Embracing the fourth Industrial Revolution - Challenges, Opportunities and Path Forward for Propulsion

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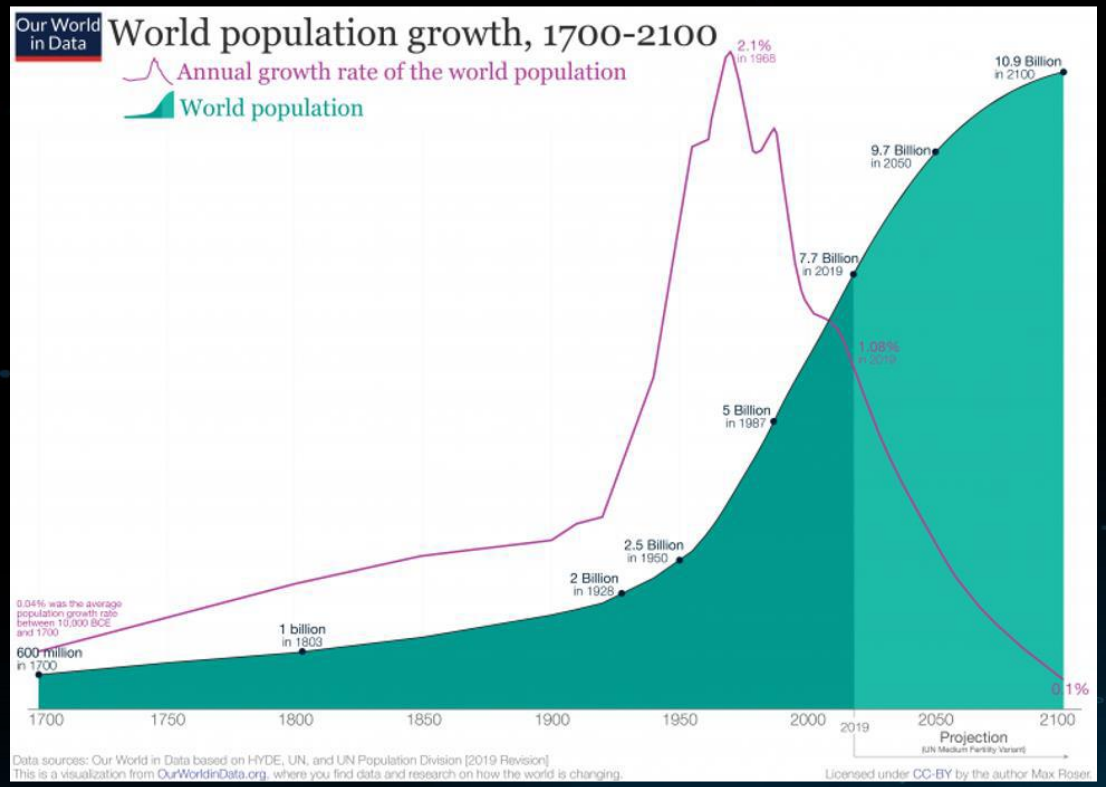
Embracing the fourth Industrial Revolution

IDEAS

SciTech 2022, Jan 3

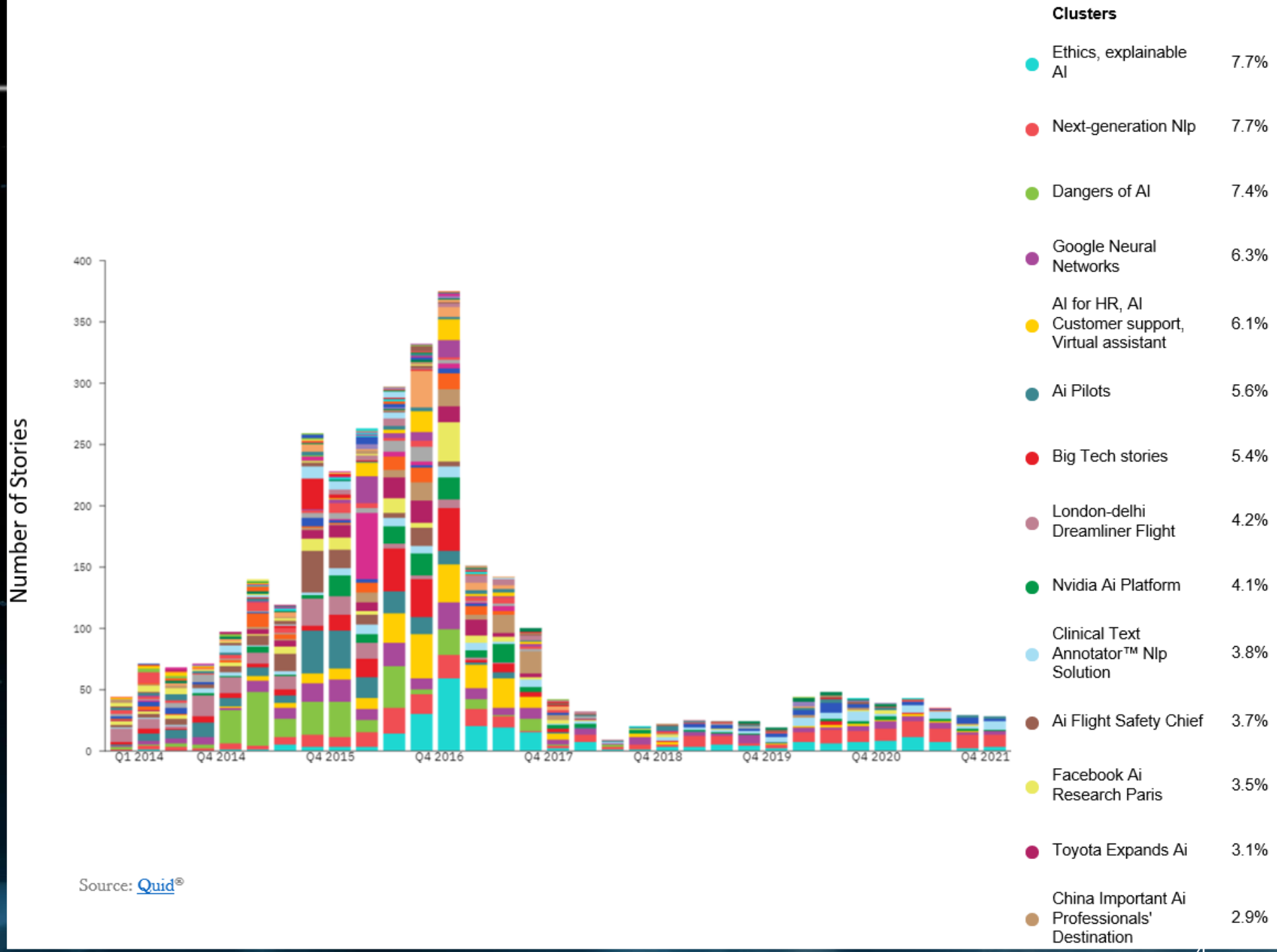
Dr. Vikram Shyam

Global perspective



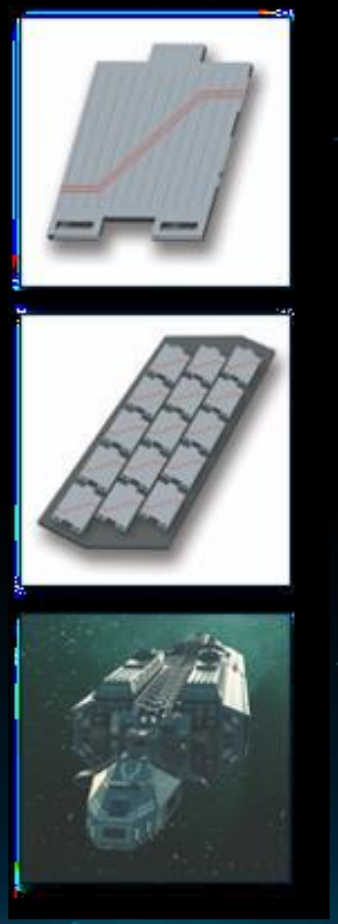
- Resources
- Labor
- Technology growth
- Climate change
- New challenges

Ethics and Explainability

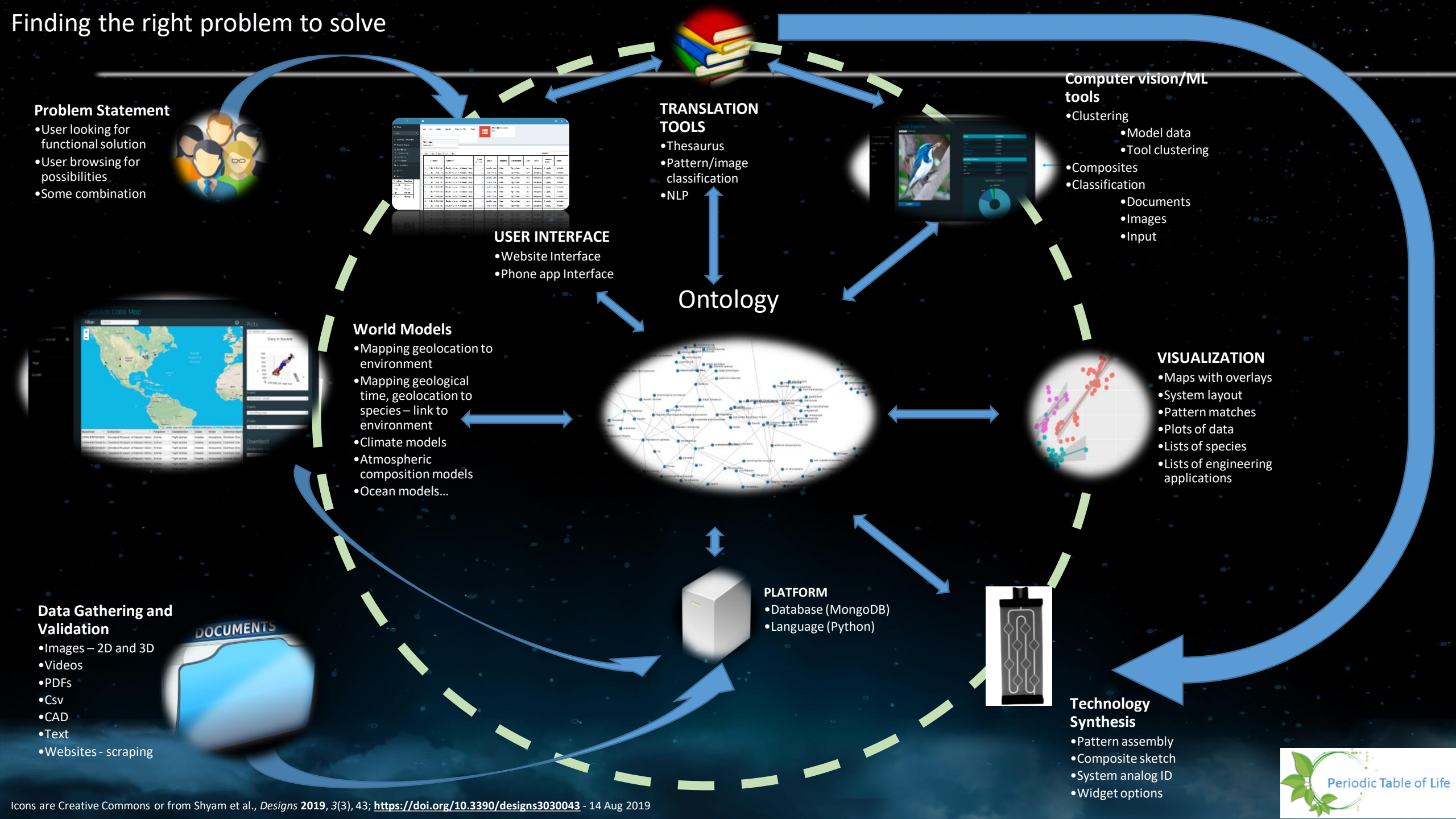


Source: Quid®

Mind-shift from maximizing to resilient



Finding the right problem to solve



Problem Statement
- User looking for functional solution
- User browsing for possibilities
- Some combination

TRANSLATION TOOLS
- Thesaurus
- Pattern/image classification
- NLP

Computer vision/ML tools
- Clustering
  - Model data
  - Tool clustering
- Composites
- Classification
  - Documents
  - Images
  - Input

USER INTERFACE
- Website Interface
- Phone app Interface

Ontology

World Models
- Mapping geolocation to environment
- Mapping geological time, geolocation to species – link to environment
- Climate models
- Atmospheric composition models
- Ocean models…

VISUALIZATION
- Maps with overlays
- System layout
- Pattern matches
- Plots of data
- Lists of species
- Lists of engineering applications

PLATFORM
- Database (MongoDB)
- Language (Python)

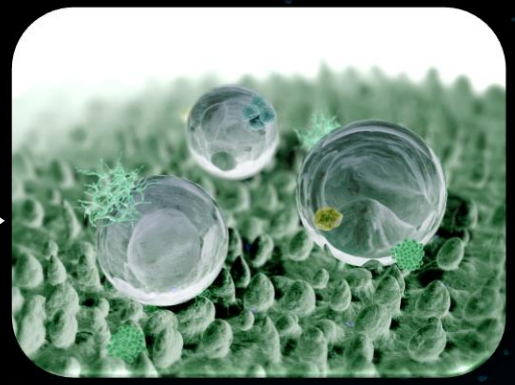
Data Gathering and Validation
- Images – 2D and 3D
- Videos
- PDFs
- Csv
- CAD
- Text
- Websites - scraping

Technology Synthesis
- Pattern assembly
- Composite sketch
- System analog ID
- Widget options

Periodic Table of Life

Icons are Creative Commons or from Shyam et al., *Designs* **2019**, *3*(3), 43; **https://doi.org/10.3390/designs3030043** - 14 Aug 2019

- Nature's rules and framework



- Train AI using biology's solutions and patterns

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

The next phase in human evolution

Biocene 2022 – May 18-20, 2022

- Theme – Future of Transport
- Audience – Enthusiasts, practitioners, people curious about bio*
- Organizer – Ohio Aerospace Institute

General Objectives of IDEAS 2019 Workshop

How to integrate AI into propulsion design to include innovative tools, multi-functionality, cost, time, manufacturing etc. initially, These 3 categories were considered:

A. Data:

- Identify quantity and quality of data available?
  - Various databases in academia – open but no common taxonomy
  - Various industry databases – private
  - Government data
- Identify data management methods/practices?
  - Database/ontology/network graph/other
- Identify top challenges/barriers related to data (big/small data)
  - Storage
  - Sharing
  - Collection
  - Use
  - Privacy

B. Applications:

- Generate a list of available tools, platforms and applications.
- Identify a model problem/challenge as benchmark.

C. Identify roles for Industry, academia and government.

Barriers and Enablers

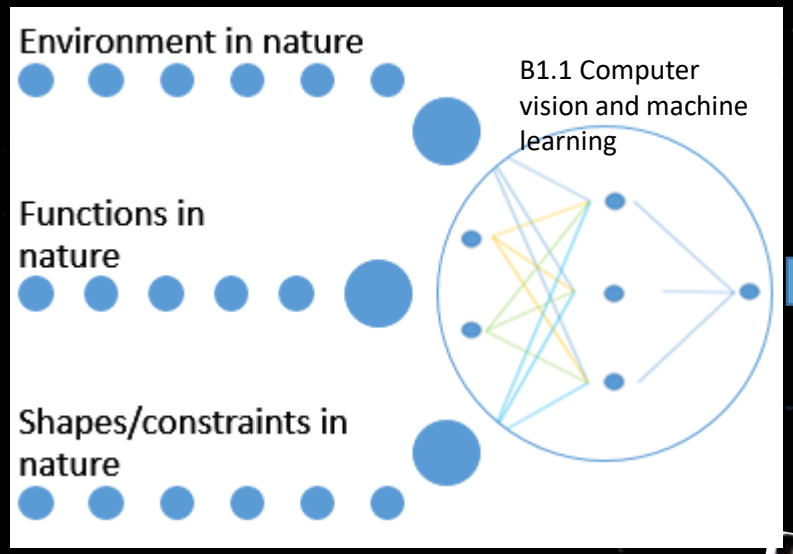
- Barriers
  1. Data Privacy
  2. Data sharing infrastructure
  3. Legal/mechanisms
  4. Data Management
  5. **Need for common ontology**
  6. Data Storage
  7. NASA lacks IT resources
  8. Need for specific problem
  9. Data quality control
  10. Discoverability
  11. Industry not perceiving benefits
  12. Pace difference

- Enablers
  - NASA facilitation of collaboration
    - NRAs
    - Workshops
    - ULI
    - Fellowship
    - SBIR
    - STTR
    - Internships
    - Cooperative agreements
  - Common problem (TMS)
  - Facilities and SMEs

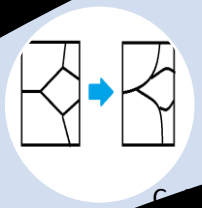
General Model

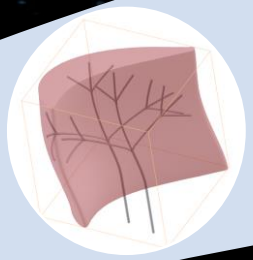
- Generate database architecture through several small prototyping projects.
- Once demonstrated, open up project to allow participants to scale up for general use.
- Run several in parallel to achieve broader goal.
- Targeted high risk prototypes

Design and build a system that is not possible with current technology and design methods that engages new workforce, tackles climate change, global threats and infuses new technology into existing program structure

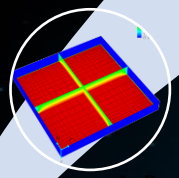


B1.1 Computer vision and machine learning





E. Apply to rel… chitecture



A. Problem definition

1. Define thermal management problem for a coupon.
2. Define constraints (environment, volume, shape)

B. Identify unique topology from natural and synthetic databases using machine learning

C. …

D. Use … "design" para… system and … synthetic dataset if sufficient data is available to provide resolution

Capstones

NASA data Framework definition

- oscillating heat pipes
- heat exchangers
- branched heat pipes
- porous structures

including materials, parametric variations

Shyam et al., *Designs* **2019**, *3*(3), 43; https://doi.org/10.3390/designs3030043 - 14 Aug 2019

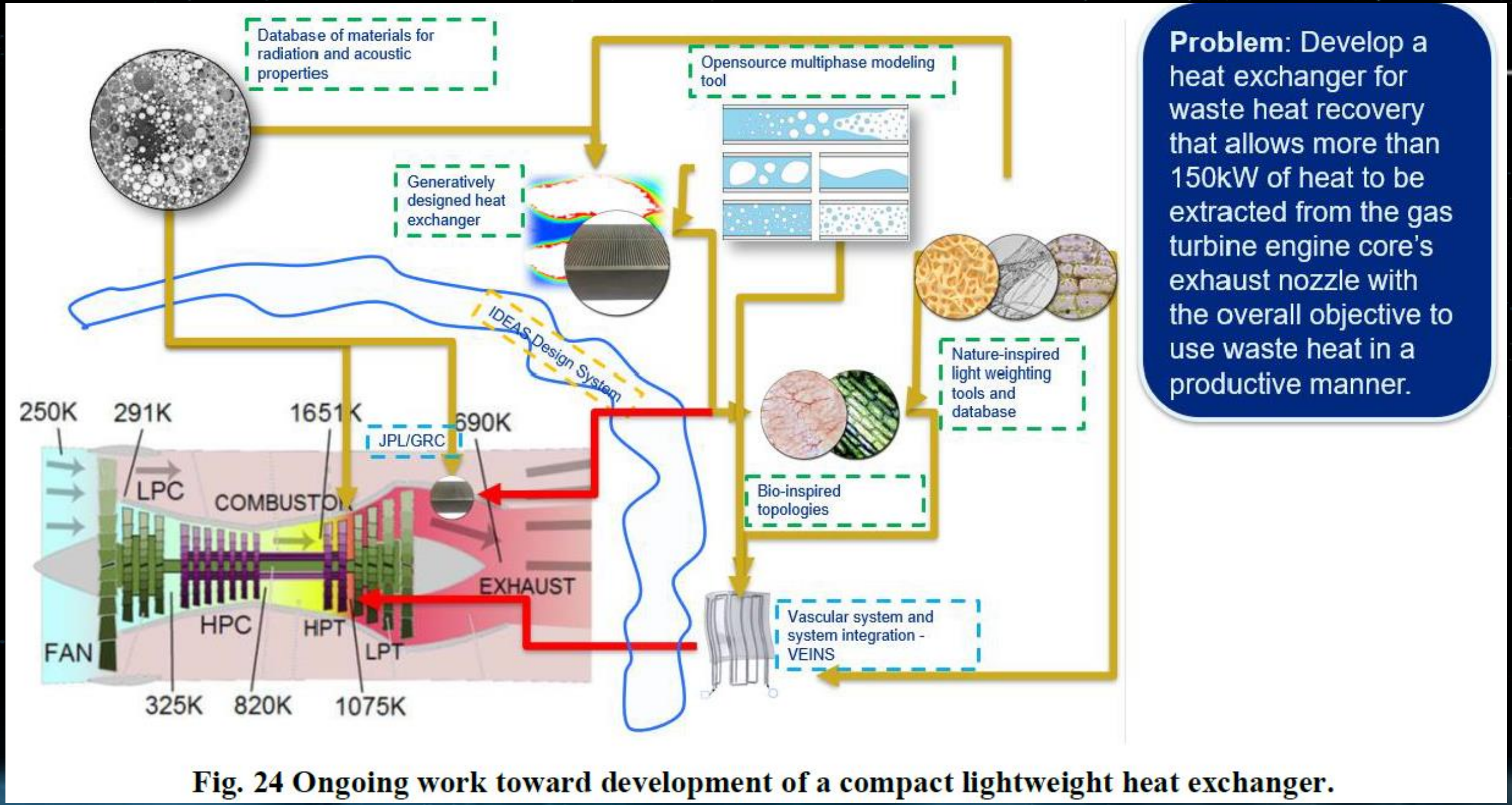
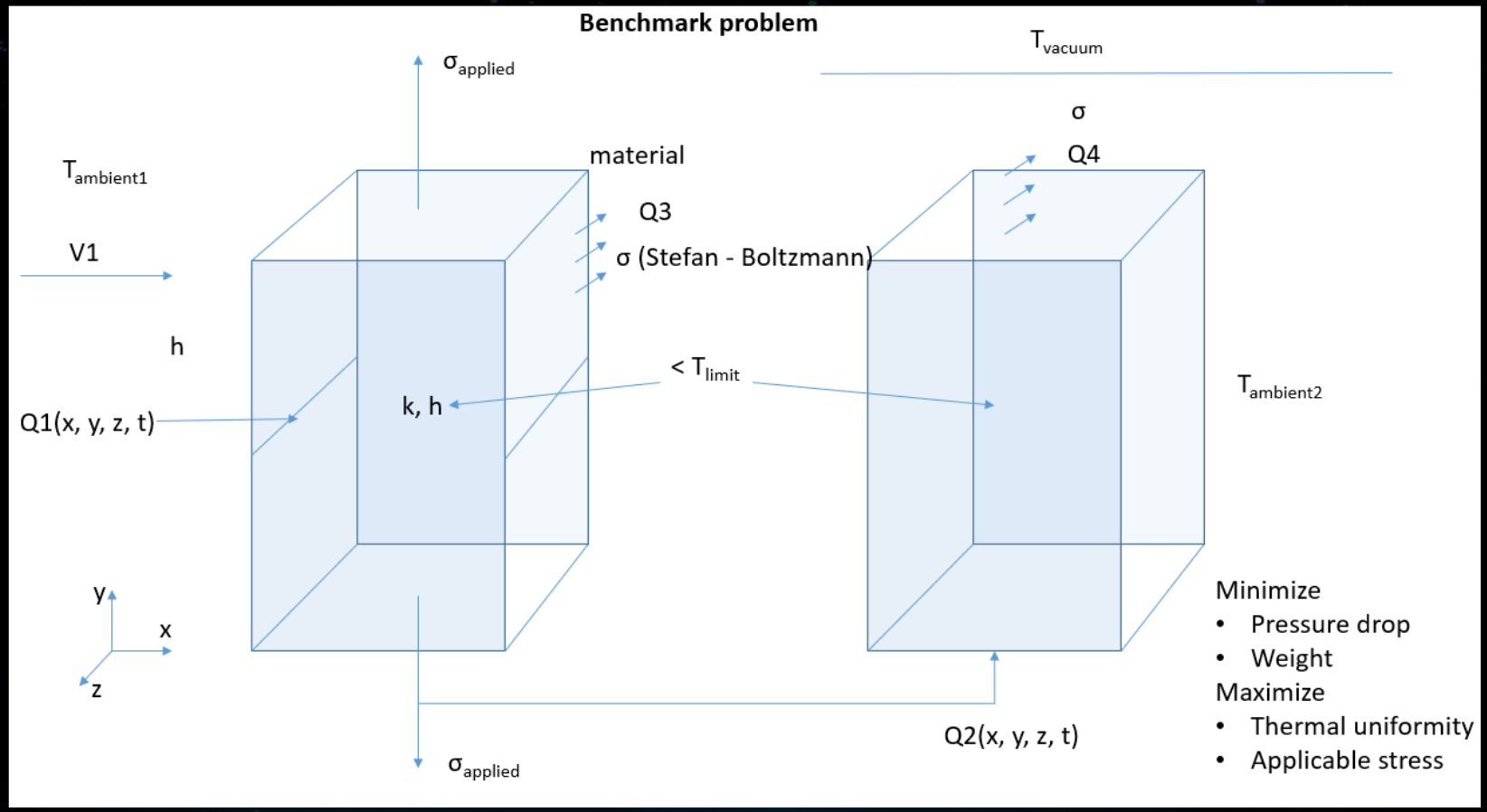


Fig. 24 Ongoing work toward development of a compact lightweight heat exchanger.

McNichols, EO, Jones, SM, Mirhashemi, A, Juangphanich, P, & Shyam, V. "Preliminary Study of Heat Pipe Turbine Vane Cooling in the NASA N+3 Reference Engine." Proceedings of the ASME Turbo Expo 2021: Turbomachinery Technical Conference and Exposition. Volume 5B: https://doi.org/10.1115/GT2021-59352.



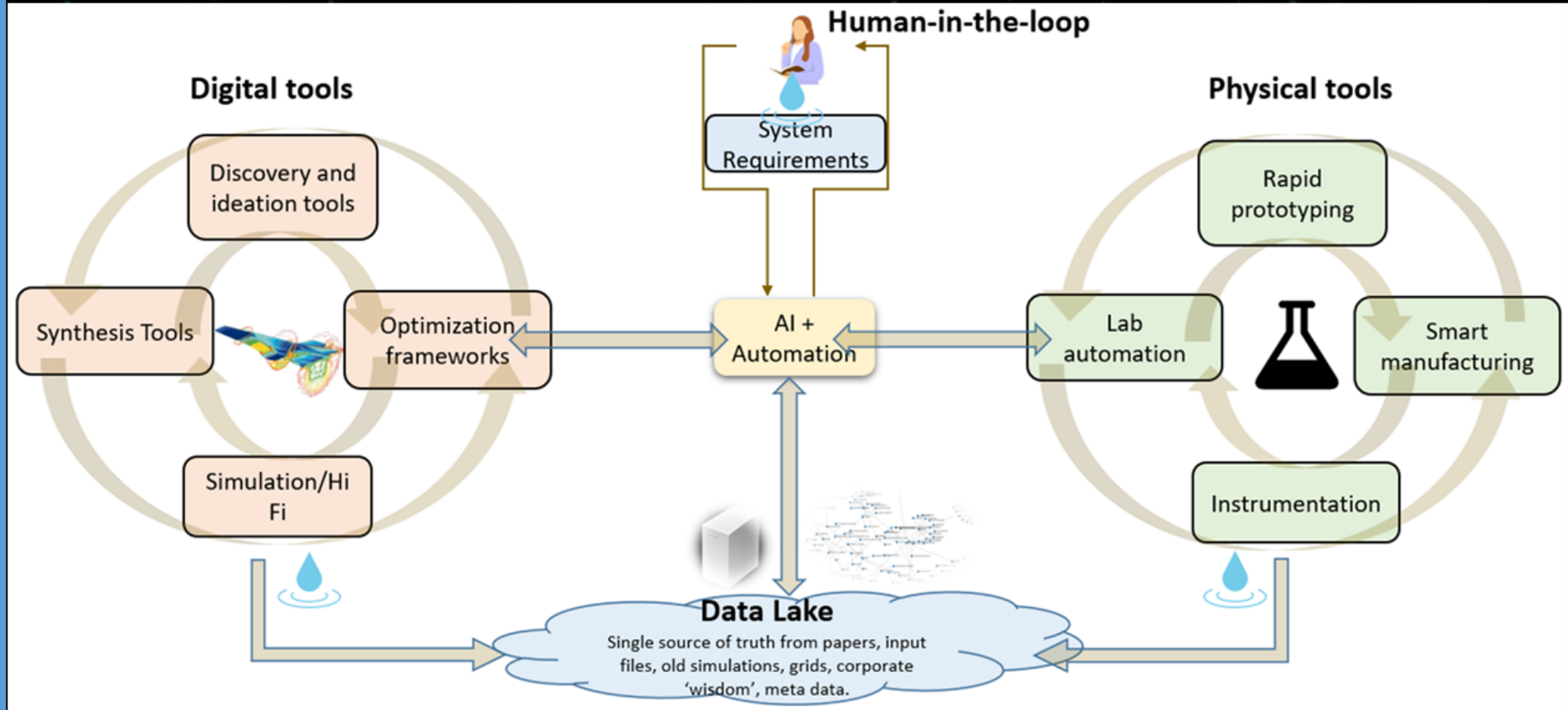
- Penn State - Mekki, B., Lynch, S., "Voxel Based Three-Dimensional Topology Optimization of Heat Exchanger Fins", Proceedings of AIAA SciTech 2022, Jan. 3-7 2022.
- UC Irvine - Jonathan Sullivan, Ziqi Yu & Jaeho Lee (2021) Optical Analysis and Optimization of Micropyramid Texture for Thermal Radiation Control, Nanoscale and Microscale Thermophysical Engineering, 25:3-4, 137-152, DOI: 10.1080/15567265.2021.1958960.
- NCAT - Bharath Kenchappa and Kunigal Shivakumar, "Development of Ultra-Lightweight Acoustic Absorption Material/Structural System for Acoustic Management", ongoing work.
- ASU/PADT - Rajeev, A., Grishin, A., Agrawal, V., Santhanam, B., Goss, D., Niverty, S., Cope, G., Penick, C., Chawla, N., Shyam, V., McNichols, E., & Bhate, D., "Parametric Optimization of Corner Radius in Hexagonal Honeycombs under In-plane Compression", Manufacturing Letters, 50th SME North American Manufacturing Research Conference (NAMRC 50, 2022), to be published.
- ASU - Goss, D., Mistry, Y., Niverty, S., Noe, C., Santhanam, B., Ozturk, C., Penick, C., Lee, C., Chawla, N., Grishin, A., Shyam, V., & Bhate, D. (2020). Bioinspired honeycomb core design: An experimental study of the role of corner radius, coping and interface. Biomimetics, 5(4), 1-24. [59]. https://doi.org/10.3390/biomimetics5040059.

Challenges

- Data is sparse or highly targeted
- Data is distributed among industry, academia, etc.
- Each application may require different approach/workflow

Approach

- Industry collaboration
- Leverage existing data
- Fill-in incomplete data
- Partner with Academia
- Decompose problem and train algorithms that will be amendable to future integration



Advanced Instrumentation, Diagnostics and Controls for Applications in Turbomachinery (AIDCAT-2022)

Penn State University

May 22-24, 2022

University Park, Pennsylvania, USA

Abstracts due February 1, 2022 (Presentations and Posters)

Questions for audience

- Do you think creating open common models is viable? Raise hands
- In chat write your perspective.
- Do you think taxonomy/ontology is a good first step?
- Would you be interested in participating in a workshop to work on this?
- Where might be points of collaboration?
- What are some fundamental things you think NASA should work on related to AI/ML?

17