluation and acceptance criteria (based on Life's Principles)

- Requirements driven from NS Stakeholder analysis, risk assessements
- Bio-inspired requirements syntax (solution-agnostic)

Bio-inspired Design (form, structure, function, behavior)

Bio-inspired architecture: (deep patterns, modularity, distribution, connectedness)

Consideration of NS-SOI interfaces, sources & sinks

Natural Systems can be leveraged at every step of the system life-cycle

Natural Systems in SE Vision 2035

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SUMMARY OF
SYSTEMS ENGINEERING BY 2035
ADAPTS TO CHANGES IN ITS GLOBAL CONTEXT

- Strong demand from across industry and governments for systems engineering to provide balanced system solutions to complex problems

- Systems engineering is a highly valued discipline
  - Readily available education programs
  - Well-established career paths
  - Opportunity to innovate, lead, and work across disciplines and technical domain
- Collaborations between industries, academia, and governments continues to advance systems engineering

SYSTEMS SOLUTIONS
(including cyber-physical, service-oriented, socio-technical, ...)

DIGITAL ENTERPRISE
- Knowledge as an asset
- Agile and efficient
- Innovative
- Distributed and diverse workforce

DELIVERS

INCREASING SYSTEMS COMPLEXITY
- Interconnectedness
- Data
- Software
- Human interaction
- Competing stakeholder expectations

Global competition
Technology
Regulatory environment
Cyber threats
Supply chain

BROAD APPLICATIONS
- Power and energy systems
- Healthcare systems
- Transportation systems
- Defense systems
- Education systems
- Exploration systems
- Agricultural systems
- Telecommunication systems
- Manufacturing systems
- Information systems
- . . . and many others

RESULTS IN

IMPACTS ON ENVIRONMENT AND SOCIETY

ENVIRONMENTAL IMPACT
- Natural resources
- Biodiversity
- Climate change
- Pollution

SOCIETAL CHANGE
- Global interdependence
- Population
- Lifespan
- Socio-economic condition

SYSTEMS ENGINEERING
aims to ensure the pieces work together to achieve the objectives of the whole.

SUPPORTS

RESULTS IN

PRACTICES
- Agile
- Model-based
- Analytic framework
- Architecting for trust, resilience, and other key stakeholder concerns
- Leveraged reuse
- Human-centered design

TOOLS AND ENVIRONMENT
- Part of digital ecosystem
- Seamless interactions and trusted collaboration
- Automated workflow
- Managed digital thread
- Enterprise reuse repository
- AI assist

EDUCATION AND TRAINING
- Life-long learning
- Technical and leadership competencies
- Standardized curriculum adapted to application domains
- Theoretical foundations and systems engineering principles part of standard curriculum
- Systems thinking taught broadly across engineering disciplines

DRIVER OF

GROWING STAKEHOLDER EXPECTATIONS
- Capability
- Dependability
- Ease of use
- Scalability and adaptability
- Sustainability
- Social acceptability
- Affordability