NASA/TM—2020-220482

Biocene 2018

Vikram Shyam
Glenn Research Center, Cleveland, Ohio

March 2020

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Biocene 2018

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Cleveland, Ohio 44135

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Biocene 2018

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Abstract

This 'minds-on' workshop will explore emerging cross-discipline tools and techniques for moving Bio-Inspired Design (BID) into “standard practice” in systems engineering and engineering design. Discussion will center on state-of-the-art in BID tools, emerging toolkits for engineering innovation, and industry best practices.

The aerospace industry is at a point where components are reaching design maturity and performance improvements are incremental. Aggressive goals for fuel burn reduction and the threat of climate change necessitate a new paradigm. An artificial intelligence (AI) approach that enables revolutionary changes in system architecture, mission analysis and performance metrics is needed. The growing interest and development in the field of machine learning presents an opportunity to speed up by 10 times or more the discovery, analysis and development of aerospace systems using artificial intelligence and natural systems.

Biocene 2018

Welcome to the period of *new life*

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Periodic Table of Life

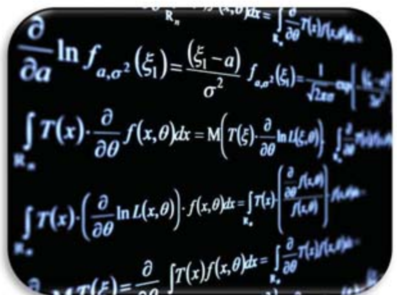
Wouldn’t it be great to live in a simulation?

- How many want a world where you are free to think and do what you want without stepping on the wants and desires of others?
- But where technology and exploration continues to grow.
- This will be a world of empathy, technological greatness and human growth the likes of which we have never seen.
- This is what I call the Biocene, the beginning of the age of *new life*

Biocene

Biocene is the period of new life. When our descendants look back at this period in time, they will see evidence, in the geologic and electronic record, of anthropic climate change, growing population, and scarcity of resources. But they will also see the rebirth of human ingenuity as we overcame the challenges that faced us through nature-inspired exploration.

Math provides rules for all hypothetical existence – real and unreal – abstract patterns.
Physics describes the real world – reality we are aware of.
Biology turns abstraction into reality.
We can use biology to train AI and go beyond nature,
To create a future that is selfish and yet fair to all



Reference 1

- Nature's rules and framework

Reference 2

- Train AI using biology's solutions and patterns

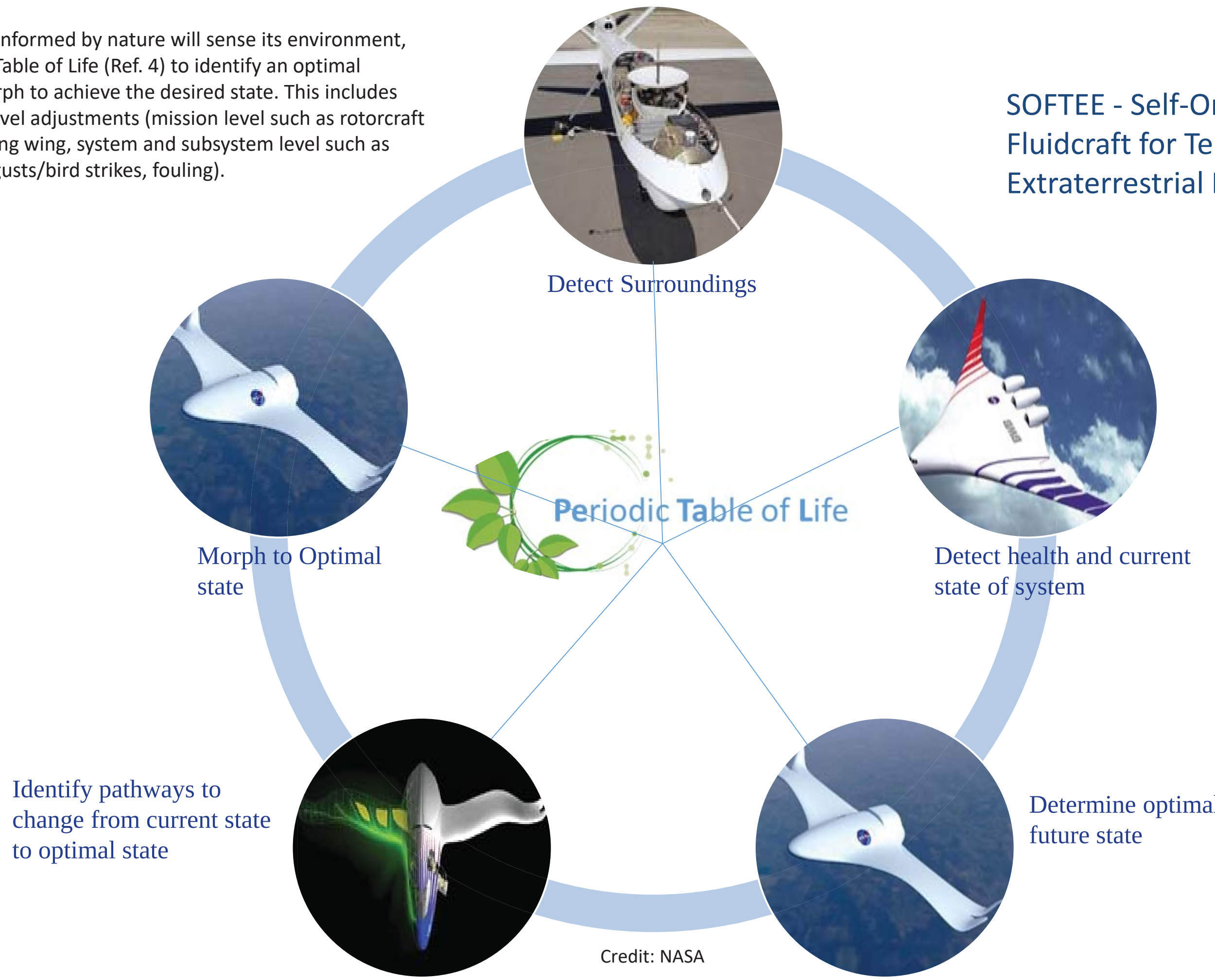
- Synthetic biology
- Simulated evolution
- Directed evolution
- Artificial Intelligence

Reference 3

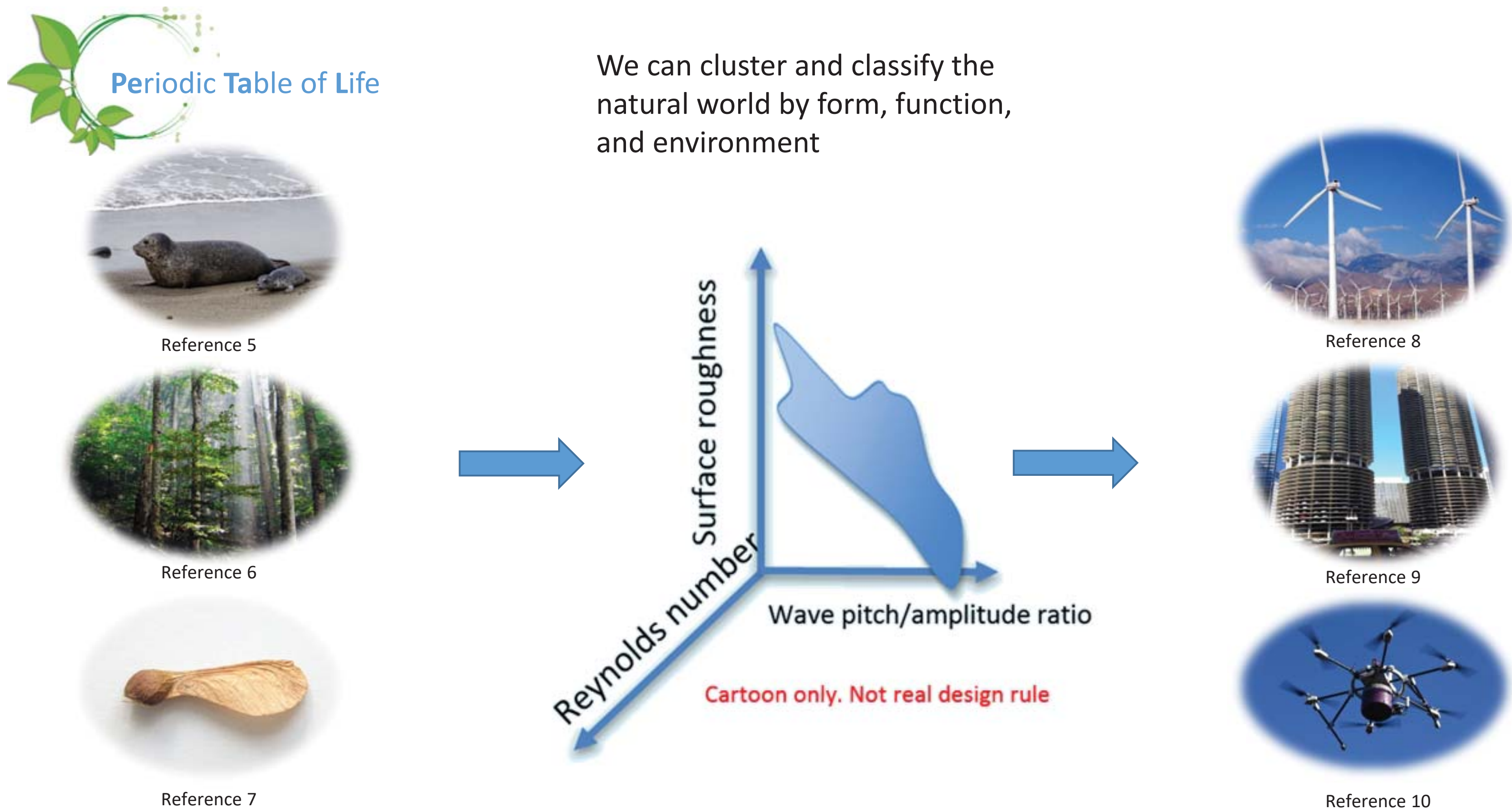
The next phase in human evolution

A closed loop system informed by nature will sense its environment, draw on the Periodic Table of Life (Ref. 4) to identify an optimal configuration and morph to achieve the desired state. This includes multiscale and multilevel adjustments (mission level such as rotorcraft to fixed wing or flapping wing, system and subsystem level such as adjustments to wind gusts/bird strikes, fouling).

SOFTEE - Self-Organizing Fluidcraft for Terrestrial and Extraterrestrial Exploration



Credit: NASA



Need an automated, intelligent design tool to enable nature-inspired system design

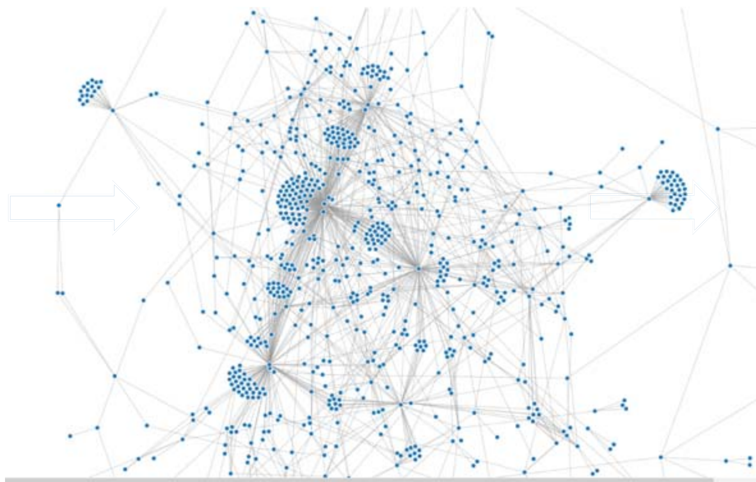
Periodic Table of Life

And see patterns that emerge


Reference 5


Reference 6


Reference 7




Reference 8


Reference 9


Reference 10

Need an automated, intelligent design tool to enable nature-inspired system design

Periodic Table of Life

And find gaps in our knowledge

Reference 5

Reference 6

Reference 7

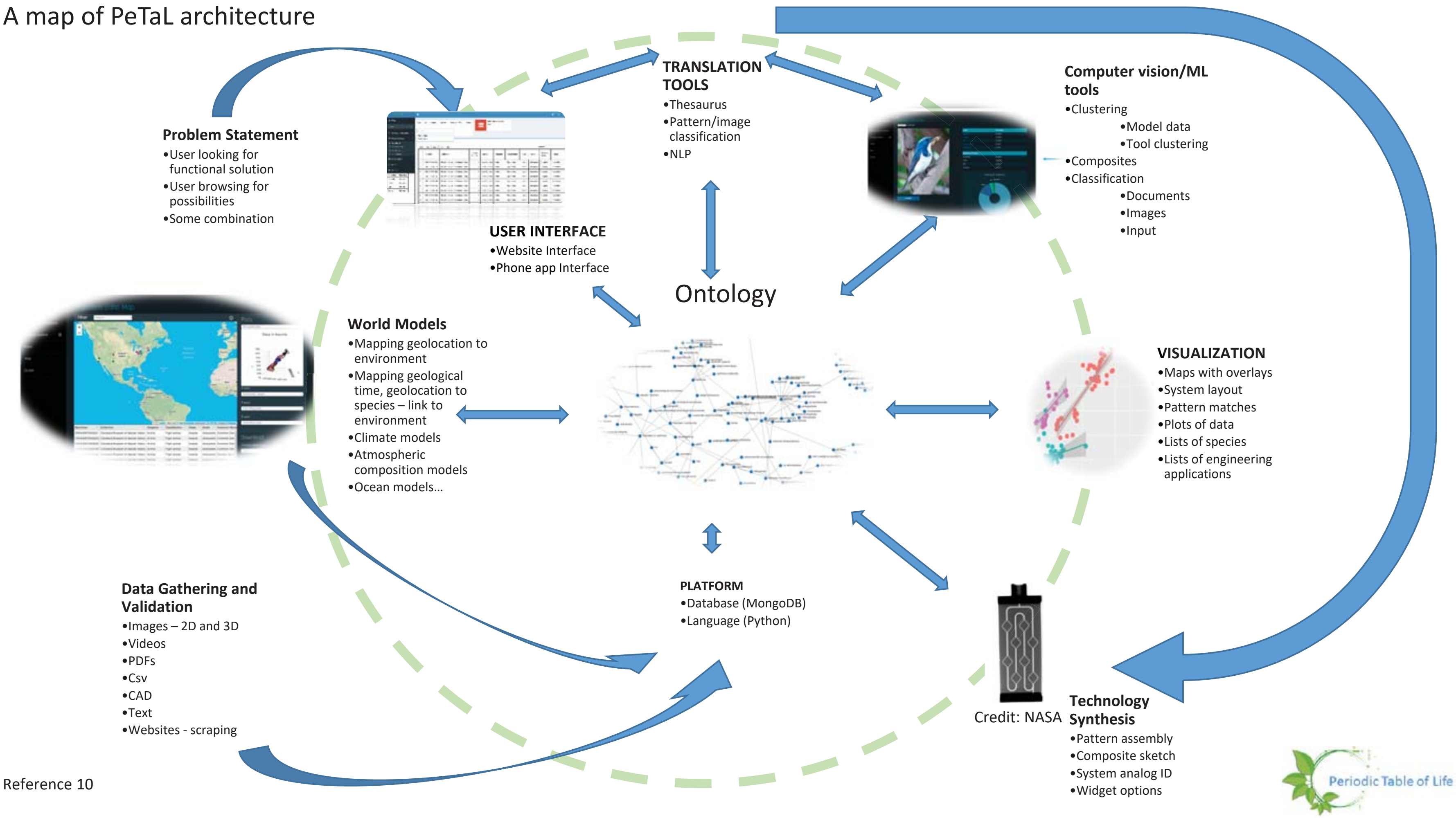
Reference 8

Reference 9

Reference 10

Need an automated, intelligent design tool to enable nature-inspired system design

A map of PeTaL architecture



Reference 10

Personality and Problem Solving

Reference 10

Periodic Table of Life

How does personality impact decision making

- How much planning is involved?
- How many people are involved?
- How many steps? In what order?
- Do you question the problem? Should you be solving a different problem?

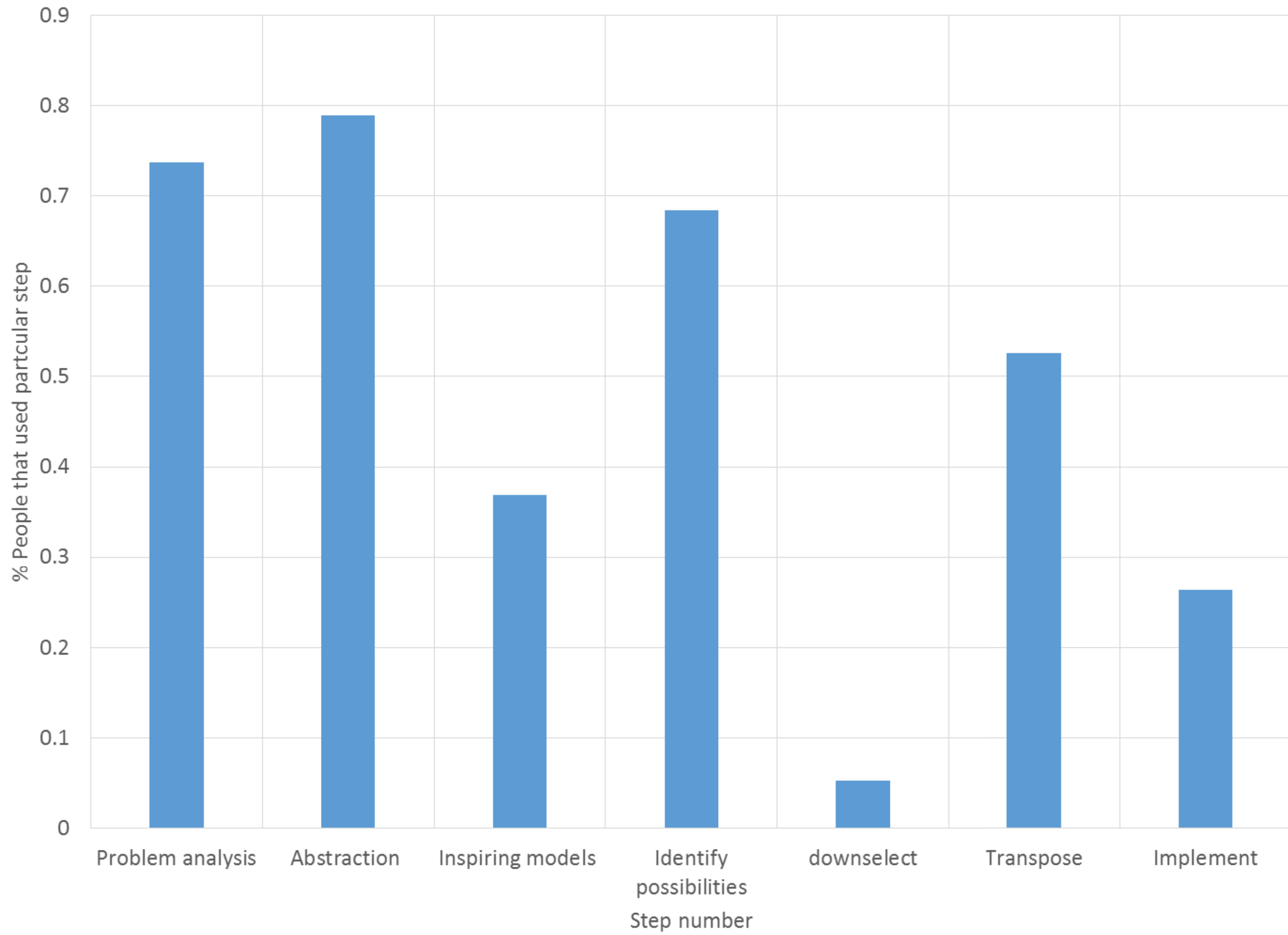
Periodic Table of Life

Approach to problem-driven design

Reference 11

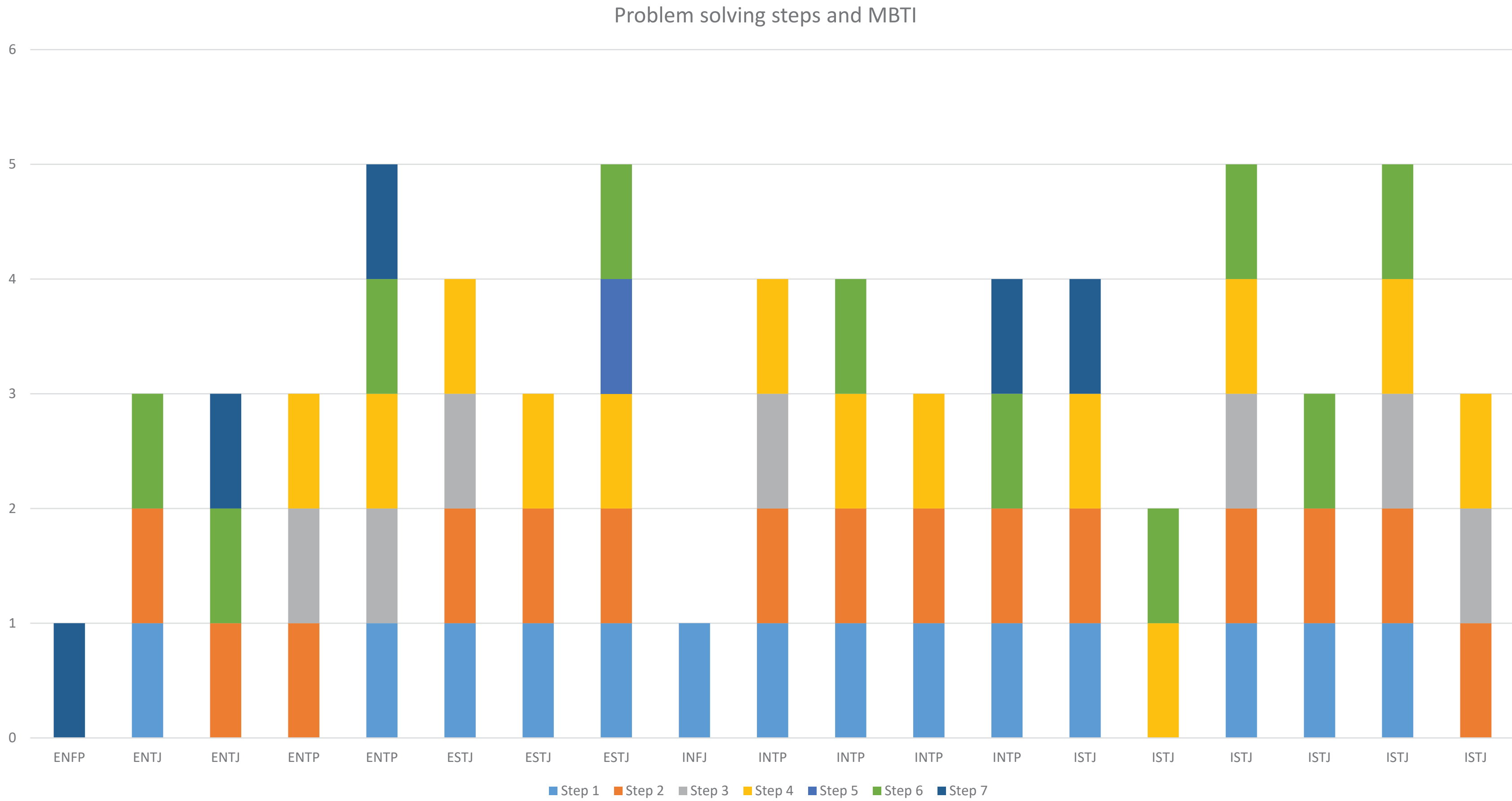
- Step 1: Problem analysis (analysis) – What is the problem you are solving? How many components? Any constraints?
- Step 2: Abstraction of the Technical Problem (abstraction) – Other ways of phrasing the problem? Can you zoom out and try achieving a higher level result with another technical approach?
- Step 3: Transposition to inspiring models (transfer) – ask the question, how would nature do xyz…how would neighbors do xyz
- Step 4: Identification of potential models (application) – select possible options
- Step 5: downselection of model(s) of interest (analysis) – Based on constraints, how many objectives does this model achieve? Downselection
- Step 6: Transposition to technology (transfer) – Figure out how to replicate the model for your situation/problem
- Step 7: Implementation and test of the concept (application) – apply the new approach and compare with what you were doing before.

Periodic Table of Life

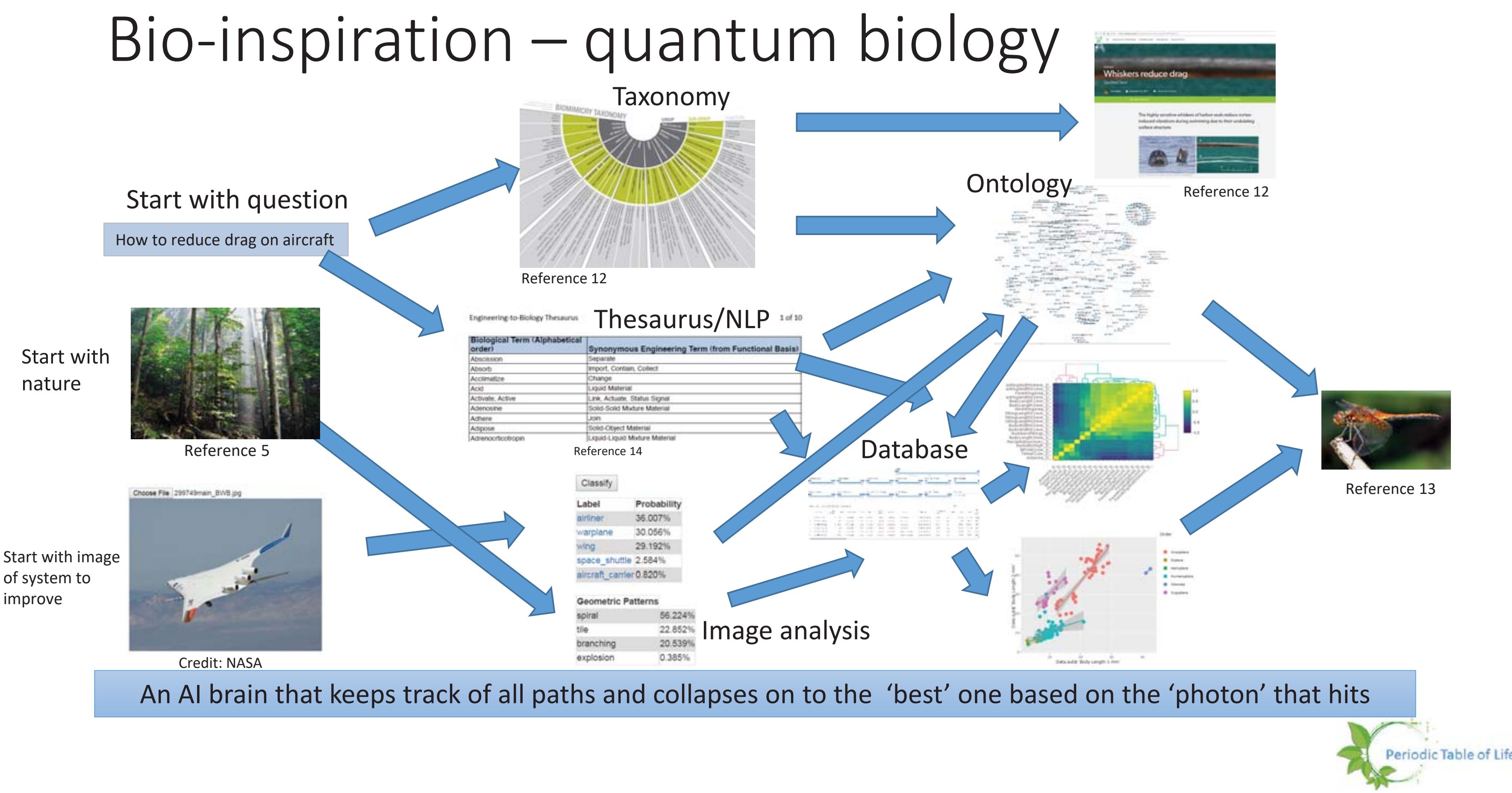


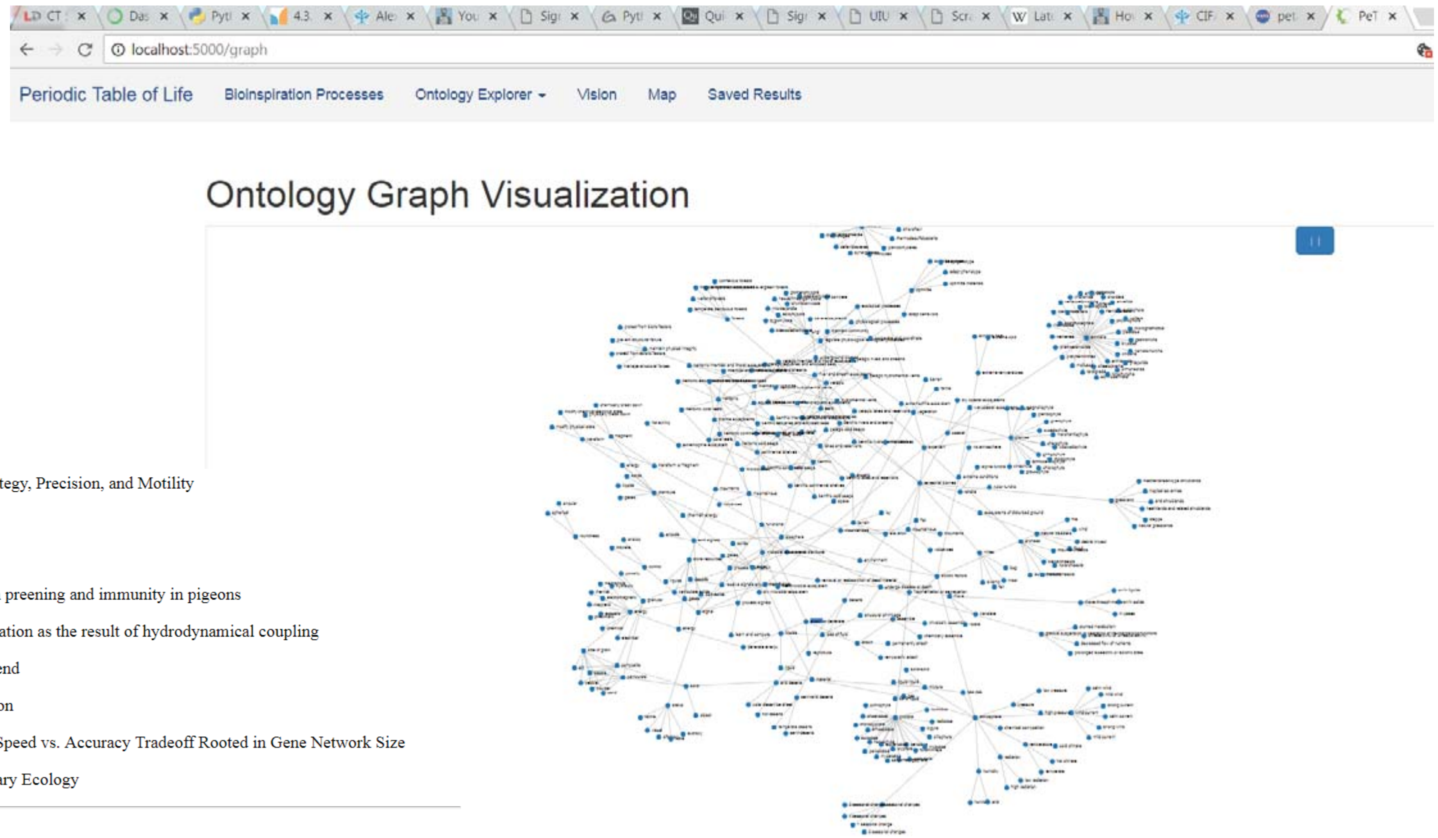
Reference 10

Periodic Table of Life



Reference 10


Bio-inspiration – quantum biology
Taxonomy
Reference 12
Start with question
How to reduce drag on aircraft
Whiskers reduce drag
Reference 12
Ontology
Thesaurus/NLP
Engineering-to-Biology Thesaurus
Biological Term (Alphabetical order)
Synonymous Engineering Term (from Functional Basis)
Abscission
Separate
Absorb
Import, Contain, Collect
Acclimatize
Change
Acid
Liquid Material
Activate, Active
Link, Actuate, Status Signal
Adenosine
Solid-Solid Mixture Material
Adhere
Join
Adipose
Solid-Object Material
Adrenocorticotropin
Liquid-Liquid Mixture Material
Reference 14
Start with nature
Reference 5
Database
Reference 13
Classify
Label
Probability
airliner 36.007%
warplane 30.056%
wing 29.192%
space_shuttle 2.584%
aircraft_carrier 0.820%
Geometric Patterns
spiral 56.224%
tile 22.852%
branching 20.539%
explosion 0.385%
Start with image of system to improve
Credit: NASA
Image analysis
An AI brain that keeps track of all paths and collapses on to the ‘best’ one based on the ‘photon’ that hits
Periodic Table of Life



E. coli superdiffusion and Chemotaxis-Search Strategy, Precision, and Motility

Thermal adaptation of viruses and bacteria

Tradeoffs in bacteriophage life histories

Feather bacterial load shapes the trade-off between preening and immunity in pigeons

Cilia internal mechanism and metachronal coordination as the result of hydrodynamical coupling

Dynamics and mechanics of the microtubule plus end

Sympatric speciation under incompatibility selection

Evolution of Competitive Ability: An Adaptation Speed vs. Accuracy Tradeoff Rooted in Gene Network Size

Tradeoff s and Negative Correlations in Evolutionary Ecology

Related

Superclasses
Subclasses
material
energy
signal
organism
See Also

Periodic Table of Life

- An image is decomposed into constituent patterns
- Features are recognized
- These help determine relationship between form and function and in defining systems and subsystems
- This can help identify solutions by connecting the ontology to the elements in the image

localhost:5000/vision

Image Classifier

Choose File IMG_0778.JPG

Classify

Label	Probability
accordion	65.480%
drum	18.769%
chain_mail	2.187%
shield	1.563%
vending_machine	0.868%

Geometric Patterns	
tile	65.250%
branching	26.661%
spiral	6.683%
explosion	1.406%

Periodic Table of Life

Topic modelling and classification

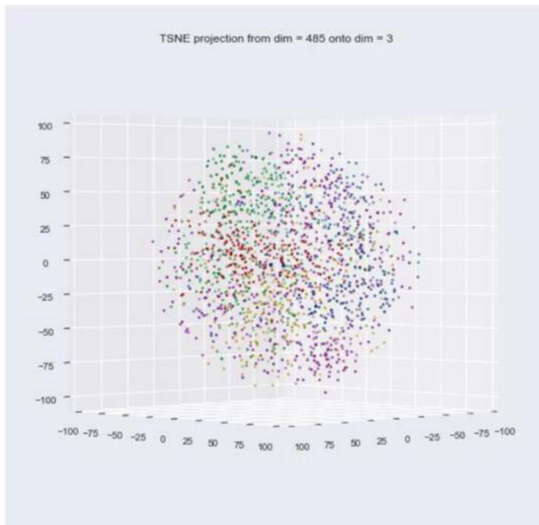


Figure 1. TSNE Topic Clusters projection. *Visualizing the documents as projected downward onto three dimensions.*

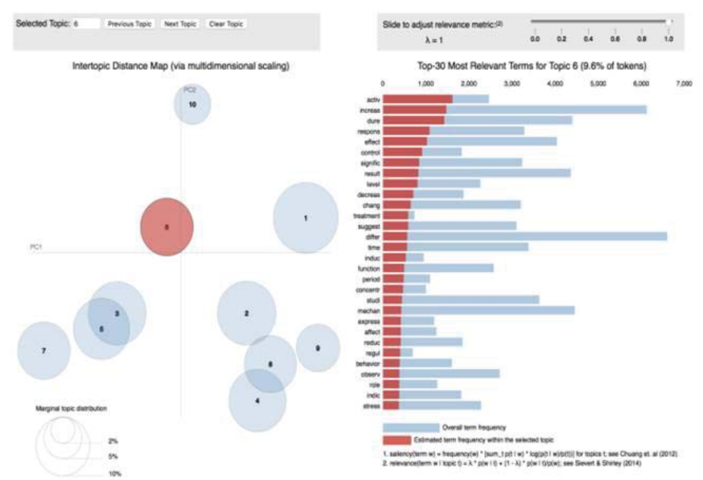
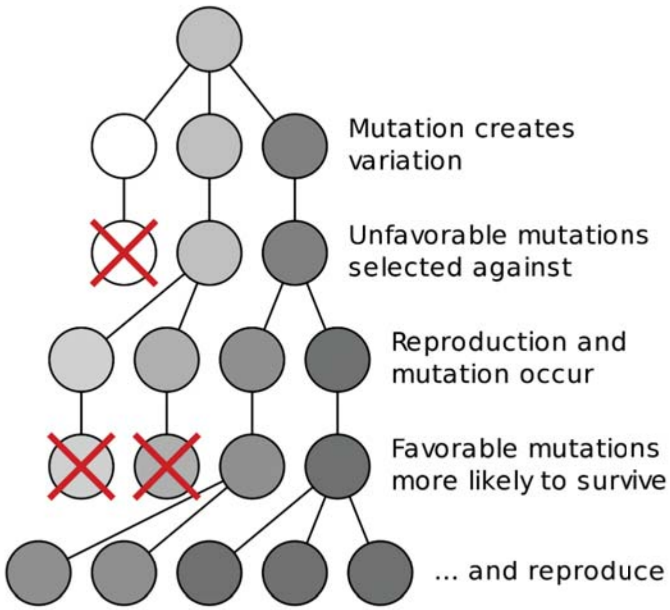


Figure 3. pyLDAvis topic choice 6. *Here is an initial launch of the cluster tool. The relevance slider is set to 1, presenting the top 30 relevance terms according to the relevance metric*[3]

Figures from Reference 10. Automated clustering of source texts and creation of 'clusters'. New articles can be sorted into these clusters. Clusters linked to ontology through thesaurus

Periodic Table of Life

Bio-inspiration - evolution



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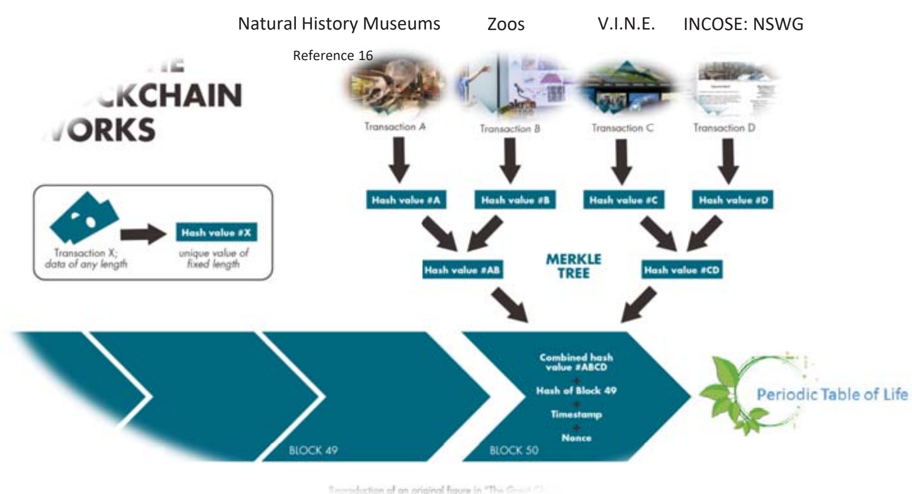
- Tools that are used often, produce reliable results and that have not been modified may remain in the genome (PeTaL)
- Tools that have spawned new tools or that have not produced reliable results are deprecated (selected against)
- Pathways that are cumbersome or inefficient are weighted down (extinct)

Periodic Table of Life

Giving credit to nature and its stewards – Use blockchain to track changes, use tools, and reward contributions while protecting IP



Reference 15

Bring natural resources into the development pipeline
Use revenue generated to support research, conservation and education

Periodic Table of Life

Data Challenge

- Citizen Science: ways we can engage the public to build a robust database
- Technology Development: Ways to use datasets in AI tools and ways to generate data suitable for machine learning
- IP Business – Ways to fairly use/license ideas, data and technology

Periodic Table of Life

Short term work ahead

- UI for topic modelling tool and interfacing with main PeTaL interface
- PeTaL UI
- Focus on challenge to demo system

VINE Clusters – Thursday - Auditorium

- Develop Applications that generate function data for PeTaL
- Develop tools and processes that add to PeTaL AI suite

Technology Cluster	Description	VINE Catalyst(s)
Big Data, Artificial Intelligence, Machine Learning, Sensors, Robotics	Develop ways to generate data for PeTaL, Develop machine learning tools (share with PeTaL) to recognize patterns in nature that, ML for system architecture layout and design, Algorithms for fault detection, prediction of life, performance. Develop sensors using PeTaL, generate data from application research	Herb Schilling, Calvin Robinson
Synthetic Biology, Artificial Evolution and Human Persistence in Space	Ways to manipulate the structure of life in a safe, controlled manner using biomimetic principles to perform functions and exhibit behaviors not found in nature. Ways to enable human presence in space with minimal support from Earth. Includes protection from radiation and other environmental factors in space, Life support systems, space medicine, space law and unforseen issues. Generate data for PeTaL.	Anita Alexander, Marjan Eggermont
Multi-functional Materials, Structures, Processing	Development of materials and structures that serve more than one function (structural integrity and power storage, propulsion and fuel, sensor and actuator, ice-phobic and drag reducing). Generate data for PeTaL.	Chris Maurer
Hybrid and alternative manufacturing, design and architecture, ISRU	Applications and advances in additive manufacturing, nanotechnology and subtractive manufacturing to achieve reusable recyclable materials and structures, biomimetic architecture, design. Applications of natural systems to in-situ resource utilization - use local (on earth and in space) resources sustainably, efficiently and using nature's principles. Generate data for PeTaL.	Emil Reyes/ Andrew Trunek
Information, Communication, Education	Disseminate information to and from biomimetic community. Develop education tools, identify opportunities to implement PeTaL and other tools for education and business. Generate data for PeTaL.	Marjan Eggermont
Systemology, systems engineering	Develop, assess and implement processes for systematic bio-inspiration. Identify pathways for incorporation of natural principles in systems engineering. Develop design challenges to tie-in other clusters.	Jacquelyn Nagel/ Curt Mcnamara
Energy conversion, power, propulsion, mobility	Ways to harvest, convert, distribute and use energy and power for aeronautics and space, Ways to move and to enable motion including aerodynamics, surface mobility, hydrodynamics, gears, mechanisms. Generate data for PeTaL.	Tim Peshek

Periodic Table of Life

PeTaL Team and Contributors

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- Alexandra Calvin, Kent State
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- Ezra Mcnichols, NASA GRC/LTE

External

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Dr. Jacquelyn Nagel – biosearch tool and thesaurus

Dr. Julian Vincent – trade-off articles

Dr. Gavin Svenson – Cleveland Museum of Natural History

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- Herb Schilling, NASA GRC – Computer Science
- Vikram Shyam, NASA GRC – P.I.
- Laura Stokely, NASA GRC – Project manager
- Andrew Trunek, NASA GRC – Materials and ISRU

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