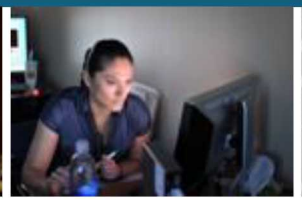
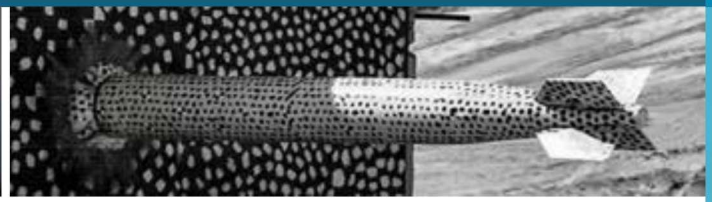
SAND2019-12410C

Sandia National Laboratories

Enabling combinatoric ideation





PRESENTED BY

Diana Bull[1], Jessica Turnley[2], Jeff Tsao[1], Peter Gambill[1]

PRESENTED AT

The 8th Atlanta Conference on Science and Innovation Policy

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U.S. DEPARTMENT OF ENERGY NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Hypothesis: changing environmental factors have increased combinatorial processes of ideation resulting in distinct innovation outcomes.

Evolving securityscape

Funding

Transforming research models

Evolution of the innovator's relationship with knowledge

Combinatoric Ideation

Assimilation

- Exploring science and technology from disparate domains to develop novel ideas through extrapolation, association, analogy and inspiration

Compilation

- Exploiting existing technology and science from disparate domains through assemblage, bricolage, and incorporation to develop surprisingly useful amalgamations

Drones

https://www.businessinsider.com/china-builds-first-stealth-amphibious-assault-drone-for-island-warfare-2019-4

Landcraft Watercraft Amphibiouscraft

https://www.sandiego.gov/ohs/unmanned-aircraft-systems

https://www.hstoday.us/subject-matter-areas/terrorism-study/terrorists-use-of-drones-promises-to-extend-beyond-caliphate-battles/

Cameras
Mapping & intelligence

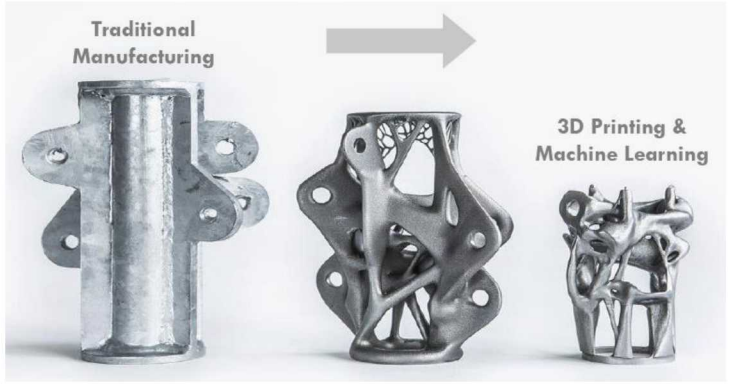
Payload delivery
Weaponization

https://www.hstoday.us/subject-matter-areas/terrorism-study/terrorists-use-of-drones-promises-to-extend-beyond-caliphate-battles/

Additive Manufacturing

https://www.popsci.com/science/gallery/2013-07/5-body-parts-scientists-can-3-d-print/

Human kidney



B. Winton, J. Wang, C. Burniske, B. Yarasuri, T. Keeney, M. Samy, J. Hemmendinger, and S. Korus. "ARK Invest Disruptive Innovation: BIG IDEAS 2017." ARK Invest, 2017. ark-invest.com.

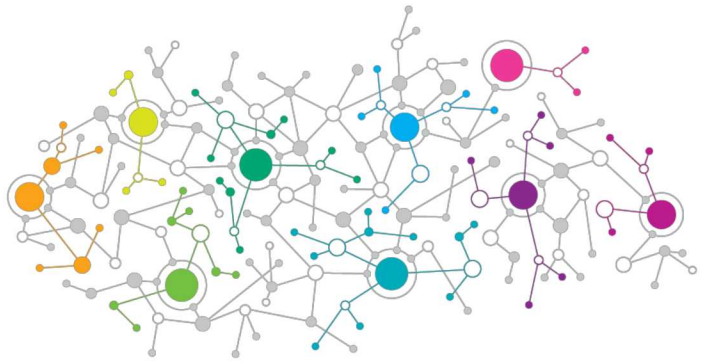
AI design of load bearing parts

What does the combinatorial ideation environment look like at Sandia National Laboratories?

Absorptive Capacity

https://ceriumnetworks.com/technologies/networking/

Combinatoric Capacity



https://ceriumnetworks.com/technologies/networking/

How are the global and accumulating knowledge and technology bases being integrated into ideation by researchers at Sandia?

- What is the diversity and degree of domain incorporation?
- Are there differences between knowledge and technology bases in the ideation stage?

What roles are disciplinarily and (potentially) geographically distributed networks playing in ideation?

Are there personal attributes that encourage the breadth needed for combinatoric ideation?

In a strong institutional environment, like Sandia, are the methods needed for combinatorial ideation encouraged?

Sandia is an NNSA laboratory that addresses national security challenges

Sandia's history is traced to the Manhattan Project--established November 1, 1949

FY18 Budget: $3.64B

Interviews

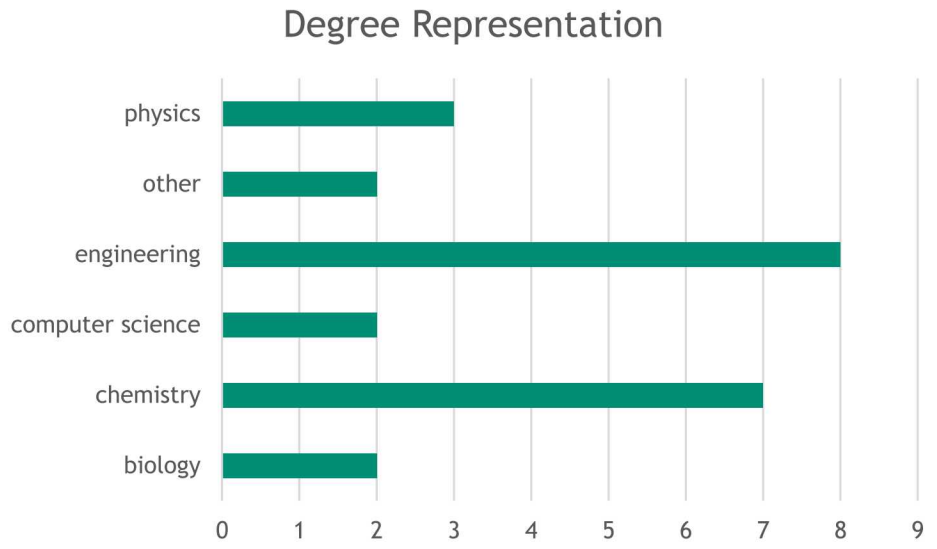
25 researchers in a snow-ball sample

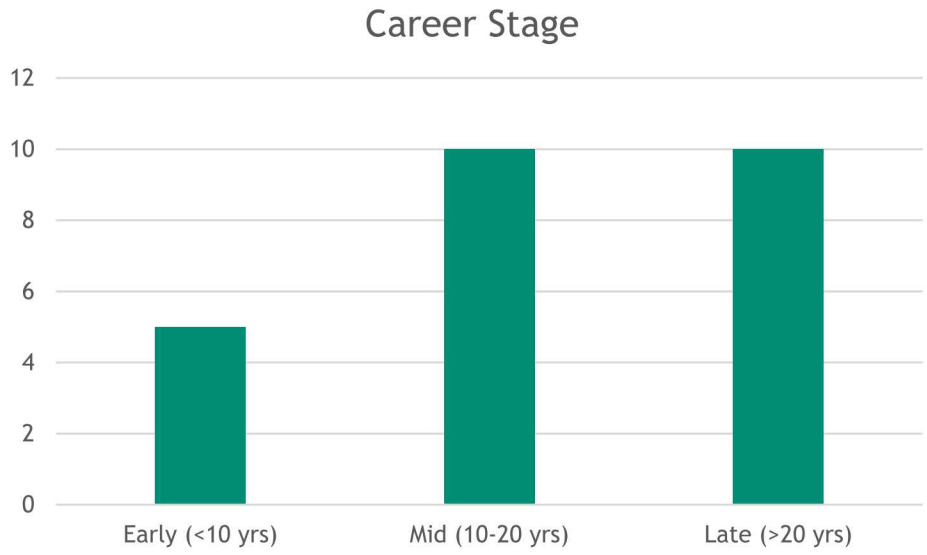
- Targeted individuals believed to be pursuing combinatoric methods
- Close to sufficiency (started getting repeat names)

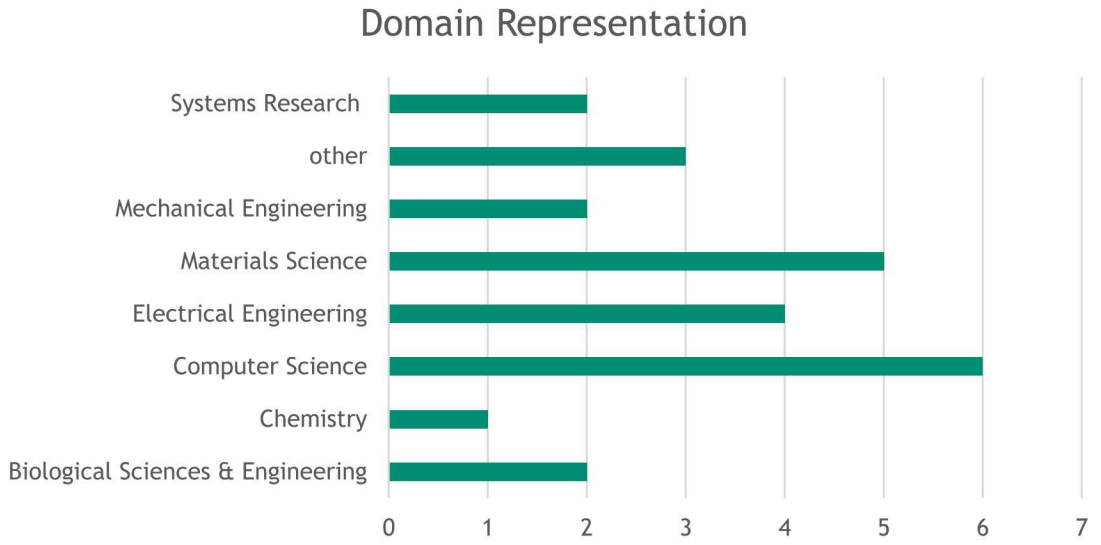
Conducted from March – June 2019

One hour duration in person (when possible)

- Dedicated note-taker





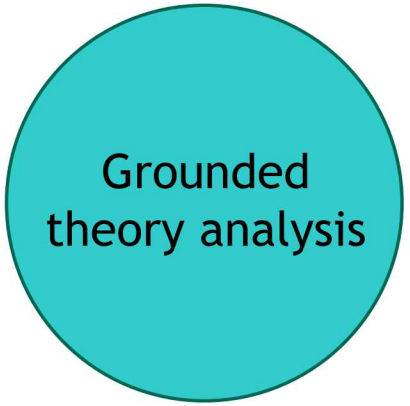


Questions

INTERVIEWS

In your research do you:

- combine multiple domains
- focus on science or technology
- learn about new areas
- engage collaborators
- employ characteristics that make you good at this
- feel SNL influencing your success
- take risks & accept failure



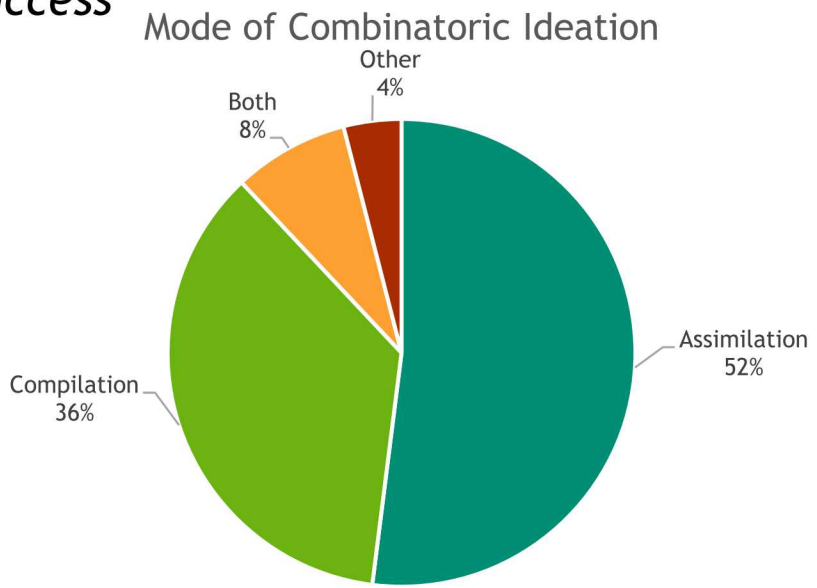
ANALYSIS

How is the combinatoric method influenced by:

- aspects of the ideation phase
- personal characteristics & achievements
- breadth of knowledge an individual possesses
- learning
- Sandia National Laboratories
- team characteristics & communication
- risk & failure tolerance

Results: Combination of Domains in Ideation

"Getting exposure to more application space increases my chance of success"



Depth of Combined Bases

- Assimilation: understanding at a first principles level (in concept (science) or form (technology)) how to fuse two domains into a new idea--explorative style thinking
- Compilation: the bricolage of two domains into a new idea--exploitive style thinking

Degree of Cross-domain Collaboration

- Multi-disciplinary— draw, as needed, upon disparate domain knowledge maintaining SME status of the individuals
  - *"These projects involve diverse expertise on materials, radiation modeling and printing. I'm a materials person and my contributions are focused on this skill."*
- Interdisciplinary— fuse disparate domain knowledge so that each team member understands multiple domains
  - *"You have to break through the jargon and really understand the concepts otherwise you can misconstrue a problem"*

https://www.lemontreedwelling.com/bell-pepper-salsa/

https://www.recipetineats.com/best-ever-authentic-guacamole/

Results—Aspects of crossing domains in ideation

Identifying and Defining the Problems

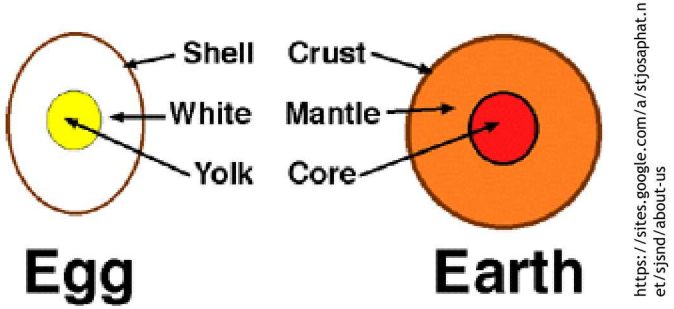
- Customer defined
- Individually (or team) constructed
- Foresight driven

http://strategic-advantage-consulting.com/identify-the-real-problem-head-in-the-right-direction/

"When I look at what people are doing I try to think ahead…what are the next couple of problems they will encounter?"

Solutions Employing Cross-Domain Approaches

- Problem complexity
- Analogic thinking worked
- Directly requested



https://sites.google.com/a/stjosaphat.net/sjsnd/about-us

"Coming at the same topic from two very different points of view is so powerful."

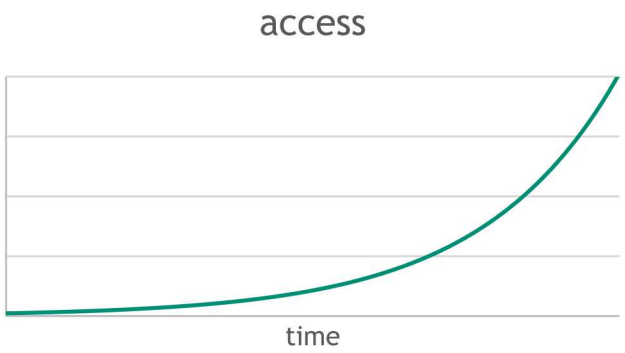
Incentives for cross-domain solutions

- Surprising solutions grab attention
- Working in the gaps decreases competition
- Increased return on investment

Focus of Combined Bases

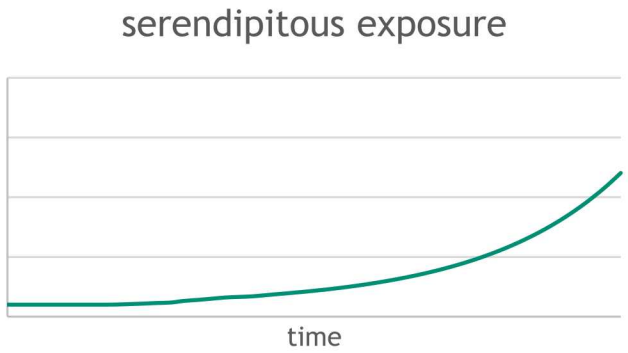
- Science: explanations of phenomena found in nature & the universe
- Technology: "artifacts, devices, methods, and materials available to humans to accomplish specific tasks." (Youn 2014)

Results—Learning



Access to Data and Information

- Online querying techniques (Google, SciFinder, ..)
- Sharing mechanisms (blogs/ forums) that keep pace with the developments in the field
- Online courses (YouTube, free universities, etc.)



Serendipitous Exposure

- Reading outside of your expertise
- *"Keeping up with what is changing in the world"*
- *"Luck is a big factor - what have you recently been seeing? That is how you become aware of how to combine two ideas"*
- *"One thing I do is keep a 'surprise log'. Whenever I'm surprised by something I make a note of it."*

Traditional Learning Methods

- Reading
- Conferences
- Personal interactions
- Experiential (i.e. craft)

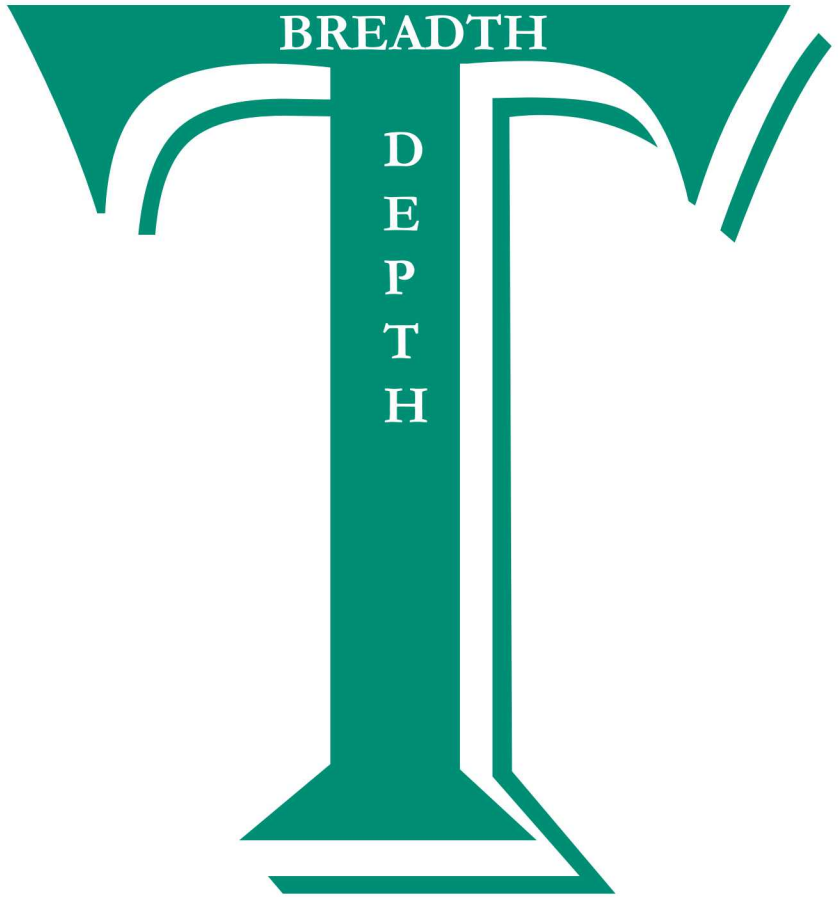
(potential) New Learning Methods

- Data mining via machine learning
- Complex modeling in user friendly packages

Rise of serendipitous exposure enables diversity of domain incorporation in combinatoric ideation

Results—The People

Curiosity & passion drive desire for Breadth



Achievement in area of core expertise (Depth) gives the experience, latitude, and confidence needed to explore breadth

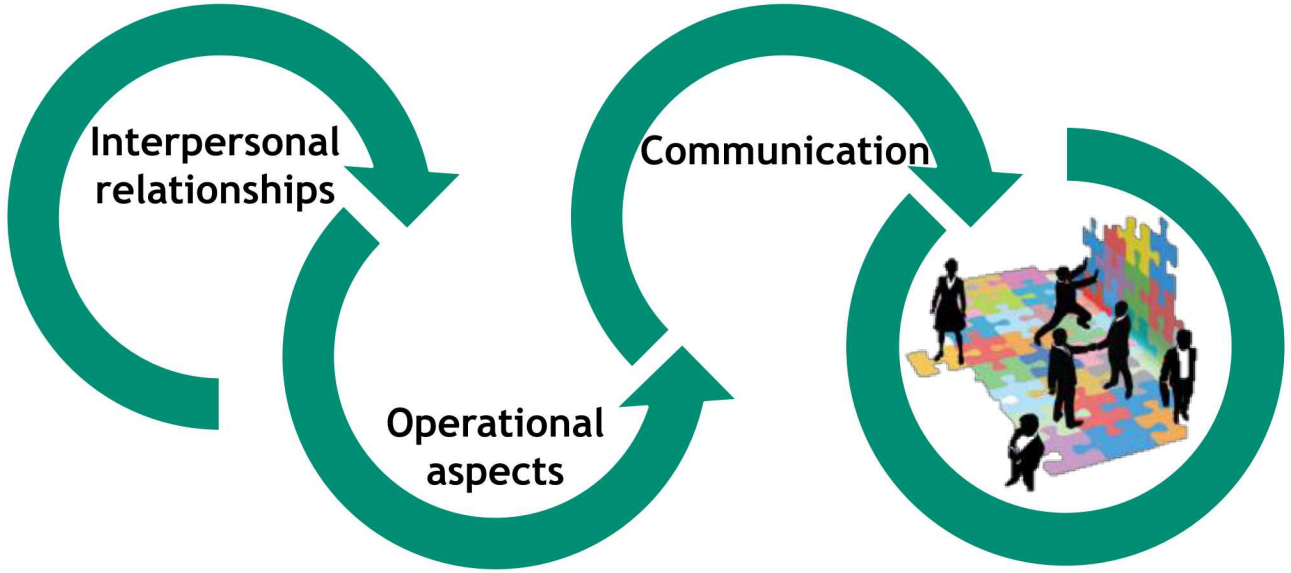
Personal Characteristics that Facilitate Breadth

- Hubris and humility
- Openness (to new ideas, experiences, …)
- Comfort with discomfort
- Risk tolerance
- Willingness to sacrifice work-life balance
- Re-framers (of failures, of problems, of …)
- IQ, willingness to team, & EQ

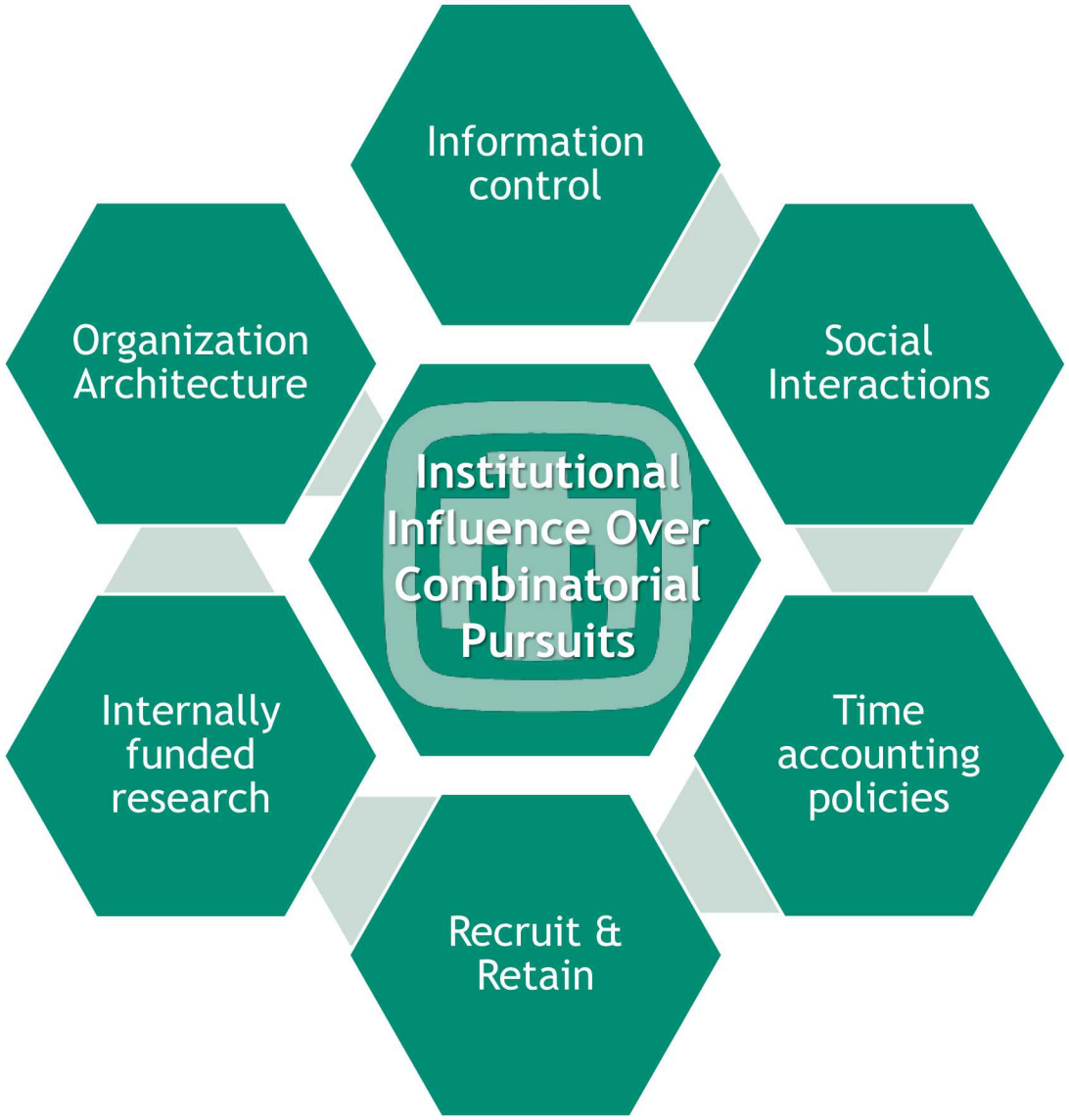
Results—Teaming

Collaboration as foundation of Combinatoric Ideation

- Internal Networks
  - Nature of protected information
  - Large diverse population at SNL
    - "*I find that I can almost always find experts in whatever I am interested in right here at Sandia*"
  - Exhibit "strong tie" characteristics
- External Networks
  - Bureaucratic challenges to overcome with external collaborations
  - Universities, other labs, and to a lesser extent industry form basis
    - "*I use my network of university colleagues and build out through their networks.*"
  - Exhibit "weak tie" characteristics



Results—Role of the Institution



Research Competition

- *"Everything is a competition…to see who can get papers out first"*
- *"It's hard to compete with a university in basic research. But we can make things that others can't."*

Research Cooperation

- *"Type of work requires a big collaboration with external [players]."*
- *"Work with a lot of industry. Codeveloping materials. Working on licensing."*
- *"Everyone knows each other in this field. There is a snowball effect once you get established with a good reputation."*

Research Reputation

- *"Publications have gone down. We have concentrated for so long on projects and deliverables."*
- *"Having a Sandia business card opens doors"*
- *"Our ability to attract is proportional to our reputation for good work."*

What does the combinatorial ideation environment look like at Sandia National Laboratories?

By "*be willing to delve into areas you don't know anything about, but also humble enough to recognize that you know so little that you can't work there*" combinatorial ideation is present at SNL.

A subset of employees:

- recognize the importance of cross-domain work
- embrace importance of serendipitous learning
- see technological advances to increase learning rates (but are currently under-utilized)
- have the personal characteristics that support breadth development needed for cross-domain work
- can develop the teams needed to implement cross-domain work

The scope of SNL and the nature of its work seems to favor internal as opposed to external networks.

- this may have long term impacts as there is an exponentially growing corpus of knowledge and technologies in all areas

Although combinatoric ideation does occur, there are barriers at the institution that make it difficult to achieve.

BACK-UP

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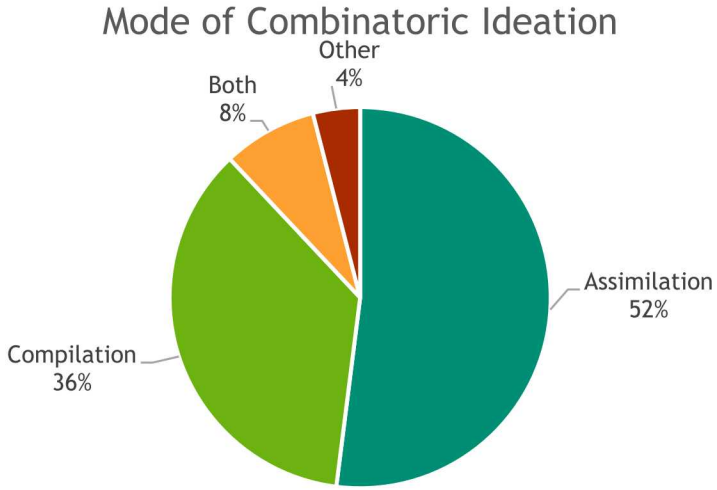

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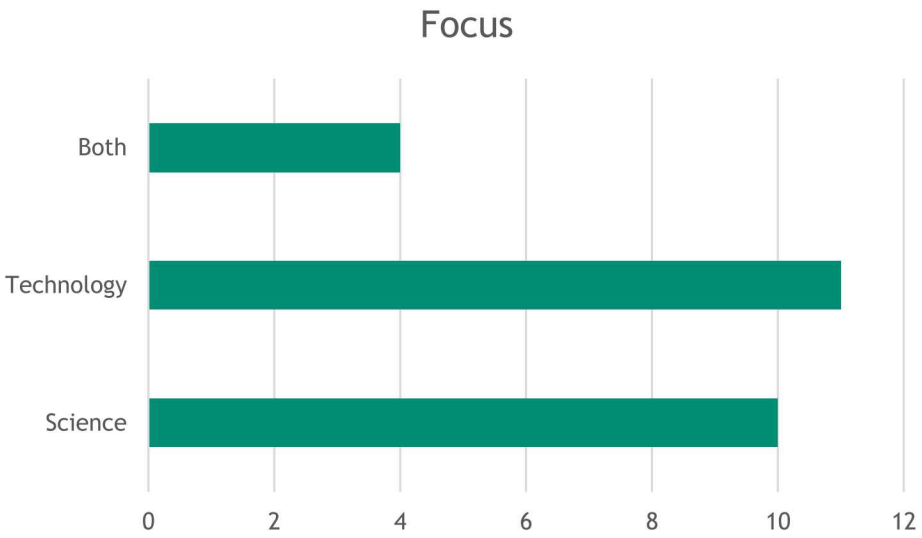

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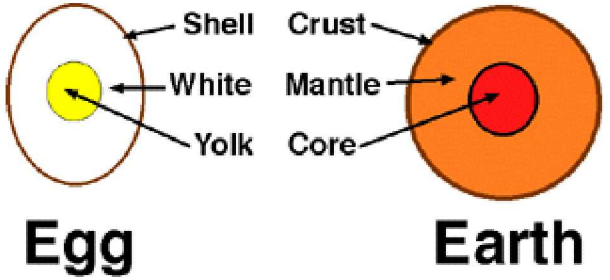

https://sites.google.com/a/stjosaphat.net/sjsnd/about-us

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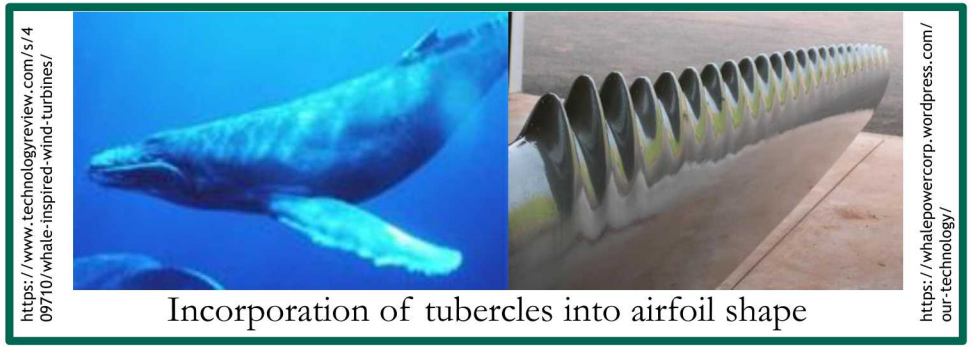


https://www.technologyreview.com/s/409710/whale-inspired-wind-turbines/

Incorporation of tubercles into airfoil shape

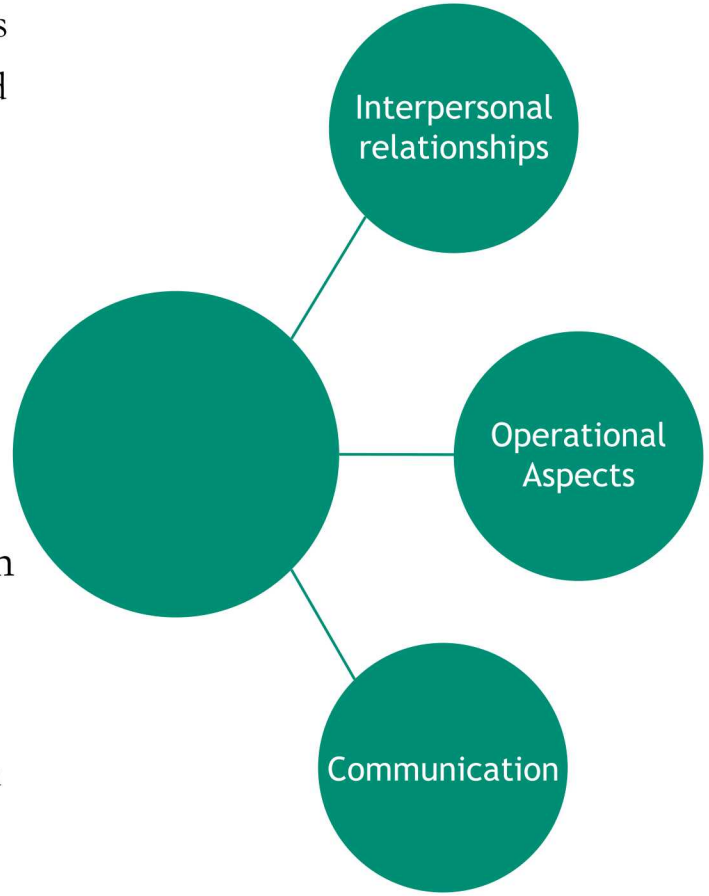
https://whalepowercorp.wordpress.com/our-technology/

"Novelty is where it isn't evident."

Results—Teaming (degree of collaboration, internal & external networks, diversity)

Networks as foundation of Cross-domain Collaboration

- Strong--Preference for internal networks
  - Nature of protected information
  - "I find that I can almost always find experts in whatever I am interested in right here at Sandia"
  - Bureaucratic challenges to overcome with external collaborations
- Weak--Non-familiar, often external, networks
  - "People get in a rut with what they know and who they work with"
  - "innovation often comes from someone familiar but a little outside"
  - Conferences seem to be main avenue for establishing weak ties



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- Multi-disciplinary— draw, as needed, upon disparate domain knowledge maintaining SME status of the individuals
  - "See synergies between what you can do and what others can do and build ideas"
  - "These projects involve diverse expertise on materials, radiation modeling and printing. I'm a materials person and my contributions are focused on this skill."
- Interdisciplinary— fuse disparate domain knowledge so that each team member understands multiple domains
  - "You have to break through the jargon and really understand the concepts otherwise you can misconstrue a problem"
  - "A good technical exchange means you have to have learned something from each other"