DARPA and Data:
A Portfolio Overview

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DARPA Dreams of Data

- Investments over the past decade span multiple DARPA Offices and PMs
  - Information Innovation (I2O): Software Systems, AI, Data Analytics
  - Defense Sciences (DSO): Domain-driven problems (chemistry, social science, materials science, engineering design)
  - Microsystems Technology (MTO): New hardware to support these processes (neuromorphic processor, graph processor, learning systems)
- Products include DARPA Program testbeds, data and software
  - The DARPA Open Catalog
  - Testbeds include those in big data, cyber-defense, engineering design, synthetic bio, machine reading, among others
- Multiple layers and qualities of data are important
  - Important for reproducibility; important as fuel for future DARPA programs
  - Beyond public data to include "raw" data, process/workflow data
- Data does not need to be organized to be useful or valuable
  - Software tools are getting better exponentially, "raw" data can be processed
  - Changing the economics (Forensic Data Curation)
- Its about optimizing allocation of attention in human-machine teams

Working toward Wisdom

Abstraction (also "value")

Wisdom

Understanding

Knowledge

Information

data

Sapience (or processing/cognitive 'load')

Wisdom: sound judgment - governance

Understanding: explanation – why

Knowledge: correlation and composition – how

Information: facts - what, who, where, when

data: representing signals or stimuli

Example of the Data-Wisdom process for model evolution and application:

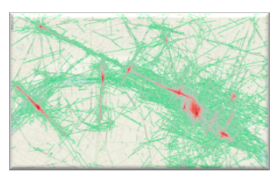
data

Data (signals) from multiple sources

Information

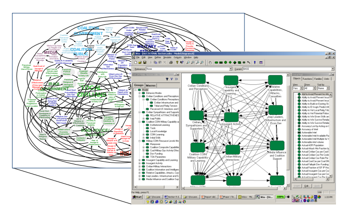
Descriptive model (symbols, syntax)

Knowledge



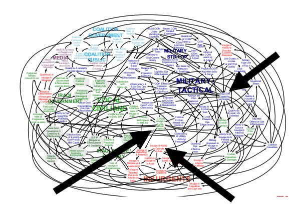
Correlative/predictive model (rules, processes, semantics)

Understanding



Explanatory model (abstractions, theories, etc)

Wisdom



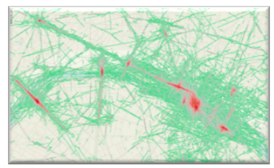
Judgement, value, insight, instinct, principles, etc

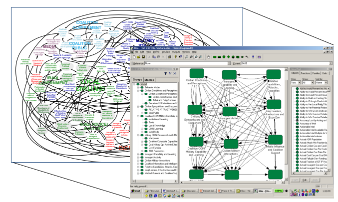
Examples of Data-to-Wisdom

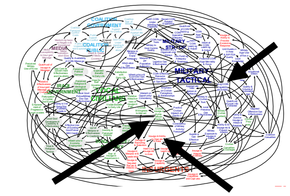
Task	Information	Knowledge	Understanding	Wisdom
	Determine facts (what, who, where and when)	*Correlate and compose (networks and systems)*	*Explain (causal mechanisms)*	*Apply sound judgement (governance)*

Hybrid operations

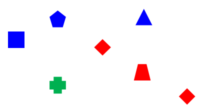
Descriptive model

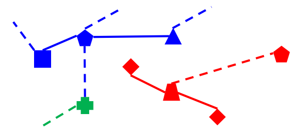

Correlative/predictive model

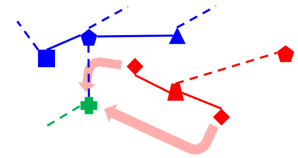

Explanatory model

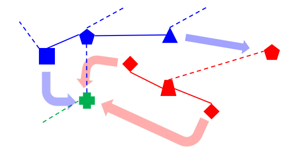

Select and execute interventions

Tactical operations


Detect and identify objects/entities

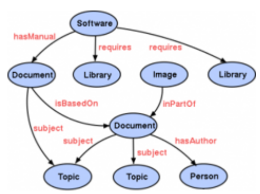

Recognize relationships and activities of objects/entities


Find endo– and exogenous causal factors driving objects/entities


Assess viability of Blue approach

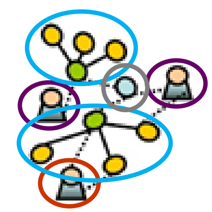
Information operations

Message translation



Message meaning


Message impact


Evolve message strategy

Security operations

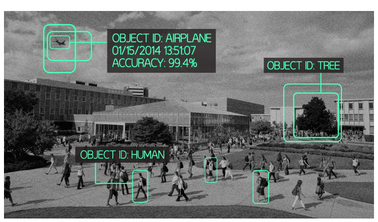
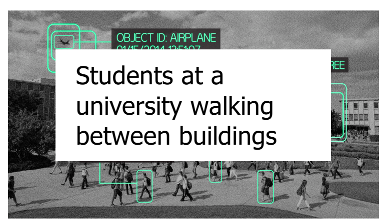
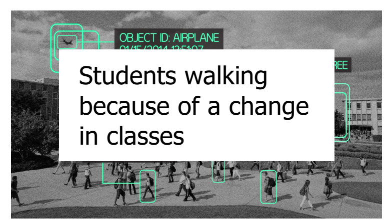


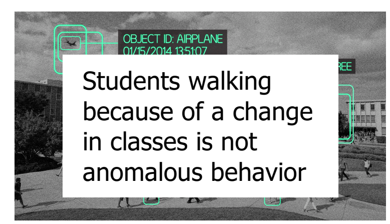
Image object identification



Scene knowledge (relationships between objects)



Scene understanding



Decide and manage responses

DARPA Investments in the Data Ecosystem

Algorithms & Analytics

Services & Middleware

Information

Determine facts (what, who, where and when)

LORELEI (I2O)
MoDyl – Dynamics from data sets (DSO)
RATS (I2O)
Visual Media Reasoning (I2O)
Global Autonomous Language Exploitation*

Brandeis – Data privacy (I2O)
EQUIPS – Uncertainty analysis tools (DSO)
Memex – Web data/info search (I2O)
SAFER (I2O)
Simplex - Unified math frameworks (DSO)
XDATA (I2O) →
PROCEED*
Signal processing programs*

Knowledge

Correlate and compose (networks and systems)

CASCADE – Integ data/tools for robust SoS (DSO)
CRAFT – Workflow/CAD tools (MTO)
Data Driven Discovery of Models (I2O)
Deep Extraction from Text (I2O)
Insight (I2O)
Make-It – Synthetic chemistry (DSO)
MENTOR2 – CAD data/tools (DSO)
Modelling Adversarial Activity (I2O)
Network Defense (I2O)
Next Gen Soc Sci – Data/tools (DSO)
QCR (I2O)
Sigma – System for CBRNE detection (DSO)
TRADES - Eng design env (DSO)
Personalized Assistant that Learns*

Cortical Processor (MTO)
EdgeCT (I2O)
GRAPHS – Graph analysis tools (DSO)
HIVE – Graph problem HW/MW (MTO)
Media Forensics (I2O)
MUSE (I2O)
SafeWare (I2O)
Deep Learning*

Understanding

Explain (causal mechanisms)

AIDA (I2O)
Big Mechanism (I2O)
Biochronicity – Tools gene regulatory nets (DSO)
Causal Exploration (I2O)
MATRIX– Multi-scale matls data/models (DSO)
Mine Better, Fund Faster – Surprise ID (DSO)
SocialSim (I2O)
Synergistic Discovery and Design (I2O)

BRASS (I2O)
Explainable AI (I2O)
FunLOL – Framework for AI/ML (DSO)
MSEE – Tools for machine understanding (DSO)
PPAML (I2O)

Algorithms & Analytics

Services & Middleware

*completed program

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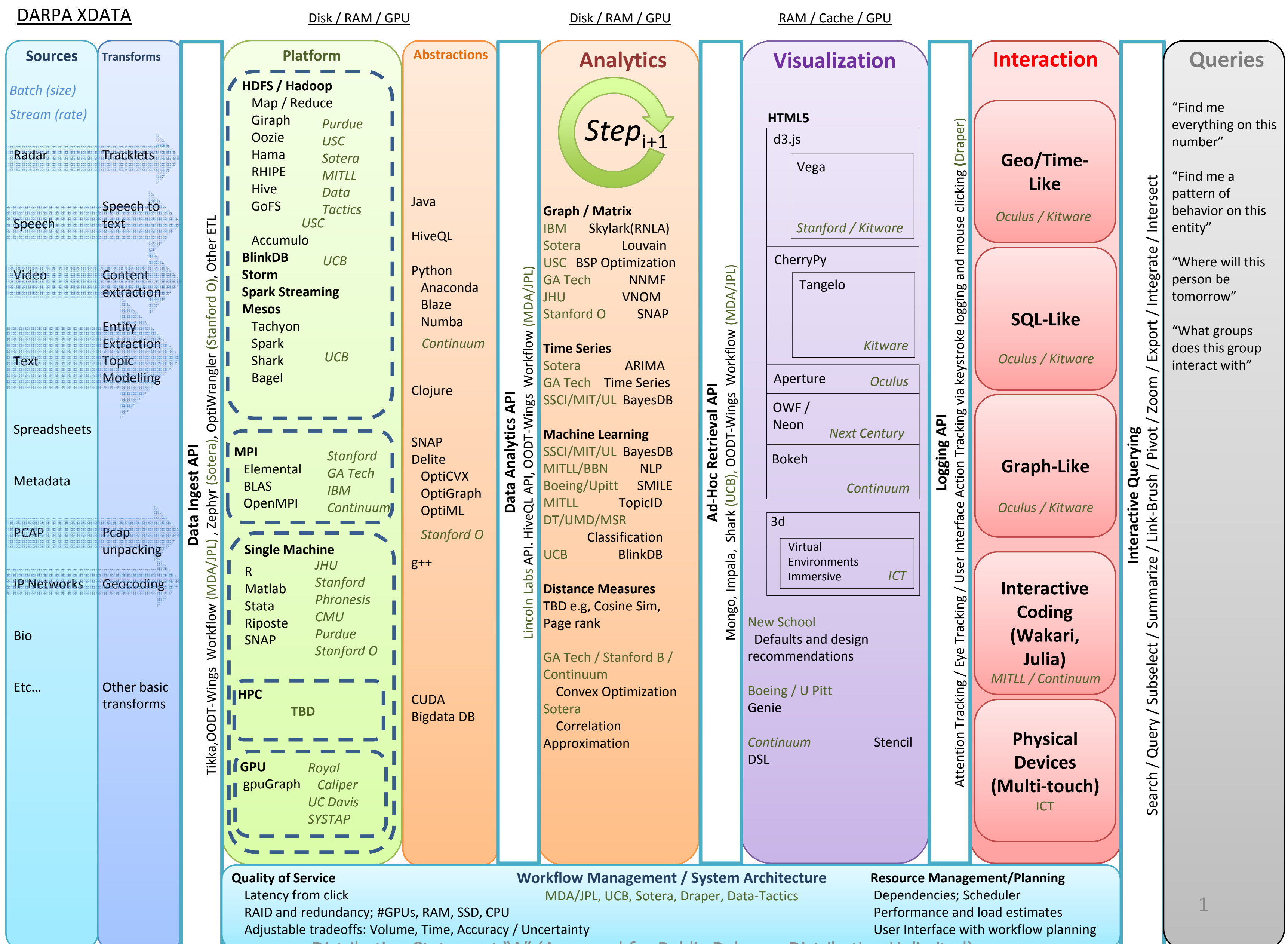
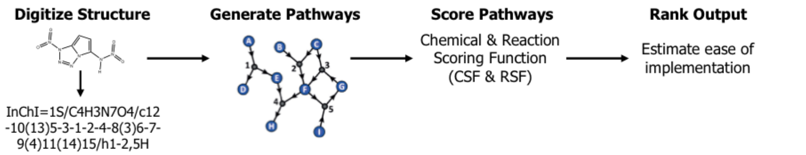
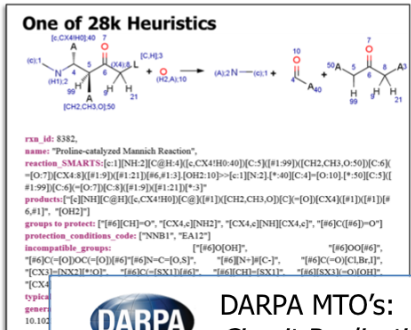
X-Data: Common Data Cyber-Infrastructure

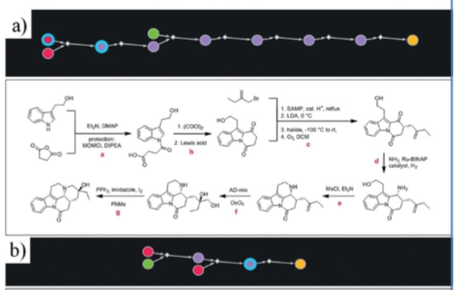


Examples: Human-Machine Symbiosis

DARPA DSO's MAKE-IT: Revolutionizing Synthetic Chemistry

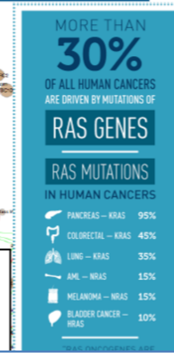


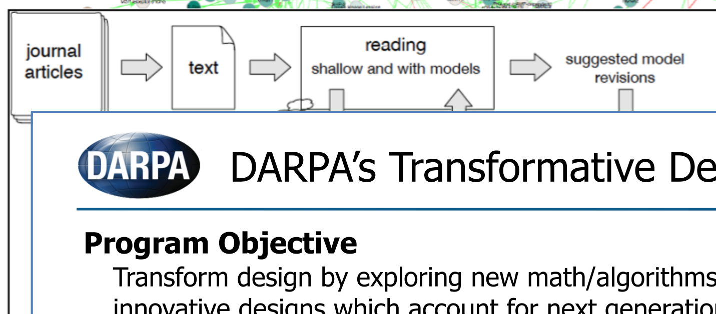




DARPA's Big Mechanism: Machine Reading vs Cancer

Goal: Machines that help humans to model and analyze very complicated systems by reading fragmented literatures and assembling and reasoning with models.





DARPA MTO's: *Circuit Realization at Faster Timescales (CRAFT)*

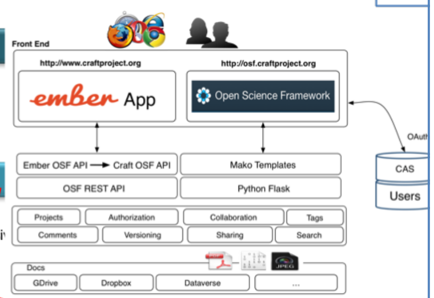
CRAFT aims to provide solutions to the three major obstacles restricting custom IC design and fabrication for DoD systems.

DESIGN

- Design requires 18-24 months of effort
- Design verification takes far too much effort
- Fab cycles are too long and too uncertain
- Access to leading-edge CMOS is difficult

PORT/ MIGRATE

- Designers are limited to one foundry
- Migration of designs from one node to another is diff... expensi...



REPOSITORY

- Severe lack of IP reusability for DoD designs
- Current audit model for custom IC design/hardware security is broken

CRAFT aims to establish a data location and methodology to ensure 50% IP* reuse by DoD performers

CRAFT 's goal is to enable more efficient custom IC design/fabrication to enable HIGH performance electronic solutions FASTER and with more FLEXIBILITY

* IP – Sub-circuits used for modern custom ICs

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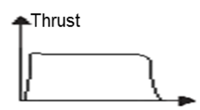
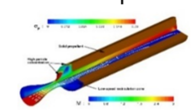
DARPA's Transformative Design (TRADES)

Program Objective

Transform design by exploring new math/algorithms to enable new and innovative designs which account for next generation materials and processes

Expected Outcomes

- Leverage computation and data at unprecedented scales
- Deal with significantly more complex and coupled design problems
- Lower the time and expertise required to create complex engineered products

Human	⇔	**Computer**
Describe the problem		Generate shape & material
		
Show me the options		Find the best alternatives

http://space.stackexchange.com/questions/12541/why-is-there-a-hole-in-solid-rocket-engines/12542

http://arrow.utias.utoronto.ca/~groth/Research.html

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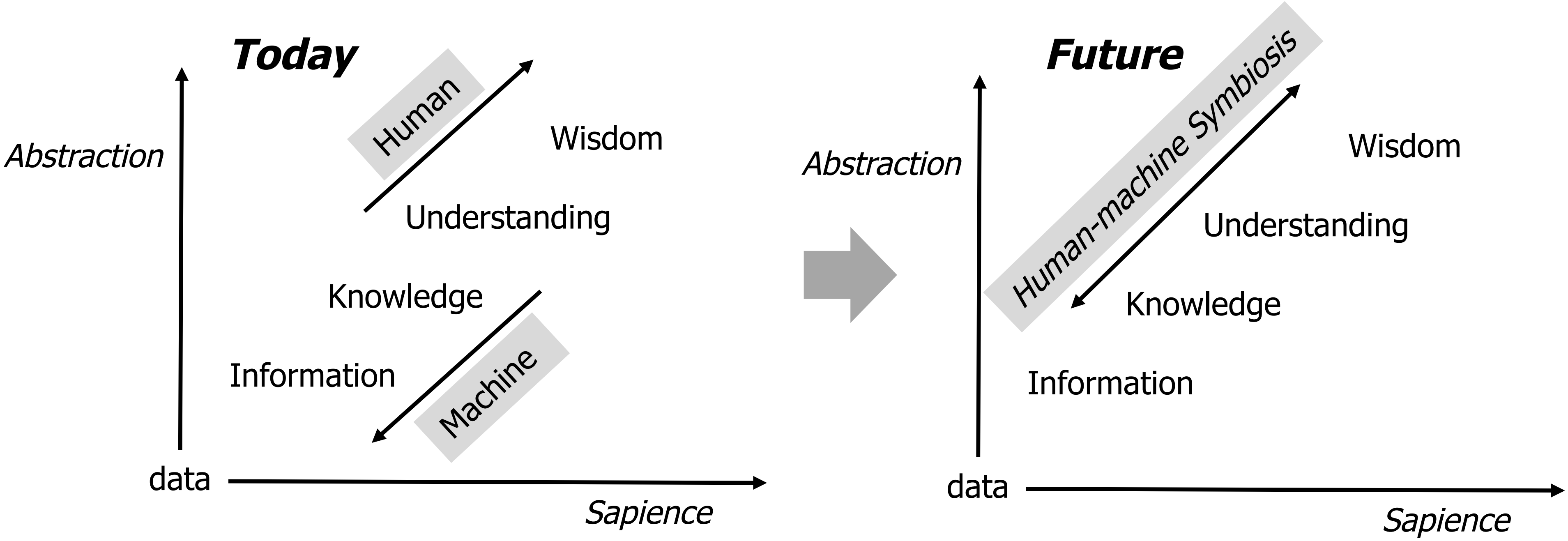
Summary



Unbound Computation & Data

Exploit computation and larger scales; leverage machine learning and AI; Produce and harvest data in more disruptive ways! ← requires culture change

Advancing the software toolbox

An ecosystem of interoperable building blocks/tools for machine-augmented problem solving; make them easier to use ← a limiting issue

Problem-Process-People Co-design

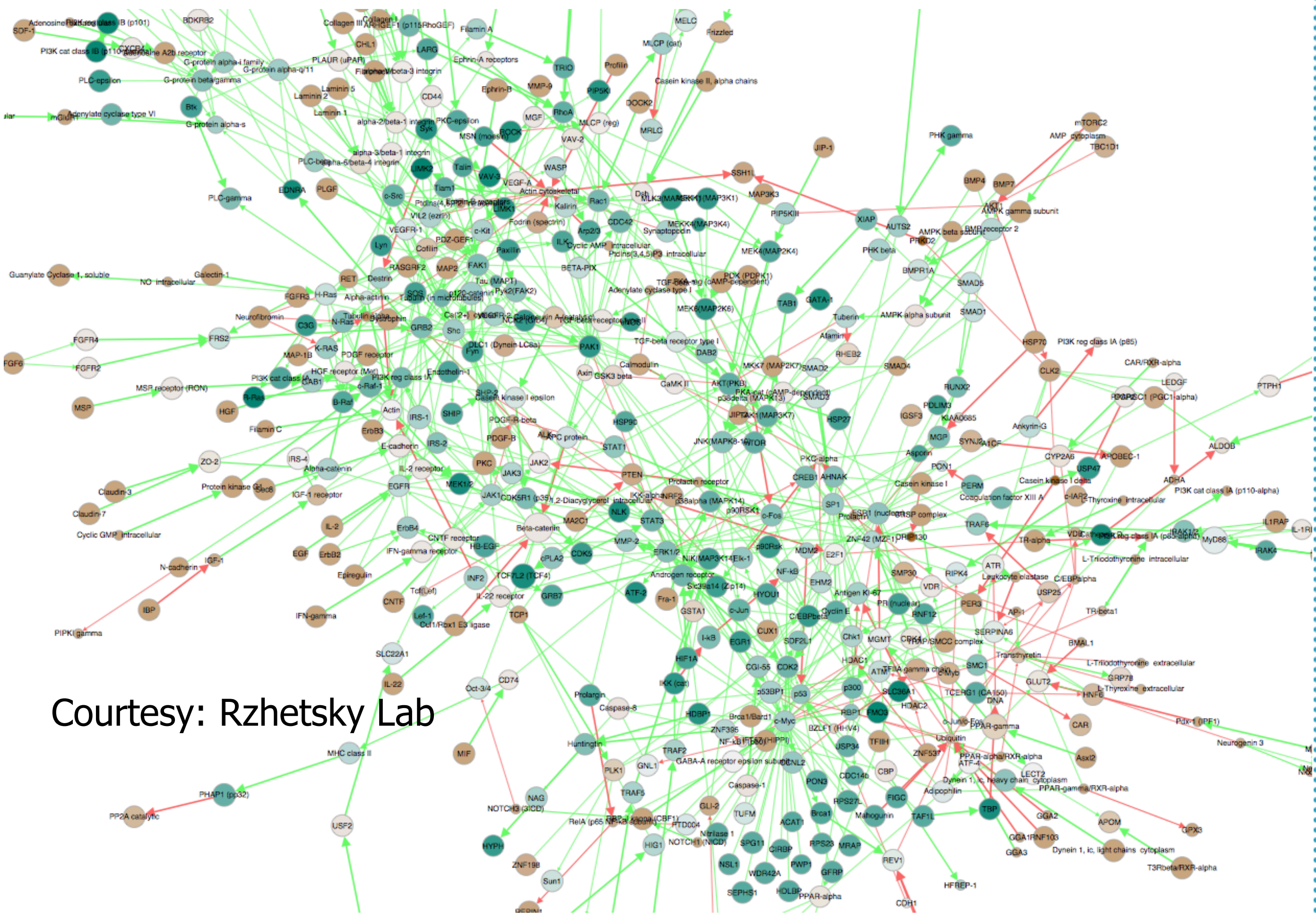
Simultaneous redesign of problem and human-machine dynamic: Thinking faster, better and functioning at higher levels ← culture change www.darpa.mil

Credit: Detroit Institute of Arts

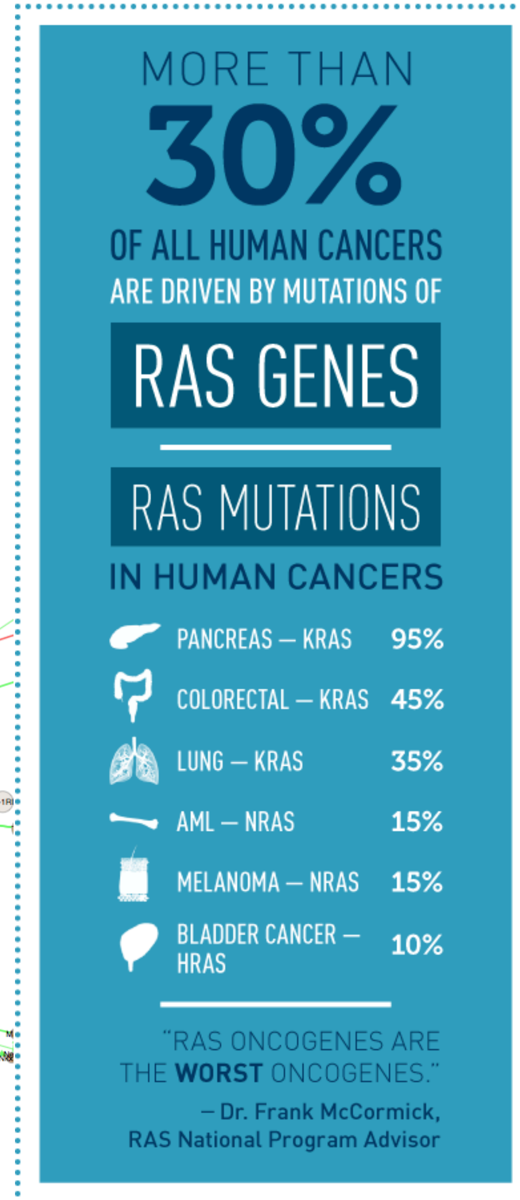
A DARPA Goal: Transform cognitive problems using machines-as-partners

Big Mechanism

Goal: Machines that help humans to model and analyze very complicated systems by reading fragmented literatures and assembling and reasoning with models.

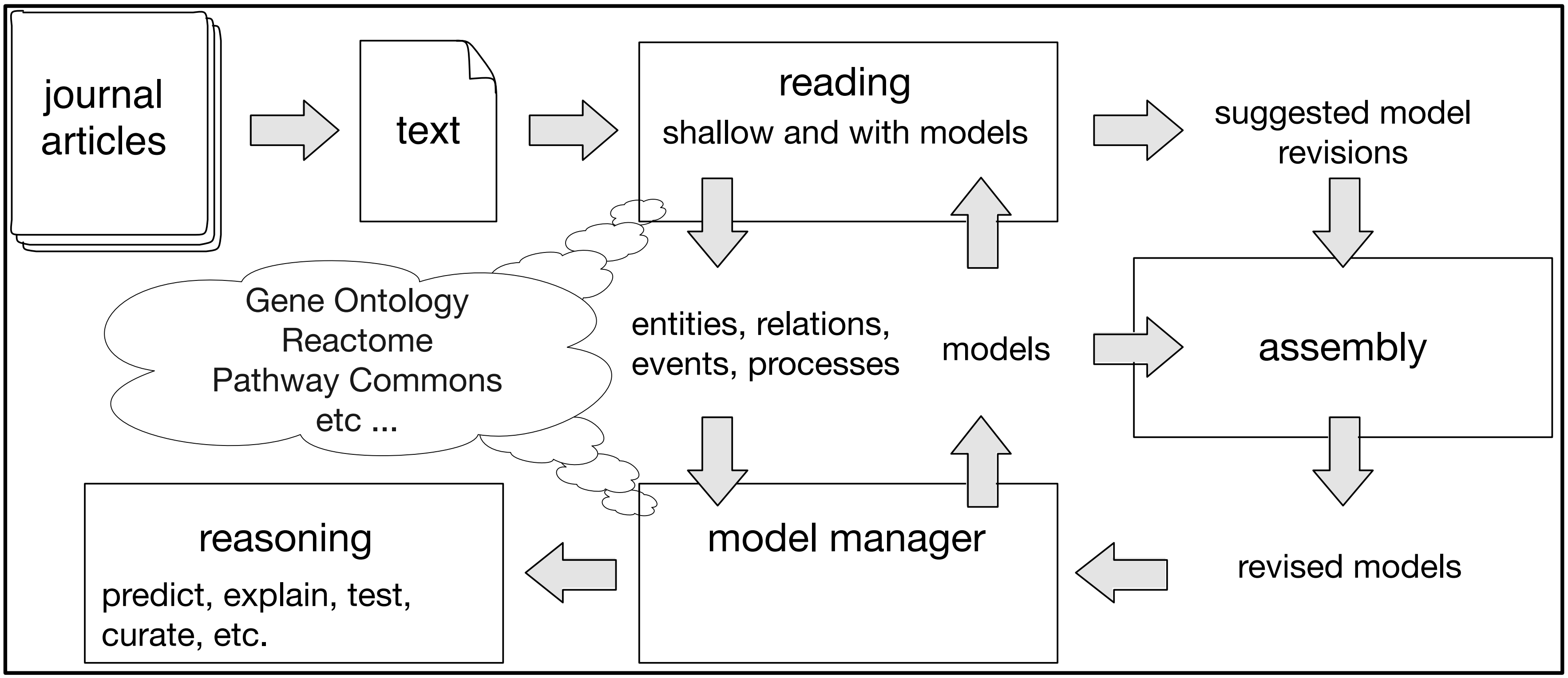


Courtesy: Rzhetsky Lab



Big Mechanism Architecture

Goal: Machines that help humans to model and analyze very complicated systems by reading fragmented literatures and assembling and reasoning with models.



Outline of today's talk: Reading; Some Results; Varieties of Big Mechanism Systems; Why it Works; Will it Work Elsewhere?

Cross-cutting Opportunities for DARPA

- **Altered Senses**
  - New sensing systems; new human-machine interaction as well
  - Neurotech being coupled with higher-order cognitive processes
- **Unbound Computation & Data**
  - Exploit computation and larger scales;
    Produce data and harvest our own in more disruptive ways!
- **Advancing the software toolbox**
  - An ecosystem of building blocks/tools for machine-augmented problem solving; make them easier to use ← a limiting issue
- **Problem-Process-People Co-design**
  - Simultaneous redesign of problem and human-machine dynamic

System Concept