IDEAS 2019 Report Out

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General Objectives of the Workshop

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

Data:

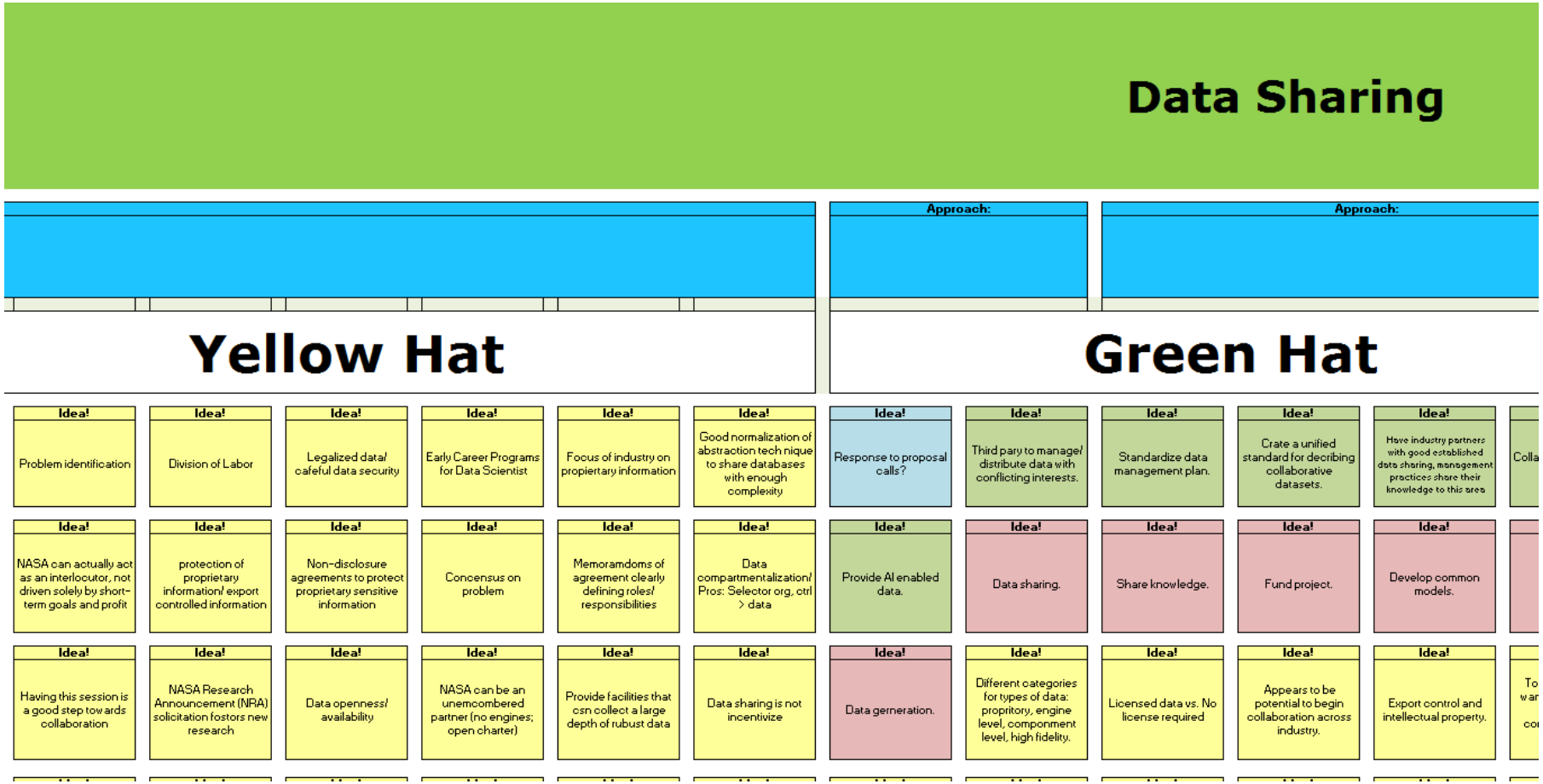
- Identify quantity and quality of data available?
- Identify data management methods/practices? Database/ontology/network graph/other?
- Identify top challenges/barriers related to data (big/small data)?
- Storage
- Sharing
- Collection
- Use
- Privacy

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.

Input from Industry/Academia



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 resources IT
  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

NASA Role

- Define a challenge problem - OK
- Organize more workshops on AI - OK
- Be the interlocutor – Until TRL 3?
- Provide incentives for data sharing - OK
- Develop large databases – OK
- ID mechanisms for protecting different types of data – Requires external entities – NSF, Private sector – we are investigating

What would you like to see NSF support in collaboration with NASA?

Action items

- Establish a common problem
- Workshop on ontology focusing on common problem – When?
- Establish formal mechanisms for collaboration – In progress
  - Need requirements from industry/academia – POC for legal to discuss with
  - NDA + proprietary + export control

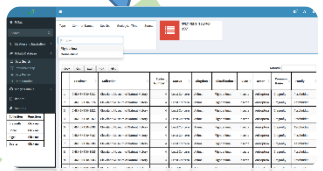
General Model

- 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

A map of design system intended architecture

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



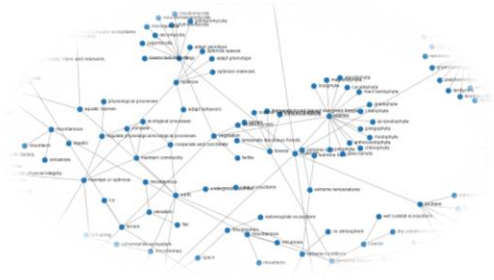
TRANSLATION TOOLS
- Thesaurus
- Pattern/image classification
- NLP

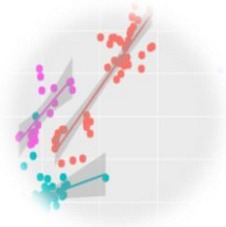
Computer vision/ML tools
- Clustering
  - Model data
  - Tool clustering
- Composites
- Classification
  - Documents
  - Images
  - Input

USER INTERFACE
- Website Interface
- Phone app Interface

Ontology

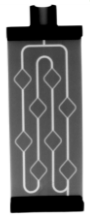
World Models
- Mapping geolocation to environment
- Mapping geological time, geolocation to species – link to environment
- Climate models
- Atmospheric composition models
- Ocean models…





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

PLATFORM
- Database (MongoDB)
- Language (Python)



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

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

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

Periodic Table of Life

How to train models with data from multiple sources?

NASA + workshop – Frame problem

- What is a good prototype we can build?
- What is the problem to solve?

Train/develop models

- Across multiple data sources
- Different models on same data set
- Validate with testing

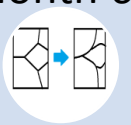
Create prototypes

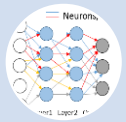
- Small scale prototypes such as drones/UAVs

Measure overall metric improvements. Create complex cost functions

Month 1

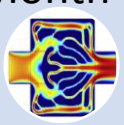
Month 6





Month 10

Month 14



Month 20

Collect data

- Capstone projects
- Internal rapid prototyping
- Internships
- Curate existing data sets

How to share data?

Develop systems

- Solve a problem using the models and downselect
- Couple with systems analysis to assess benefits

Given specific requirements output a design. Is it better to create a point design or a trade space from which to select?

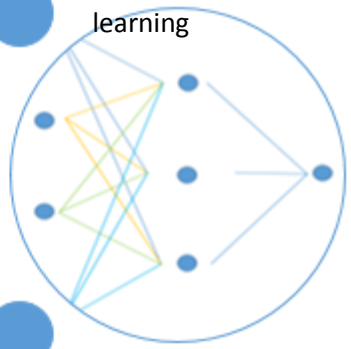
B1.0 Discovery tools

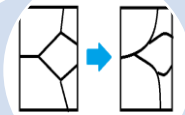
Environment in nature

Functions in nature

Shapes/constraints in nature

B1.1 Computer vision and machine learning





E. Apply to relevant architecture

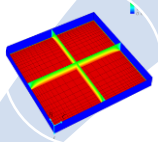
D. Compare results and downselect

C. Approaches/Workflows

1. Optimize natural topology using genetic algorithm or topology optimization if data set is sparse

2. Use machine learning to 'design' part based on natural system and augmented synthetic dataset if sufficient data is available to provide resolution

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



A. Problem definition

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

Capstones

NASA data Framework definition

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

B1.2 Synthetic data and lab data including various materials, parametric variations

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

Problem Breakdown

- Data
  - Materials, aero, structures, noise, heat transfer, chemistry
  - Cost
  - Time
  - Affordances (degrees of freedom)
  - Literature
- Models
  - Clustering – discovery, design rules
  - Classification – workflow speedup
- Application
  - Design of coupon for drone at 100W scale – Q + dP
  - Add material, fluid variability
  - Add structure (life, stress…)
  - Add 3D – inner casing of drone – electric components 100sW – 1kw
  - Mid temperature range – add radiation, noise
  - Interactions with other systems
  - Define further applications with individual entities to mature TRL

Roles

- NASA – Workflow tools, opensource tools
- Existing models - community
- Applications
  - Low TRL – NASA, industry, academia
  - Mid-TRL – SBIR, STTR
  - High TRL – NRAs, industry-NASA
- Failures -> Required models – NASA-NSF-DoD

- Publishing white paper on plan to integrate ML/AI into propulsion system design

Specific actions in progress or TBD

Advocating to ARMD

- Use/application
  - TMS is common problem
  - Capstones
  - Fellowships
    - UC Irvine
    - Penn State
    - UPR
  - STTR
    - Lattice design
  - IRAD
    - Turbine blade design
- Infrastructure
  - Establish jointly funded programs (AI institutes – NSF)
  - Establish website to host data/tools/algorithms
  - NRA to solicit data sharing/management solution
  - Infuse into ULI