Demystifying Discovery: Enhancing the Wisconsin Collaboratory

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H.F. DeLuca Forum at Discovery
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Who am I?

- Stephen C. Kleene Professor of Computer Science, Theme Leader of Optimization at WID
- Developer of world leading technology for Equilibrium Problems
- Modeling framework design and implementation
- Optimization for applications: economic policy, energy planning, structural mechanics, radiation therapy and medical devices, environmental and agricultural constraints, video-on-demand
- Guggenheim Fellow, INFORMS Fellow, SIAM Fellow

Discovery

- Observation
  - Francis Crick and James Watson (unlikely collaboration)
  - Observed Rosalind Franklin experimental results
  - Discovered structure of DNA, huge impact on modern day biology and medicine

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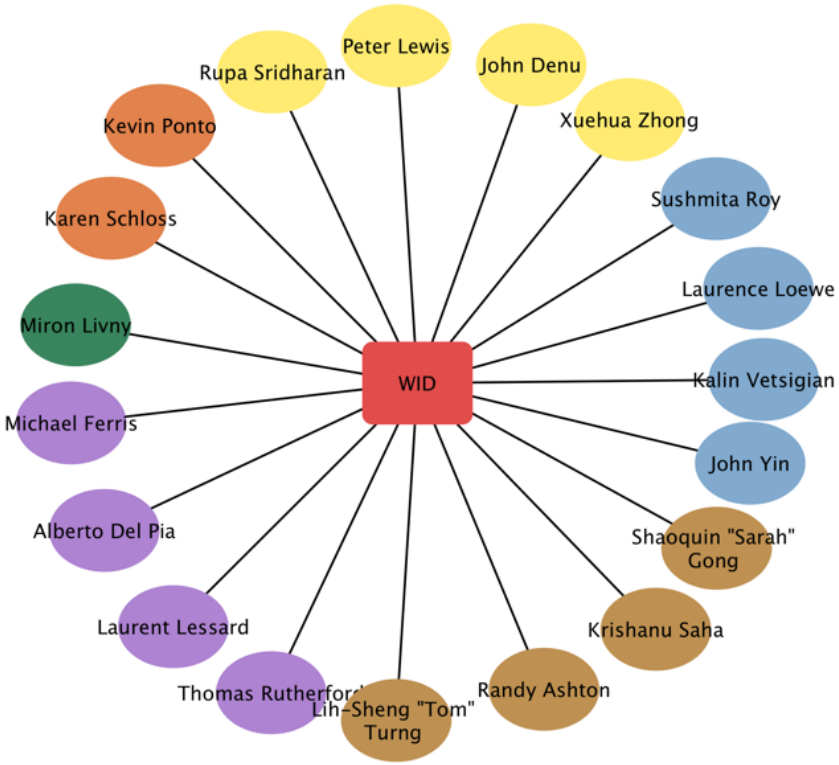
- Learning
  - Marc Goodman *Future Crimes*
  - Target sends adverts for baby clothes and cribs to 15 year old
  - Father complains, then later retracts when learns truth
  - Target learned connection between customer purchases and outcomes
  - Discovery via inference

The WID Setup



BIONATES

CCT

Epigenetics

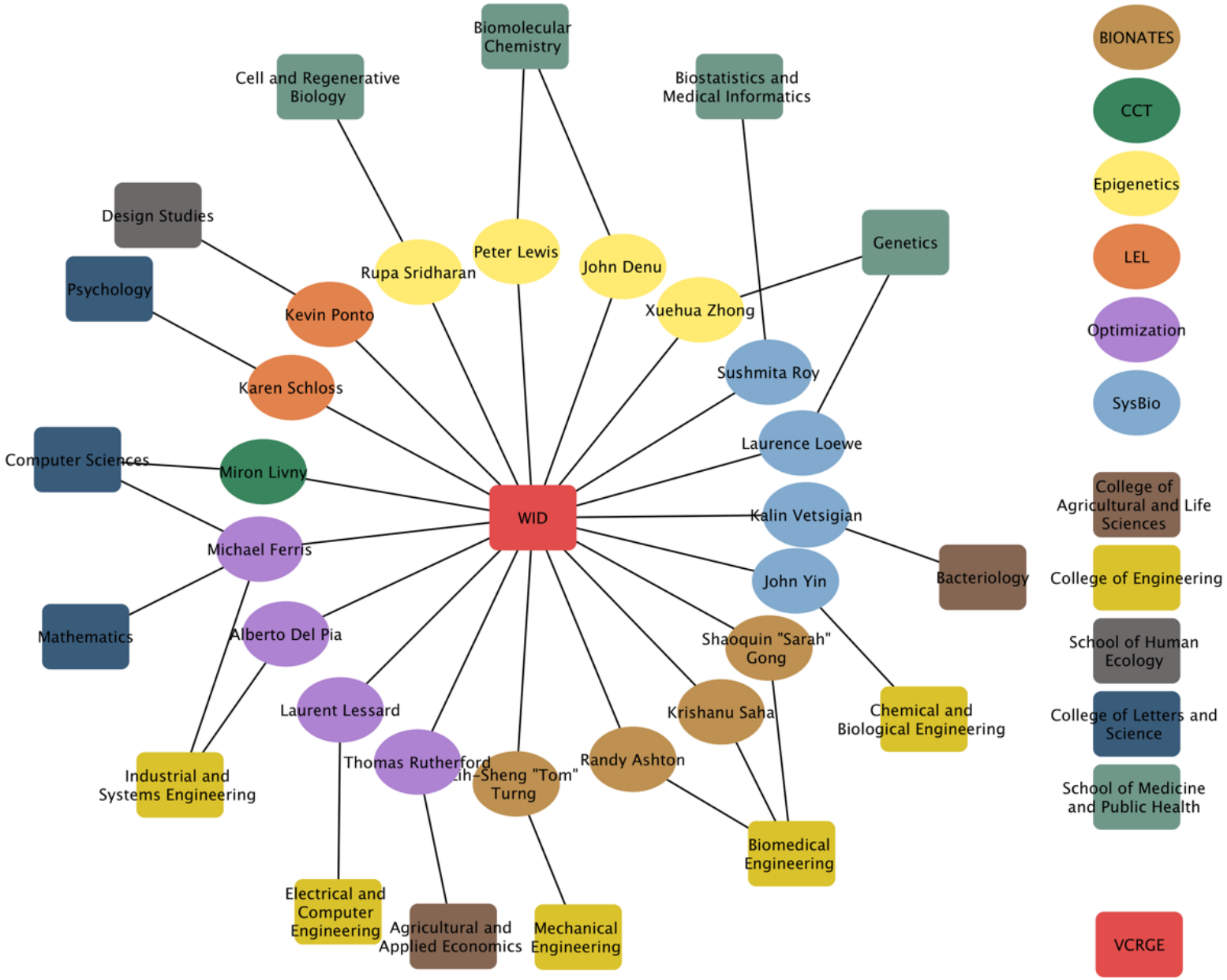
LEL

Optimization

SysBio

VCRGE

The WID Setup



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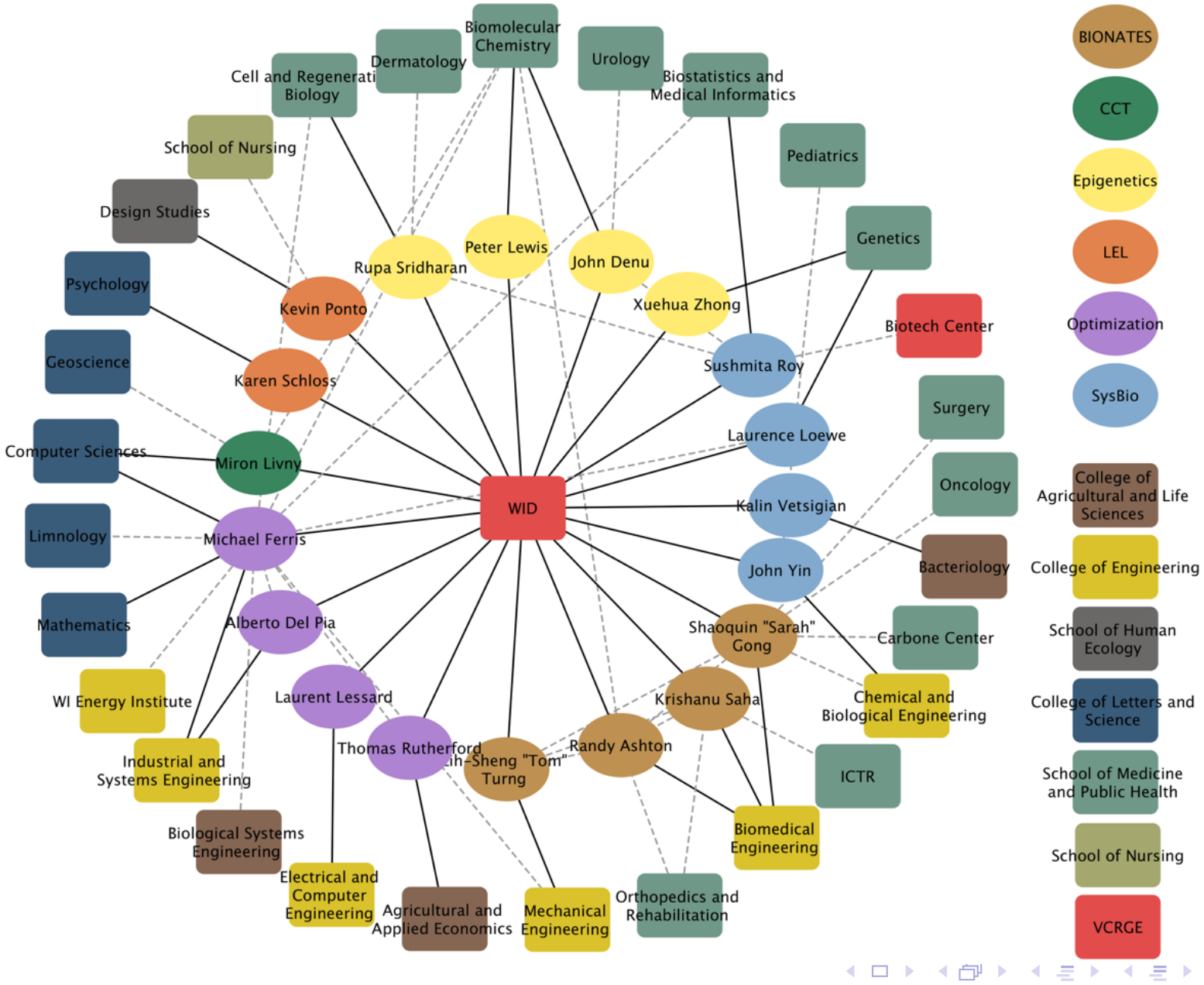
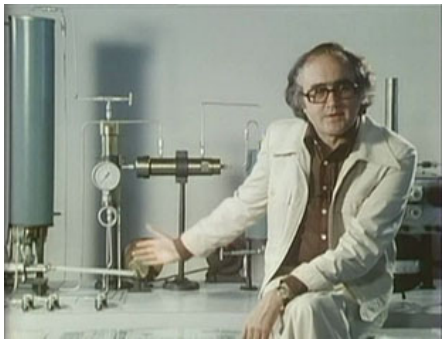


Connections: the need for more

- James Burke

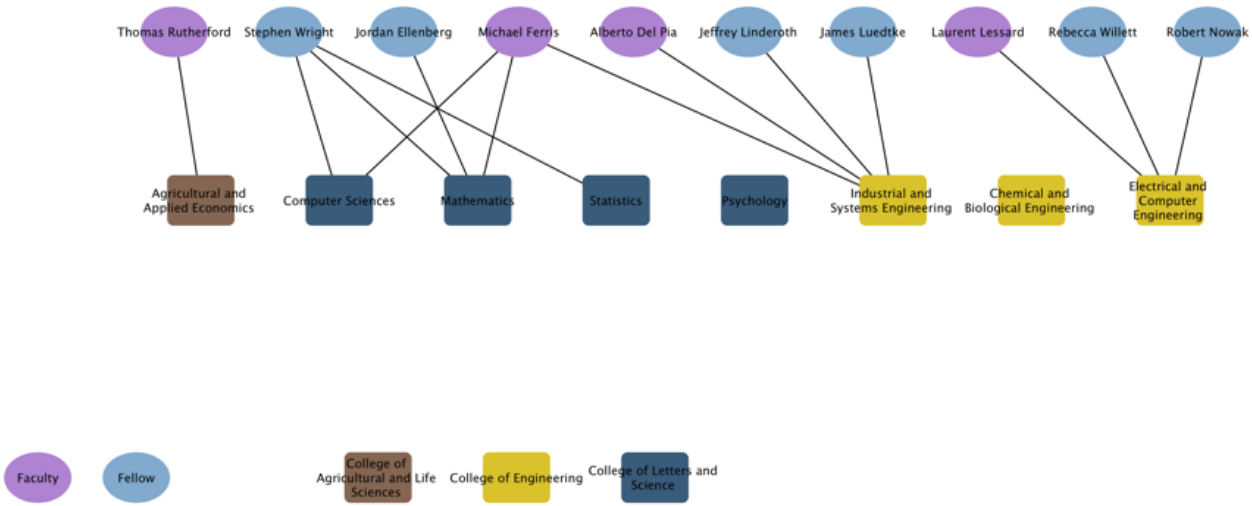


  - TV historian/science writer, and BBC series: Connections
  - modern world...result of a web of interconnected events, each one consisting of a person or group acting for reasons of their own motivations (e.g., profit, curiosity, religious) with no concept of the final result

- Stephen Hawking

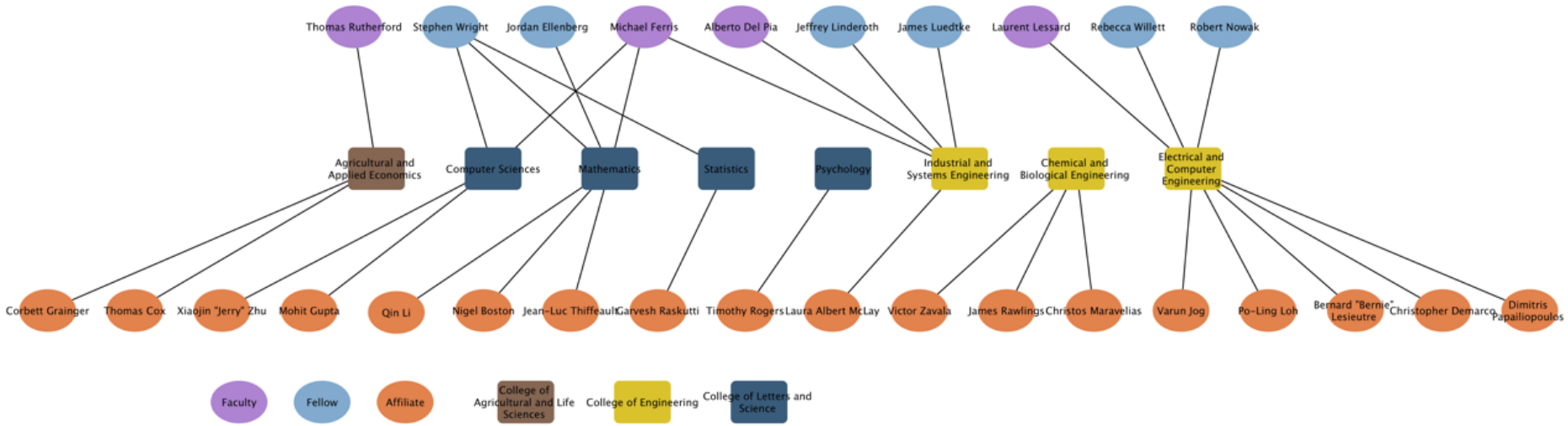
  - Tea-time at Department of Applied Mathematics and Theoretical Physics - formica table
  - Chance connections to new expertise

The Optimization Theme (Discovery Fellow)



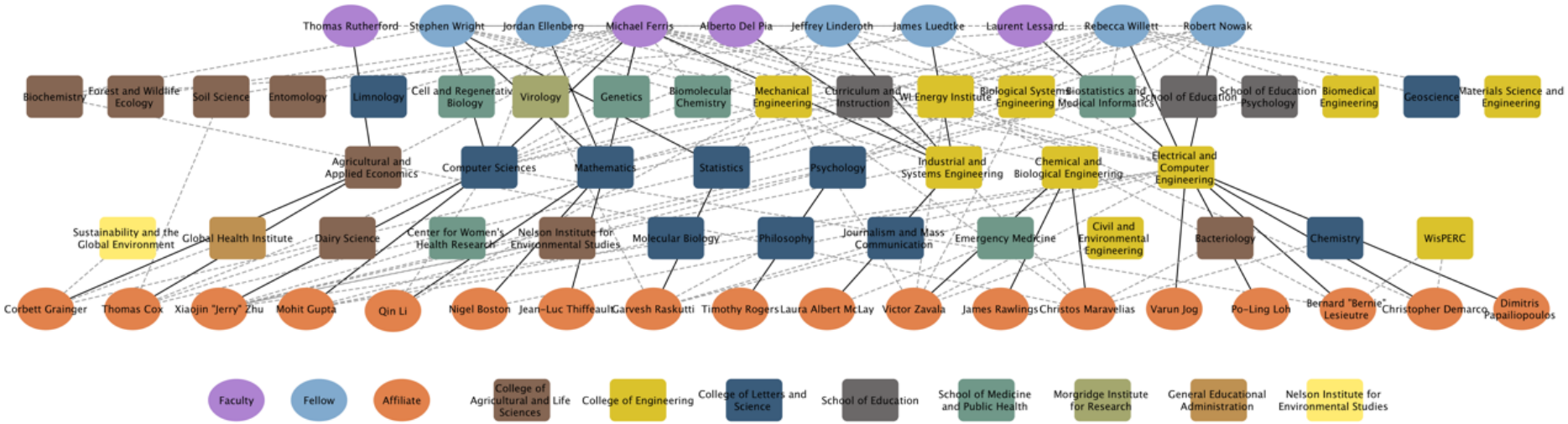
Engage and broaden expertise within theme

The Optimization Theme (Optimization Affiliates)



Allow successful connectors to engage more fully

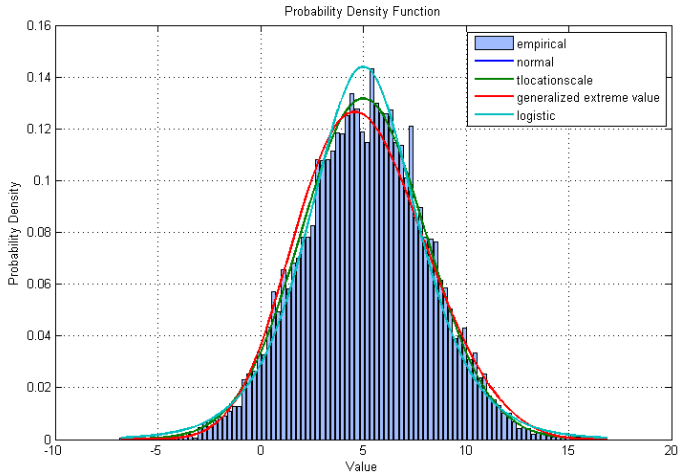
The Optimization Theme (Grants and Papers)



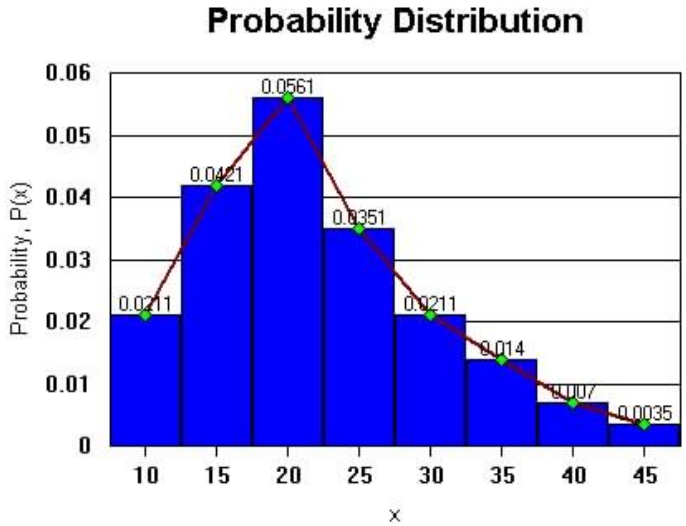
Verifiable/measurable real outcomes

Data and Computation

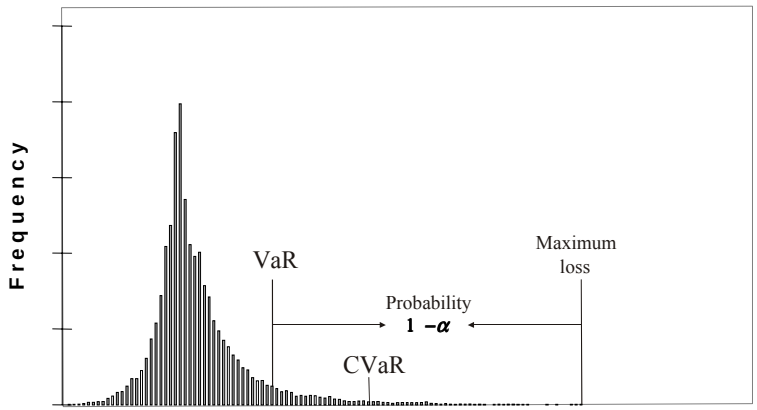
- Uncertainty: Input



- Quantification: Output

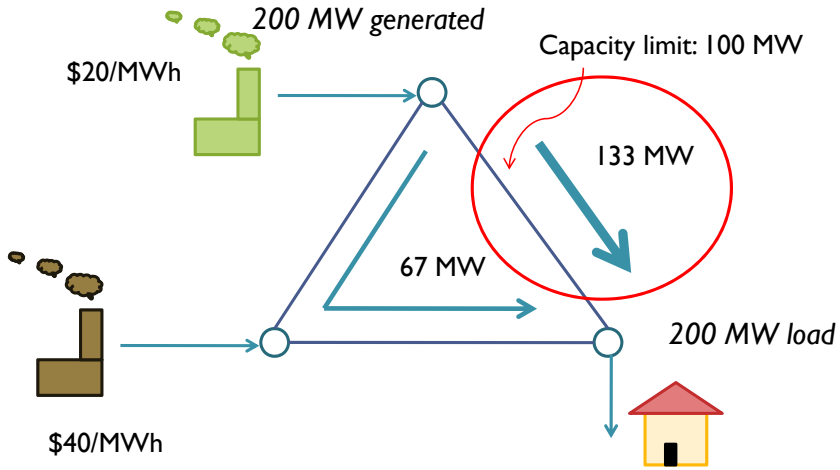


- Data can help manage or control output distribution

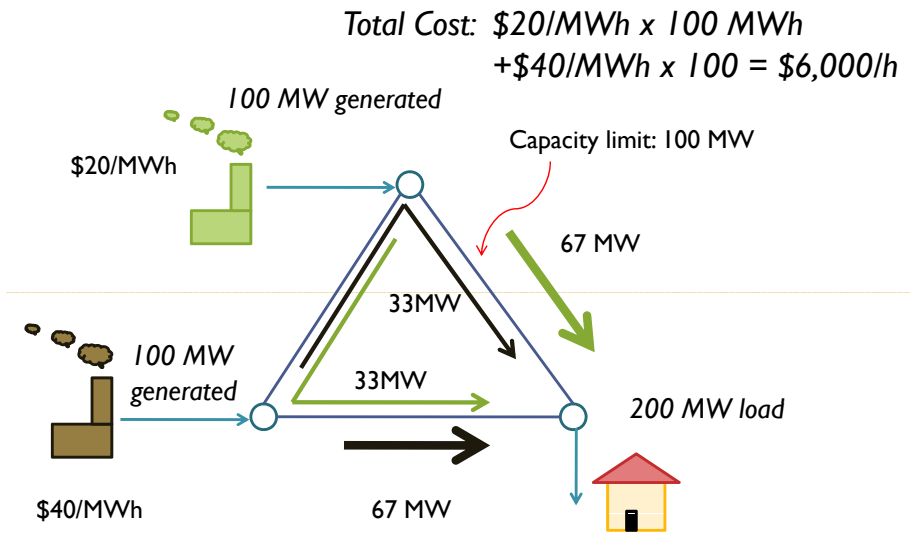


Smart Grid: Transmission switching: T

Opening (removing) lines in a transmission network can reduce cost



(a) Infeasible due to line capacity



(b) Feasible dispatch

Must use expensive generator due to power flow characteristics

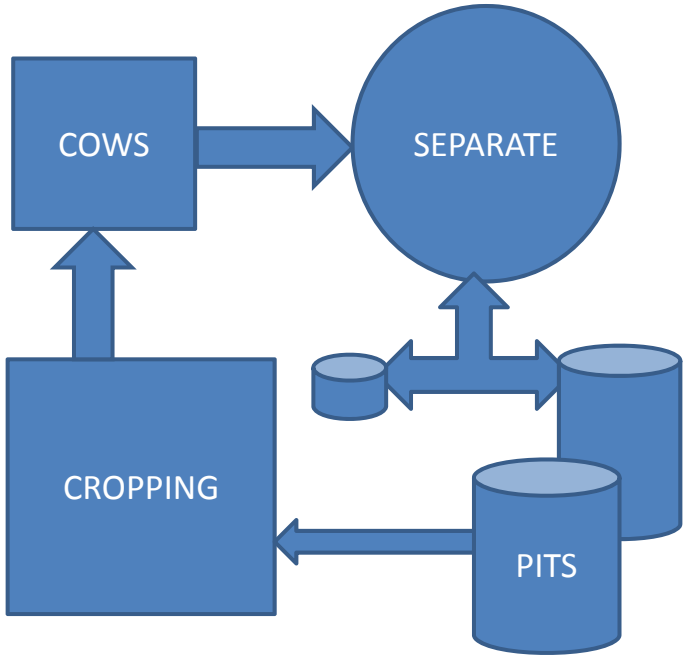
Domain expertise, integrated economic and power models, substantial (4-15%) savings estimated in $300 billion industry

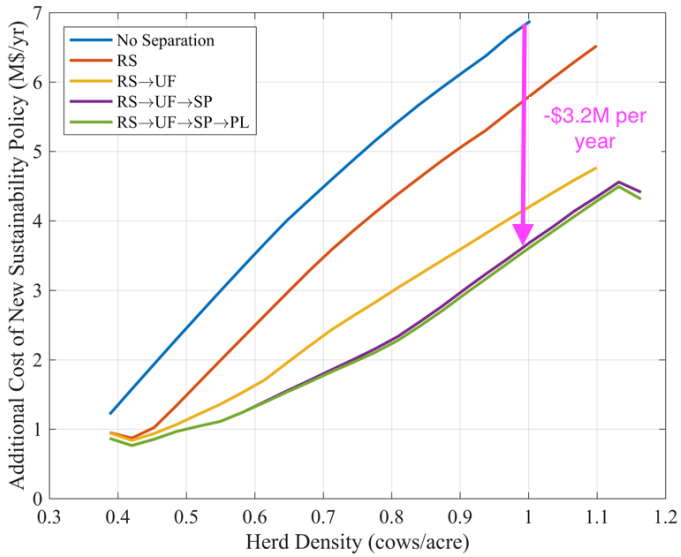
A new motto for WID

Integrating systems, ideas and data to enhance (real) outcomes

- Philosophy: collaboratory, creating ownership, engaging all levels
  - e.g. executive committee, all opinions valued, SILO, games night
- Focus on problems with national impact, relevant and able to leverage WI impact and resources
- Following provide examples of some of my existing joint projects that demonstrate the scope of the envisioned collaboratory
- Focus areas: data, energy, agriculture, environment, health, logistics

Biomass Research and Development Initiative (BRDI)

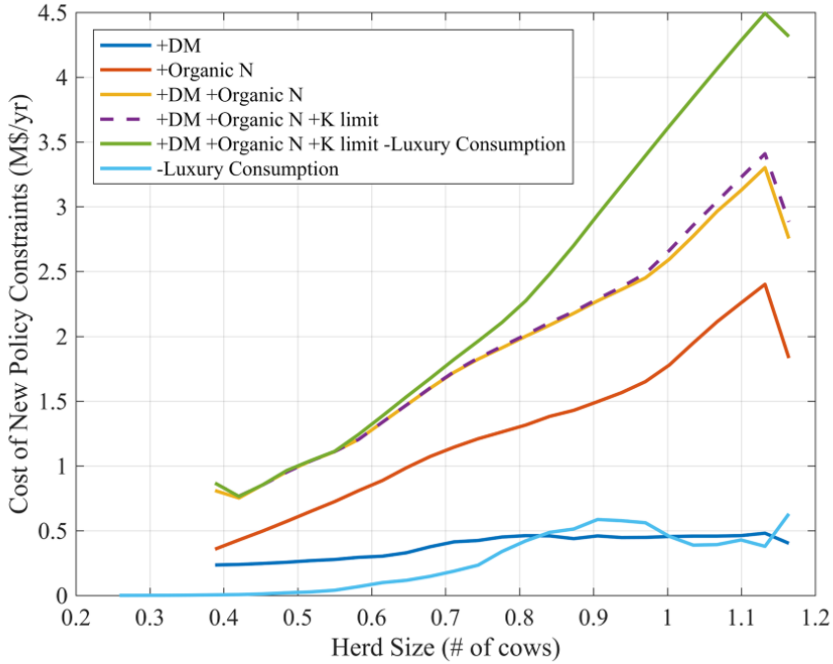




- Whole farm (complex interacting) mathematical model
- Long term sustainable (environment and financial)
- Economic/Logistic Optimization, with phosphorus runoff, other environmental restrictions
- Incorporates data analytics (e.g. SNAP+)
- Interconnected complex system linked by domain data with verifiable outcome

Nutrient management = water quality problem

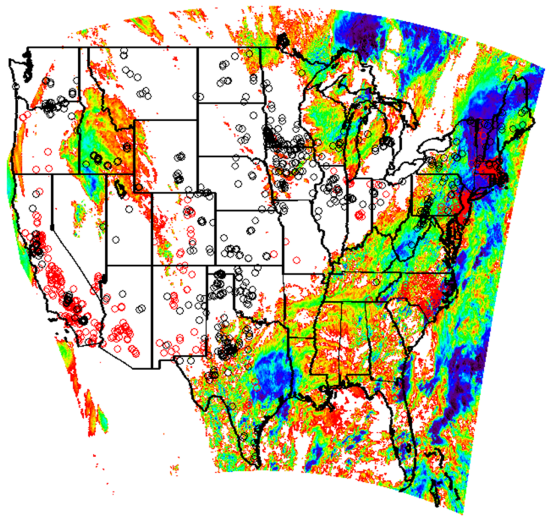
- Nitrogen, as nitrate (NH3), leaches through soil into underground wells/aquifers
- Nitrate poisoning is the leading cause of blue baby syndrome (Methaemoglobinaemia – decreased ability of blood to carry vital oxygen)
- Phosphorus tends to pollute surface waters (rivers, lakes, streams, etc) through runoff
- Nitrogen and phosphorus from agricultural sources contribute to eutrophication, causing harmful algal blooms, fish kills



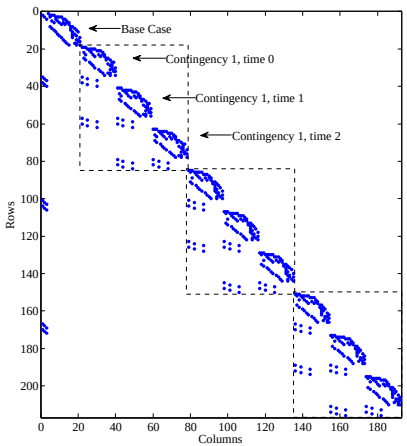
Risky problem, verifiable outcome, discover value and tradeoffs

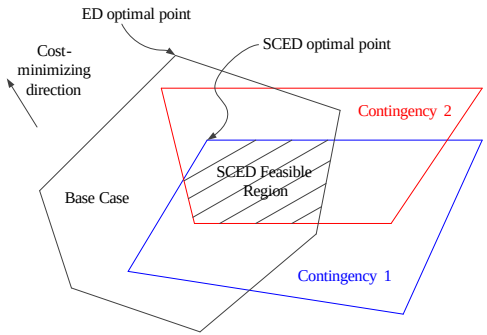
FERC, Reserves and UW 2020

Solar transmittance and power



- Federal Energy Regulatory Commission (FERC) contract to build models and data
- Outreach provision via NEOS (Network enabled optimization software)

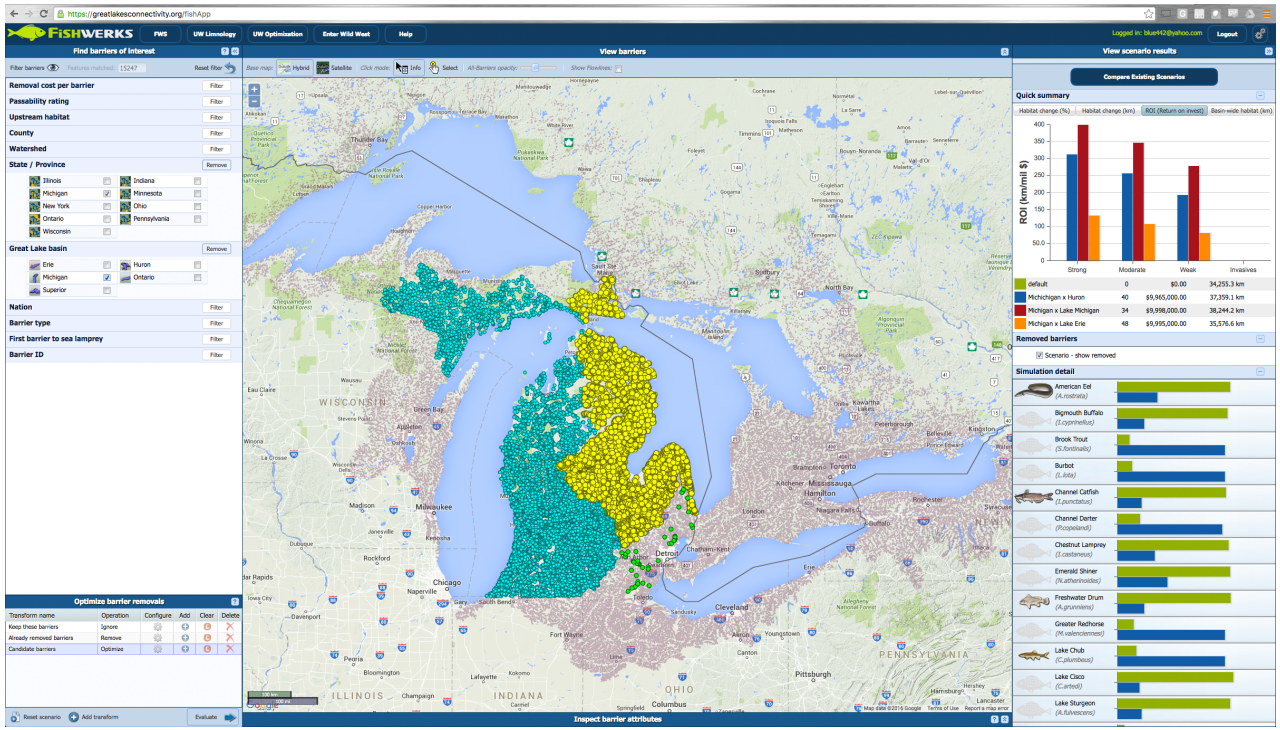




- Generators set aside capacity for "contingencies" (reserves)
- Separate energy π_d and reserve π_r prices
- Use 12 hour cloud cover forecasts to reduce reserves

- Integrate satellite forecast data with power system data to provide reliability and savings outcomes

Fishwerks: A decision support tool



- Great Lakes basin scale data visualization
- 250,000+ interdependent barriers on a river network
- Crowd sourcing data
- Complex optimization for budget constraints, specific fish guilds, invasives
- Adopted by Fish and Wildlife Service `www.greatlakesconnectivity.org`
- Data integration, connecting stream and road systems, enhances outcome

Health and logistics

- Personalized medicine (use data mining and unique "Epic" resource to provide value of patient centric "access but not own" data)
- Experimental logistics: combinatorial factor screening (software control of robot screening technology. Application to biology and chemistry in both academia and pharmaceutical industries)

Factor Tube Array

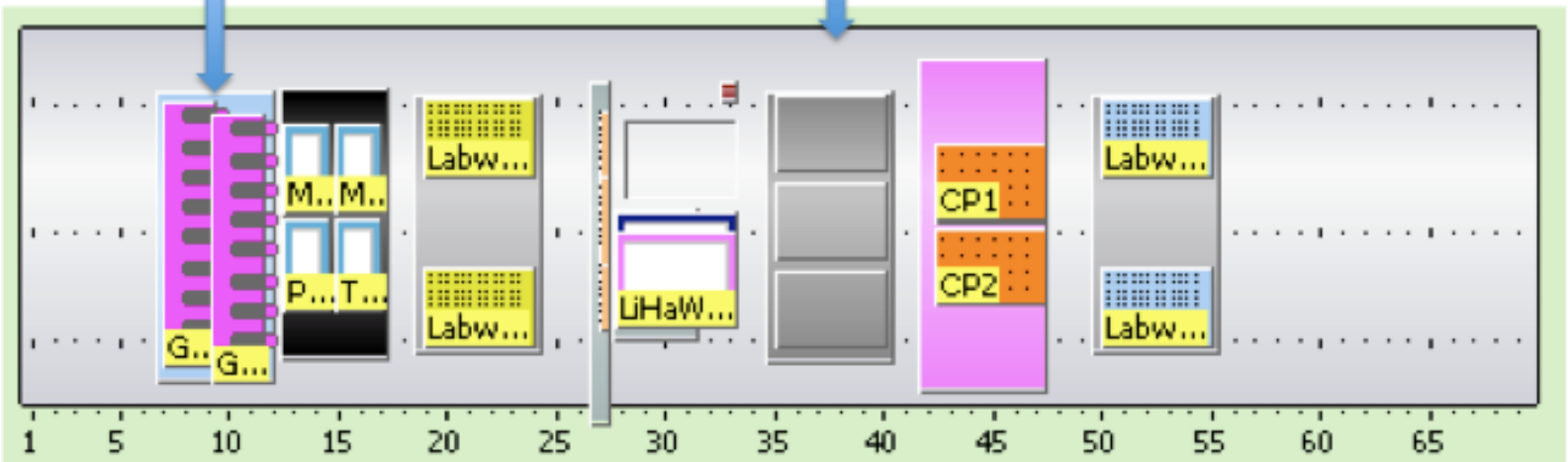
GF

1	9
2	10
3	11
4	12
5	13
6	14
7	15
8	16

24 Well Plate Array

24 Well Cell Plate

	1	2	3	4	5	6
A	1	5	9	13	17	21
B	2	6	10	14	18	22
C	3	7	11	15	19	23
D	4	8	12	16	20	24



How to?

- Consider resources (ideas, faculty, staff, students, building) as portfolio
- Director as balanced fund manager (with executive committee)
  - understand overall vision and goals
  - adjust to new research thrusts and realities
  - facilitate not dictate
  - provides flexibility and risk control
- Add integrator staff (data collection/cleansing, mining and performance computing, data visualization, cyber-security, multi-domain modelers)
- Mixed financial model (federal, state, university, philanthropic, industrial)
- Leverage (MIR, Grainger, CHTC, Nelson, Limnology, ComputingUW and WaterUW)
- Be leveraged (Town center outreach, industrial incubators, research education)

Increase Risk in Portfolio

- We need to be able to, and value, failure
- Low probability, high impact/cost events
- Climate tipping points (global climate changes from one stable state to another stable state)
- Nuclear meltdowns (disasters mitigated by harsher controls, or different mixes of generators, or elimination and enhancement of complementary systems)

- Ensure at least two large scale center grants are developed
- Scope to create integration via data and computation but focused on biology, energy, environment, medicine, planning problems

Final thought

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I ntegration

Final thought

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I ntegration

S ystems

C onnections

Final thought

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Y es we can!