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# IDEAS 2019 Report Out

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AI/ML for Propulsion

NASA Glenn Research Center

# 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.

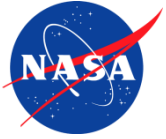
## C. Identify roles for Industry, academia and government.



# Input from Industry/Academia

## Data Sharing

Yellow Hat						Approach:		Approach:			
<b>Yellow Hat</b>						<b>Green Hat</b>					
<b>Idea!</b> Problem identification	<b>Idea!</b> Division of Labor	<b>Idea!</b> Legalized data/ careful data security	<b>Idea!</b> Early Career Programs for Data Scientist	<b>Idea!</b> Focus of industry on proprietary information	<b>Idea!</b> Good normalization of abstraction technique to share databases with enough complexity	<b>Idea!</b> Response to proposal calls?	<b>Idea!</b> Third party to manage/ distribute data with conflicting interests.	<b>Idea!</b> Standardize data management plan.	<b>Idea!</b> Create a unified standard for describing collaborative datasets.	<b>Idea!</b> Have industry partners with good established data sharing, management practices share their knowledge to this area.	Colla
<b>Idea!</b> NASA can actually act as an interlocutor, not driven solely by short- term goals and profit	<b>Idea!</b> protection of proprietary information/ export controlled information	<b>Idea!</b> Non-disclosure agreements to protect proprietary sensitive information	<b>Idea!</b> Consensus on problem	<b>Idea!</b> Memorandums of agreement clearly defining roles/ responsibilities	<b>Idea!</b> Data compartmentalization/ Pros: Selector org, ctrl > data	<b>Idea!</b> Provide AI enabled data.	<b>Idea!</b> Data sharing.	<b>Idea!</b> Share knowledge.	<b>Idea!</b> Fund project.	<b>Idea!</b> Develop common models.	
<b>Idea!</b> Having this session is a good step towards collaboration	<b>Idea!</b> NASA Research Announcement (NRA) solicitation fosters new research	<b>Idea!</b> Data openness/ availability	<b>Idea!</b> NASA can be an unemcomberd partner (no engines; open charter)	<b>Idea!</b> Provide facilities that can collect a large depth of robust data	<b>Idea!</b> Data sharing is not incentivize	<b>Idea!</b> Data generation.	<b>Idea!</b> Different categories for types of data: proprietary, engine level, component level, high fidelity.	<b>Idea!</b> Licensed data vs. No license required	<b>Idea!</b> Appears to be potential to begin collaboration across industry.	<b>Idea!</b> Export control and intellectual property.	To war co



# Barriers and Enablers

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- 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

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- 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

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- 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

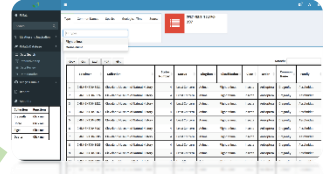
- Generate database architecture through several small prototyping projects.
- Once demonstrated, open up project to allow participants to scale up for general use.
- Run several in parallel to achieve broader goal.
- Targeted high risk prototypes

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



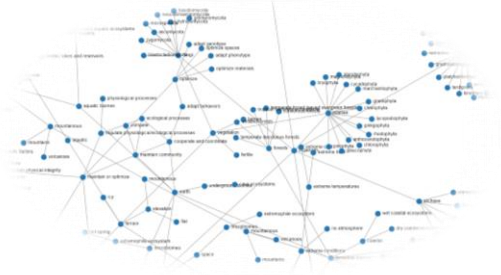
**USER INTERFACE**

- Website Interface
- Phone app Interface

**TRANSLATION TOOLS**

- Thesaurus
- Pattern/image classification
- NLP

**Ontology**



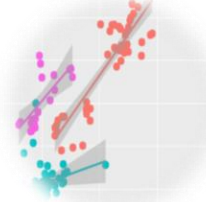
**Computer vision/ML tools**

- Clustering
  - Model data
  - Tool clustering
- Composites
- Classification
  - Documents
  - Images
  - Input



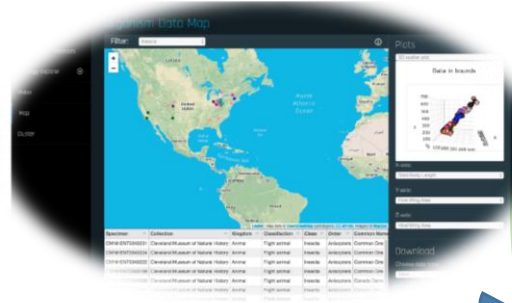
**VISUALIZATION**

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



**World Models**

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



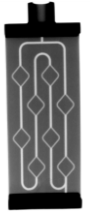
**PLATFORM**

- Database (MongoDB)
- Language (Python)



**Technology Synthesis**

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

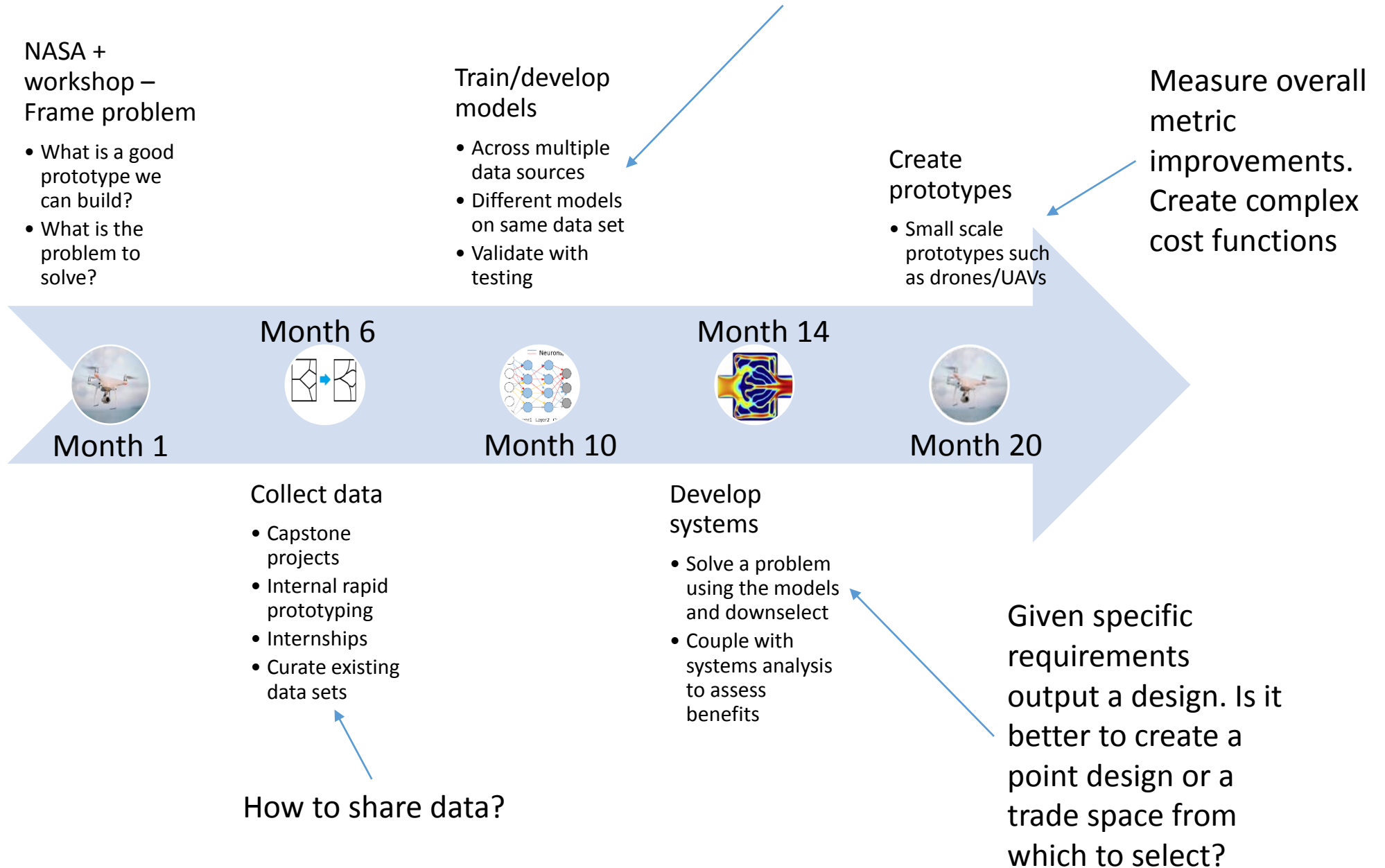


**Data Gathering and Validation**

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



# How to train models with data from multiple sources?



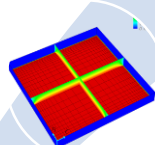
B1.0 Discovery tools

Environment in nature

Functions in nature

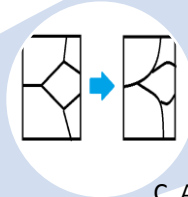
Shapes/constraints in nature

B1.1 Computer vision and machine learning



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

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



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



D. Compare results and downselect

E. Apply to relevant architecture



Capstones

NASA data Framework definition

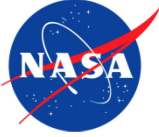
oscillating heat pipes

heat exchangers

branched heat pipes

porous structures

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

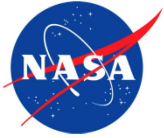


# Problem Breakdown

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- 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

- 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

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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