Thriving in the Innovation Economy through Collaborations of Government, Universities, and Industry

Presented at the National Academies of Sciences, Engineering, and Medicine – Government-University-Industry Research Roundtable.

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by

Gary Markovits

gary@innovationbp.com

Innovation Business Partners, Inc.
Connecting Minds to Markets™

Agenda

- The Innovation Economy
- Collective Intelligence the Micro-Foundation of Economic Growth
- Innovation Ecosystems as Innovation Networks
- The Living Systems of Economic Development
- Mapping Innovation Networks
- The Innovation Genotype™
- Connecting Centers of Insight to Centers of Innovation
- Triadic Policy Analysis
- Regional Mechanisms for Economic Growth
- Measuring Our Capacity for Innovation
- Creating a Culture of Innovation
- Conclusions and the GUIRR Opportunity

The Innovation Economy

- Our security and prosperity are ever more dependent upon innovation
- “Ultimately, all increases in standards of living can be traced to discoveries of more valuable arrangements for the things in the earth's crust and atmosphere.”*
- “No amount of savings and investment, no policy of macroeconomic fine-tuning, no set of tax and spending incentives can generate sustained economic growth unless it is accompanied by the countless large and small discoveries that are required to create more value from a fixed set of natural resources.”*

* Romer, Paul M. 1993. “Implementing a National Technology Strategy with Self-Organizing Industry Investment Boards”, (Brookings Papers on Economic Activity, 1993, No. 2)

Collective Intelligence

- Human intelligence is the ability to acquire and apply knowledge and skills
- Collective intelligence is the ability of a network of people to acquire and apply knowledge and skills at a rate that far exceeds that of the individual
- Micro-foundation of collective human intelligence is the tacit-explicit dialogue:

$$\text{Tacit-Explicit Dialogues} = 2^N - N - 1$$

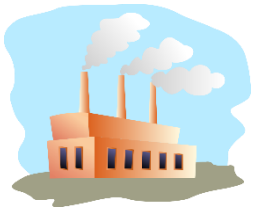
- Innovation is the human ability to acquire and apply specific knowledge and skills that change behaviors and create value in society – the innovation economy arises from human collective intelligence

Innovation Ecosystems as Innovation Networks

- "[An] innovation ecosystem models the economic rather than the energy dynamics of the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation."*
- An innovation ecosystem can be modeled as a network of networks:
  - Actors or entities ⇒ Nodes
  - Complex relationships ⇒ Links
- Enables the application of network science, mathematics, and software tools to visualize, characterize, and quantify innovation ecosystems

* Jackson, Deborah J., "What is an Innovation Ecosystem?", National Science Foundation, 15 March 2011.

The Living Systems of Economic Development



- Region
  - Network of Organizations
  - Ensemble of Cultures of Collective Intelligence
  - Innovation Economy – Policy
- Organization
  - Network of Groups
  - Organizational Culture of Collective Intelligence
  - Innovation Engine
- Group
  - Network of Individuals
  - Collective Intelligence – Reeds Law
  - Multidisciplinary Invention
- Individual
  - Network of Tacit Knowledge and Skills
  - Individual Intelligence
  - Invention

Mapping Innovation Networks

Mapping Innovation Networks

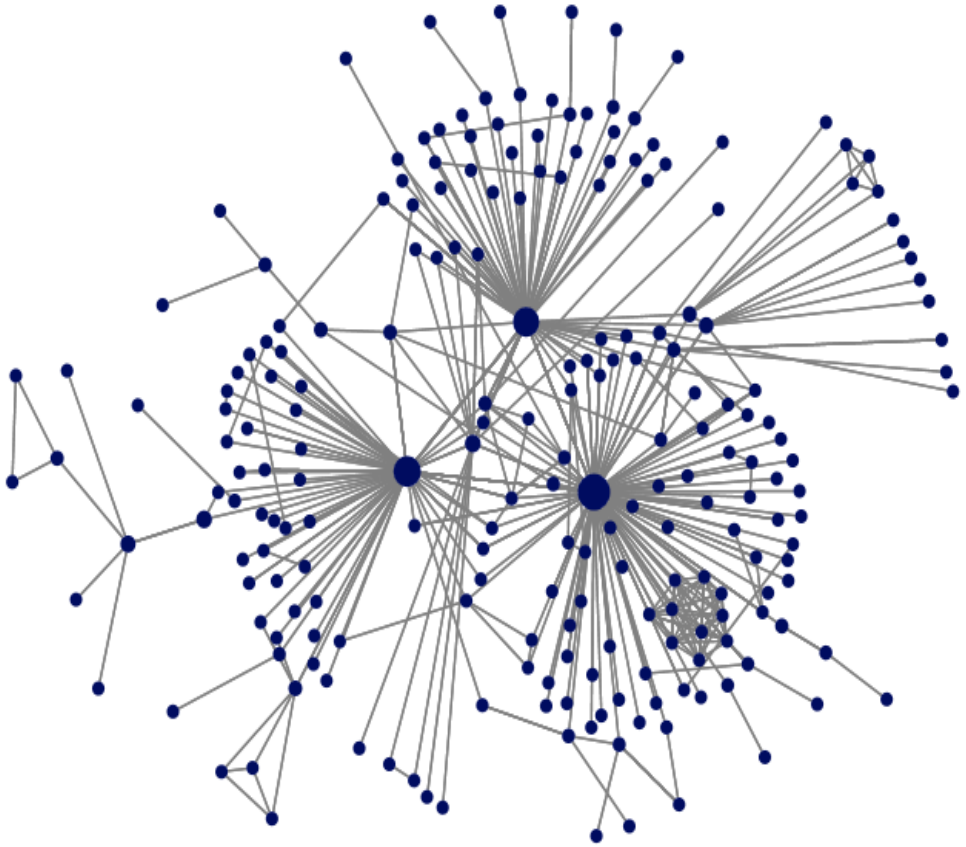
- Requires data that reveals the acquisition and application of knowledge and skills – intelligence
- Peer reviewed publications, technical journals, books, patents, etc. are all candidates
- A strong relationship exists between a region's prosperity and its ability to generate patents*
- Patents reveal new and useful processes, machines, means of manufacture, and compositions of matter – the foundations for scalable innovations
- Linked to STEM and venture capital

* The Brookings Institute 2013 report "Patenting Prosperity: Invention and Economic Performance in the United States and its Metropolitan Areas", by Jonathan Rothwell et al

Mapping Regional Innovation Networks Inter-Organization Collaboration

Maryland's Inter-Organization Collaboration Networks

- 2,959 MD inventions 1/2013 ⇒ 8/2016
- 277 inventions with one or more MD assignees and one or more MD inventors
- 241 unique organizations
- Node diameters scaled by betweenness centrality
- Dominated by Johns Hopkins, USM, and HHS
- Lymphoma cluster 24 inventors, 11 assignees from 5 countries



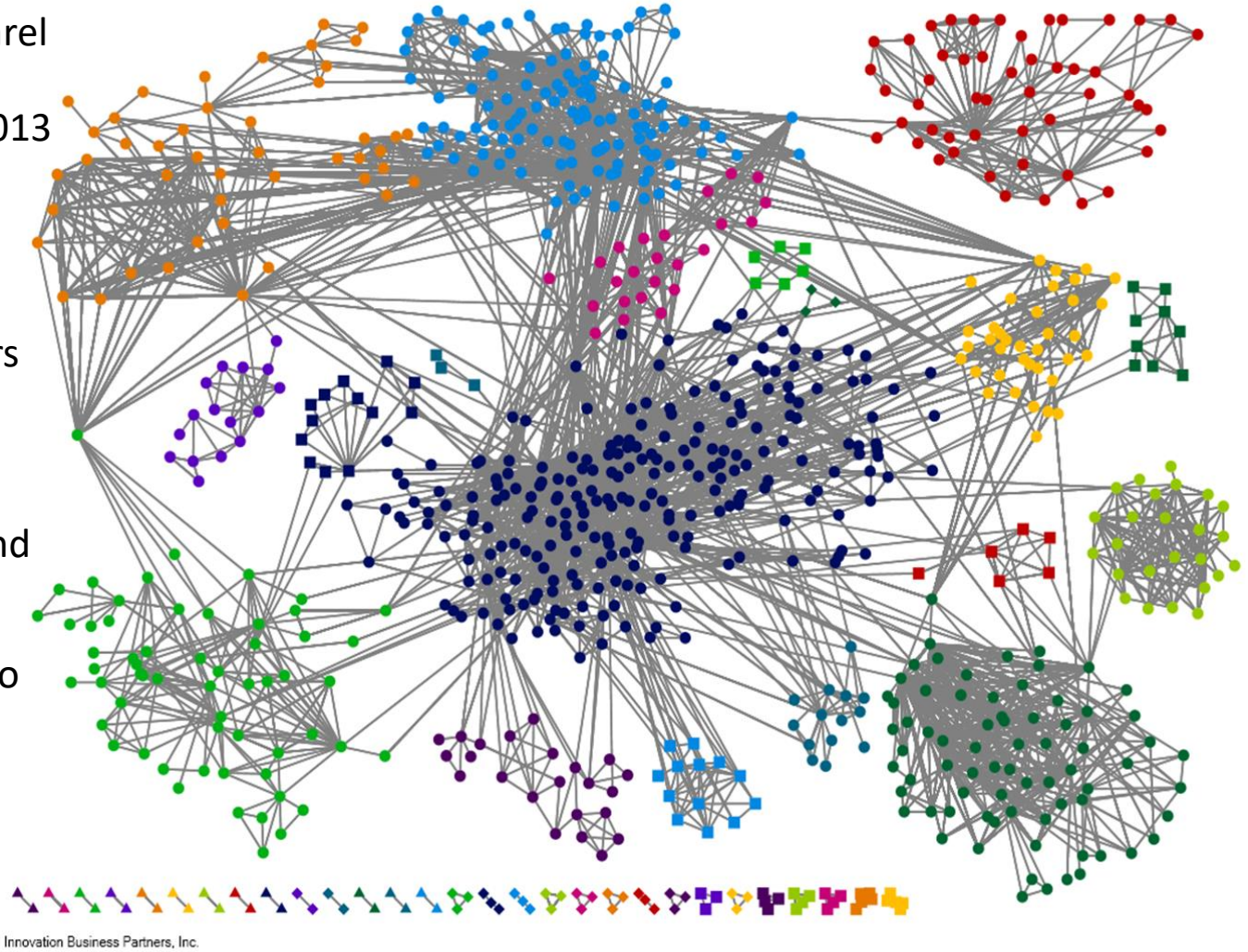
Questions from Inter-Organization Collaboration Networks

- What do Johns Hopkins, USM and HHS know about collaboration that the others do not?
- What policies and practices do they have that enable collaboration, and could they be adopted by others?
- Why is the connectivity between each dominant organization's individual collaboration networks so sparse, and what innovations could be generated by increasing connectivity between them?
- What can we learn from the lymphoma cluster collaboration that applies to other complex domains?
- The collaborators represent 10%, what are the lessons for the other 90%?
- What can the regional, state, and federal government do to increase inter-organization collaboration?
- Can regional lessons be applied at a national level?

Mapping Organization Innovation Networks Clusters, Bridgers, and Backbones

Organization Innovation Network

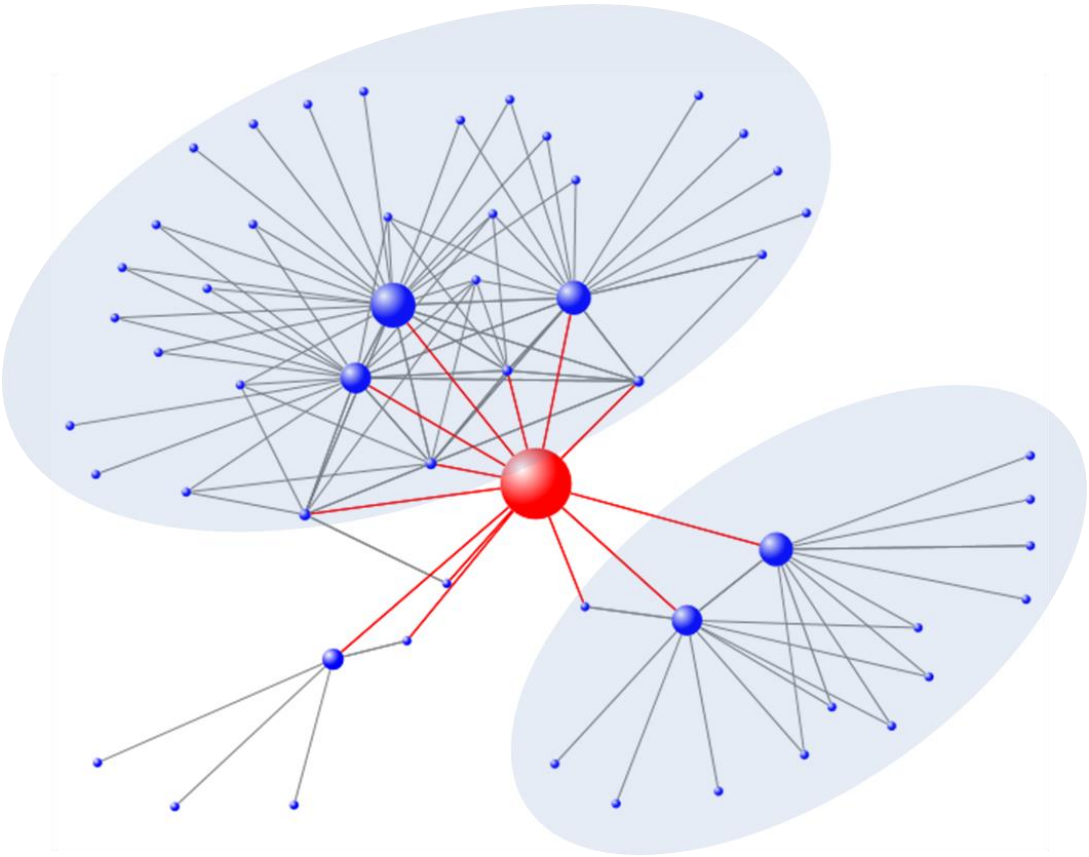
- Sportswear and Apparel company
- 1,211 inventions 1/2013 $\Rightarrow$ 12/2016
- 23 solo inventors removed
- 1,188 invention with two or more inventors
- 851 unique collaborators
- Color coded clusters reveal product line and geography effects
- 30 connected components from 2 to 771 inventors
- LCC 88% of inventor population
- Note bridgers



Insights from Organization Innovation Networks

- Network topography such as clustering and bridging are seen in all government, university and industry innovation networks
- Topology reveals the “trust network” in an organization
- Clustering can be driven by reporting structure, funding structure, product lines, geography, and even facilities structure
- The larger the largest connected component the easier knowledge propagates across the organization
- We have seen LCCs ranging from 9% to 95%
- Bridgers play a key role in knowledge propagation
- What are the organizational policy implications?

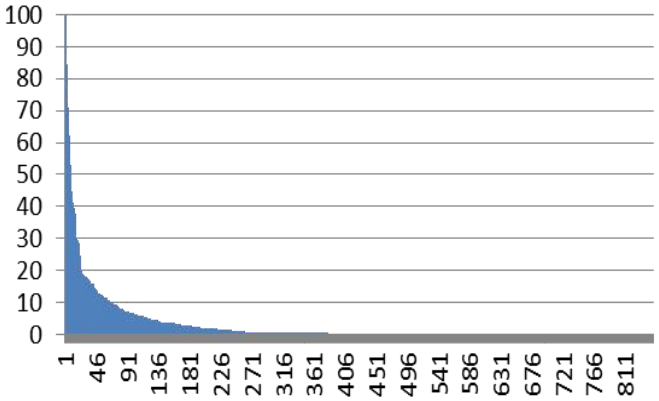
Importance of Trusted Bridgers



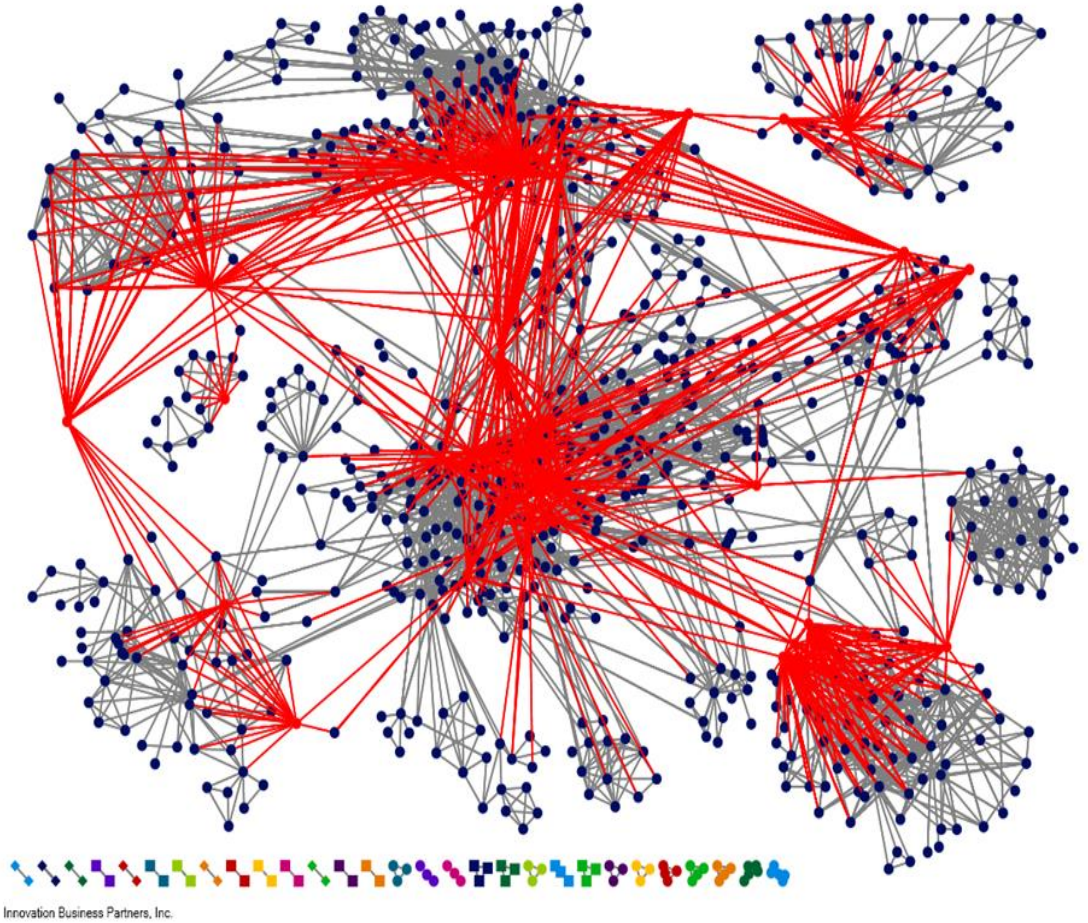
- Naval weapons development laboratory
- Two groups (ovals) located in two different buildings on the same base
- Upper blue oval is weapons systems designers
- Lower blue oval is energetic compositions of matter
- Inventor in red bridged the two groups for forty years
- No further collaborations seen after he retired
- With periodic network mapping, leadership could have seen the single point of network failure and trained a replacement

The Innovation Backbone™

Scaled Normalized Betweenness Centrality by Inventor



30 Inventors with the highest scaled NBC and their first-degree connections highlighted in red



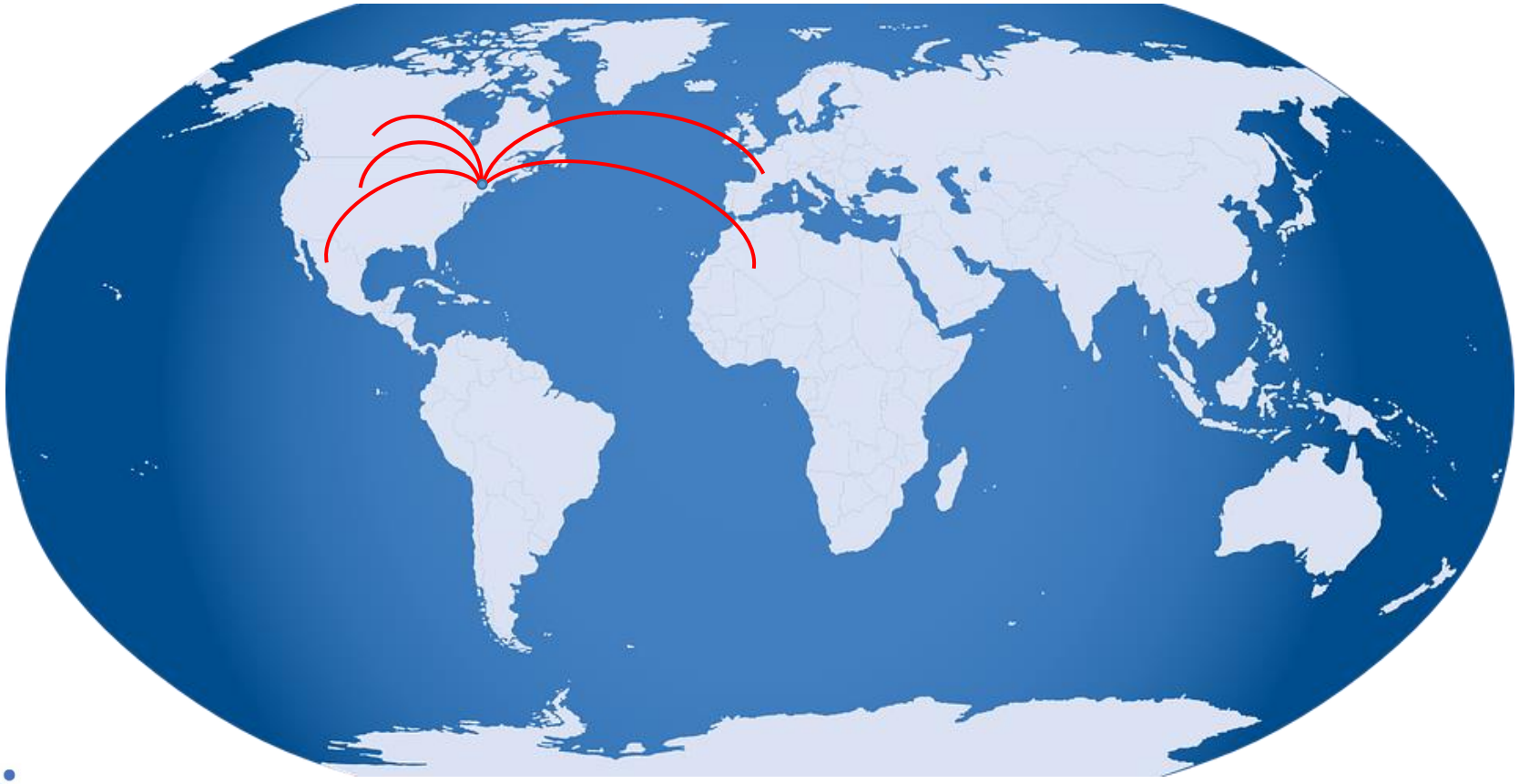
Importance of the Innovation Backbone™

- The Innovation Backbone™ has been present in every government, university, and industry organization we have examined
- Rule of thumb: 10% of the inventors own 90% of the NBC
- Interviewed 71 backbone inventors from 5 Navy labs revealing three types:
  - Deep subject matter expert
  - Owner of critical facilities
  - Internal entrepreneur
- Key resource for leadership to increase innovation
- Must maintain in companies targeted for attraction

Multinational Organizations Strong & Weak Links

Multinational Organizations

Large Multinational Organizations can provide the “weak links” to other clusters globally that introduce new or different knowledge and skills into the region



“Global connectivity and the evolution of industrial clusters: From tires to polymers in Northeast Ohio”, by Mudambi, Ram, et al, Industrial Marketing Management, 2016.

Strong and Weak Links in Networks

- In social networks strong links develop between people or organizations that interact frequently
- Clusters of strongly linked people or organizations tend to share common bodies of knowledge, skills, and beliefs – important for social trust
- Weak links connect two people or organizations that do not interact frequently
- Weak links, if trusted, can introduce new knowledge and skills that can fuel out-of-the-box innovations

Economic Development & Weak Links

- Most economic development efforts tend to target multinational organizations solely based on the number of jobs they can create, and attract them with neoclassical incentives that can be exceeded tomorrow by other regions
- An alternative is to consider how a region's collective intelligence can complement the collective intelligences of other regions the multinational organization is linked to, thus enhancing the organization's collective intelligence and producing a higher barrier to switching regions
- Networking key regions together produces a multiplicative effect for the multinational's and region's collective intelligence

Mapping Group Innovation Networks Dialogue and Triadic Closure

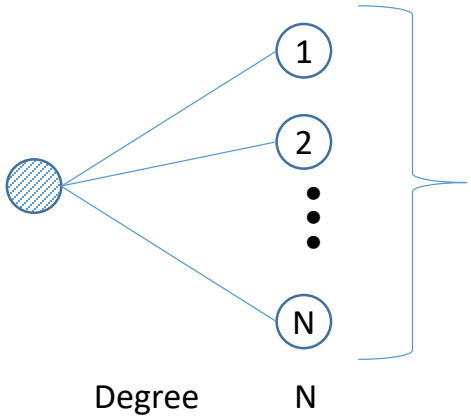
Group Innovation Networks

- Problem solving groups are the most basic form of collective intelligence
- Members of the group participate in tacit-explicit dialogues to build a basis set from which to solve a problem
- Studies by Pentland at MIT have shown that groups that engage all members in dialogue are more productive than groups dominated by an alpha-member*
- Following Reeds Law the productive groups have a greater collective intelligence

* "Social Physics: How Social Networks Can Make Us Smarter", by Alex Pentland, Penguin Books, 2014.

Groups and Triadic Closure

Personal Innovation Network for inventor in Class Code X, with Clustering Coefficient = 0



Opportunity exists for triadic closure for Group Innovation Networks of degree greater than or equal to 2. With full triadic closure the number of possible new Tacit-Explicit Dialogues between members of a Group Innovation Network, in Class Code X, of Degree N is:

$$2^{(N+1)} - (2N + 1) - 1$$

- Innovation Network mapping reveals incomplete triads
- "Blue" inventor will have a trust relationship with co-inventors 1-N
- Properly incentivized, "Blue" can use the established trust relationships to introduce inventors 1-N to each other and initiate tacit-explicit dialogues thus increasing the collective intelligence
- Also applies at regional inter-organization level – MD example

Mapping Individual Innovation Networks

Individual Innovation Networks

* "Peak: Secrets from the New Science of Expertise" by Anders Ericsson, Houghton Mifflin, 2016.

- An Individual's Innovation Network is the neural network that encodes each person's tacit knowledge
- The education system is a fundamental component of the regional innovation ecosystem that drives collective intelligence
- Weak links and exposure to new knowledge and skills is important
- Policies for education and expertise development* are critical to a region's success

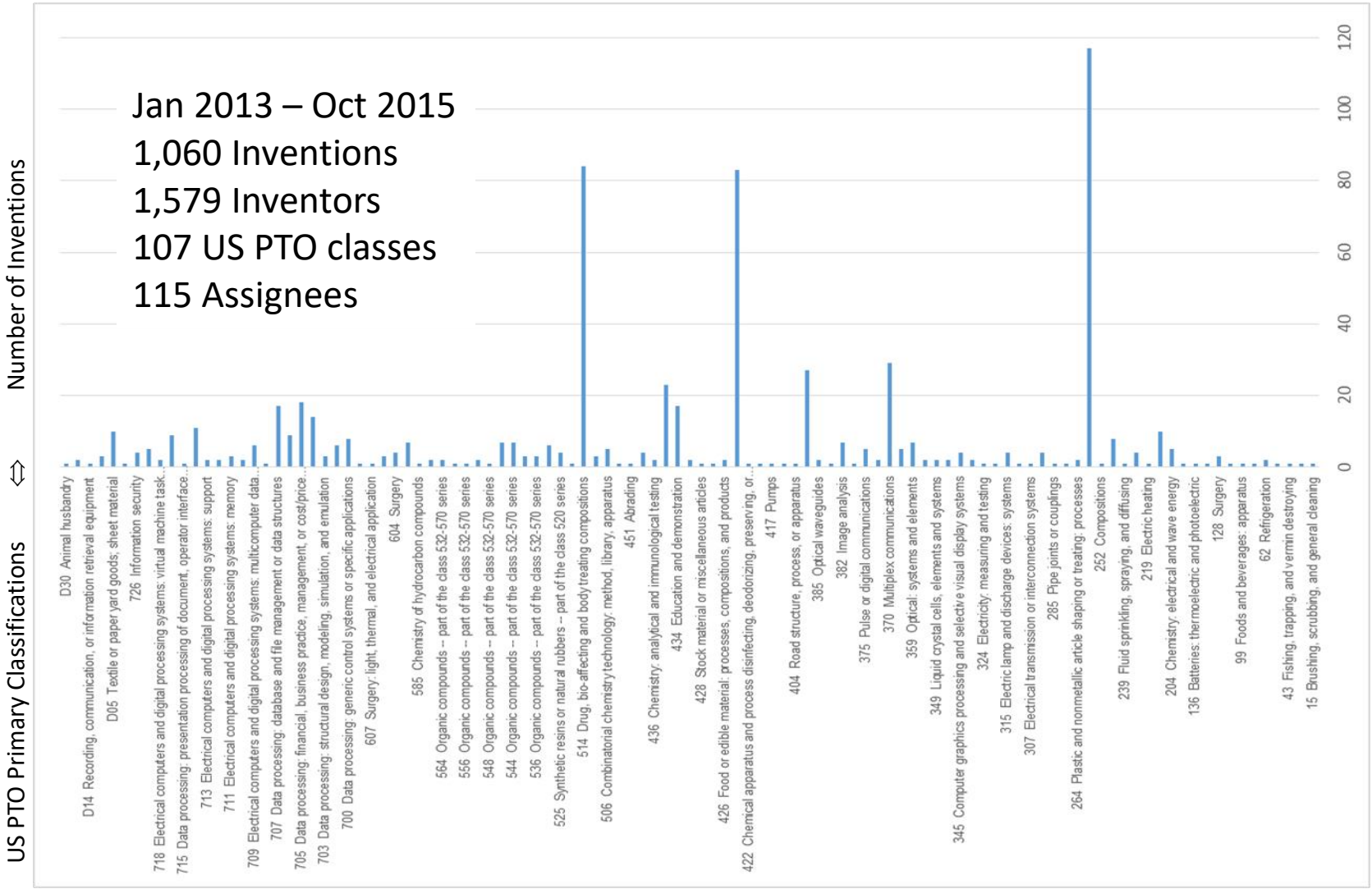
The Innovation Genotype™

The Innovation Genotype™

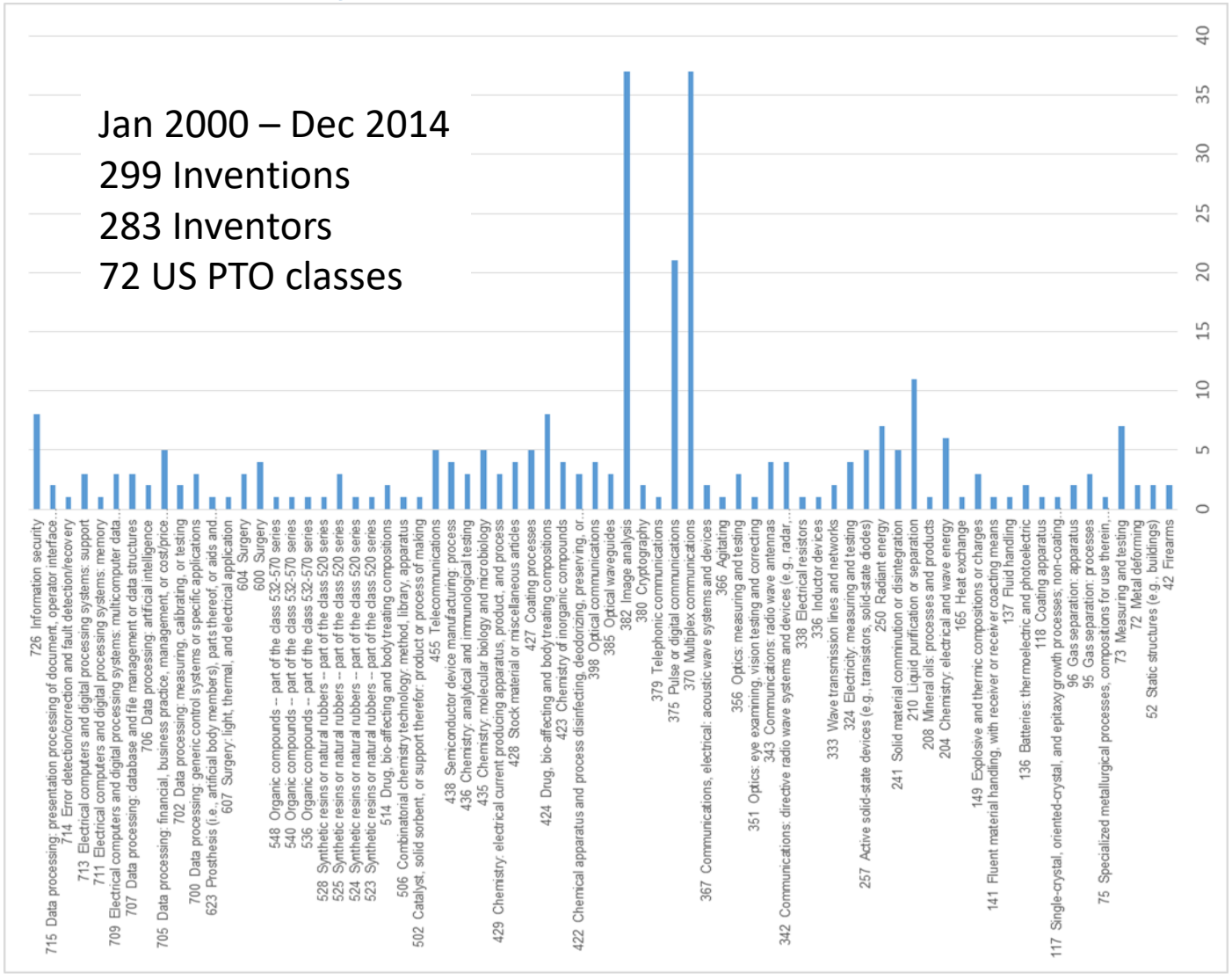
- Based on a biological metaphor
- Just as the genes in an animal's genotype express the proteins that constitute the organs, that in turn, determine an animal's ability to survive and thrive in its environment, so too, the inventors in an organization's Innovation Genotype™ express the inventions, that constitute the innovations, that in turn, determine an organization's ability to survive and thrive in the innovation economy.
- Comparative genotype analysis reveals opportunities for collaboration

The Regional Innovation Genotype™

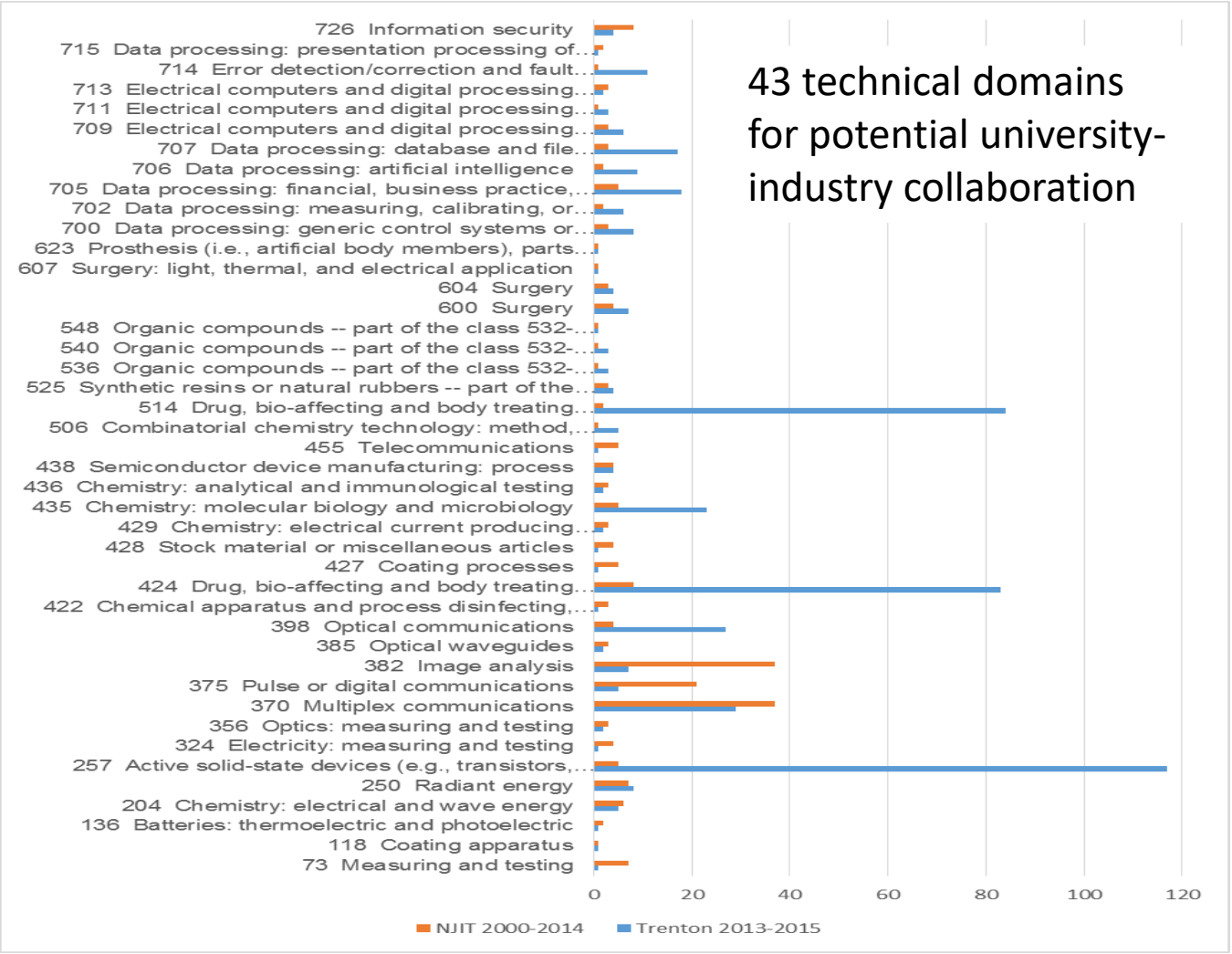
Greater Trenton Region – Industry



New Jersey Institute of Technology



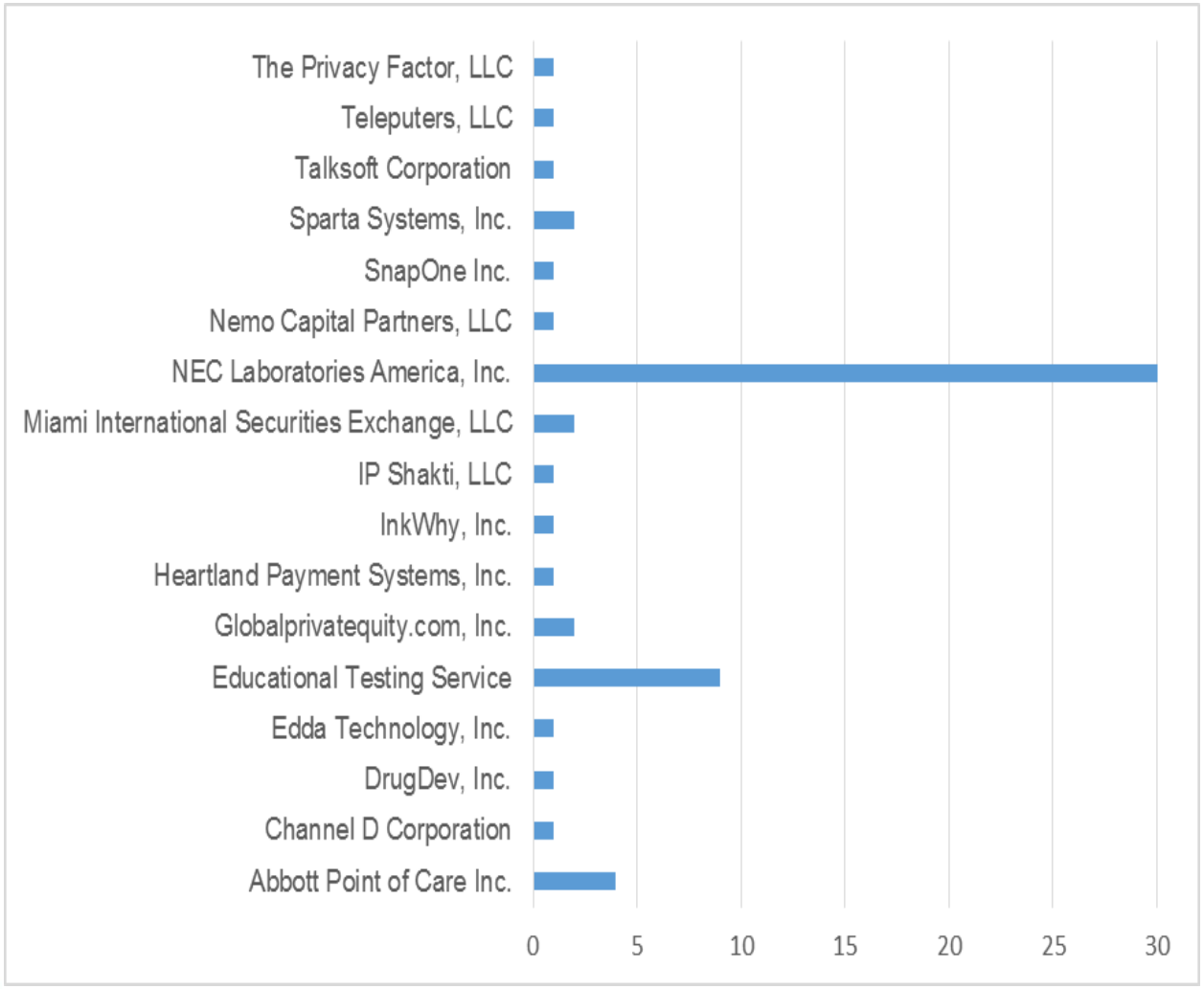
Intersection of GTR and NJIT



43 technical domains for potential university-industry collaboration

US PTO Primary Classifications ⇔ Number of Inventions

Targeting an Industrial Sector



- Certain industrial sectors may be key to the regional vision for their Innovation Economy
- Grouped data sector related US PTO classes, e.g. 700, 702, 705, 706, 707, 715, and 726
- Identify Greater Trenton Region companies inventing in that industrial sector as prime candidates for group collaboration with NJIT
- Candidates for regional risk pooling and common platform innovation

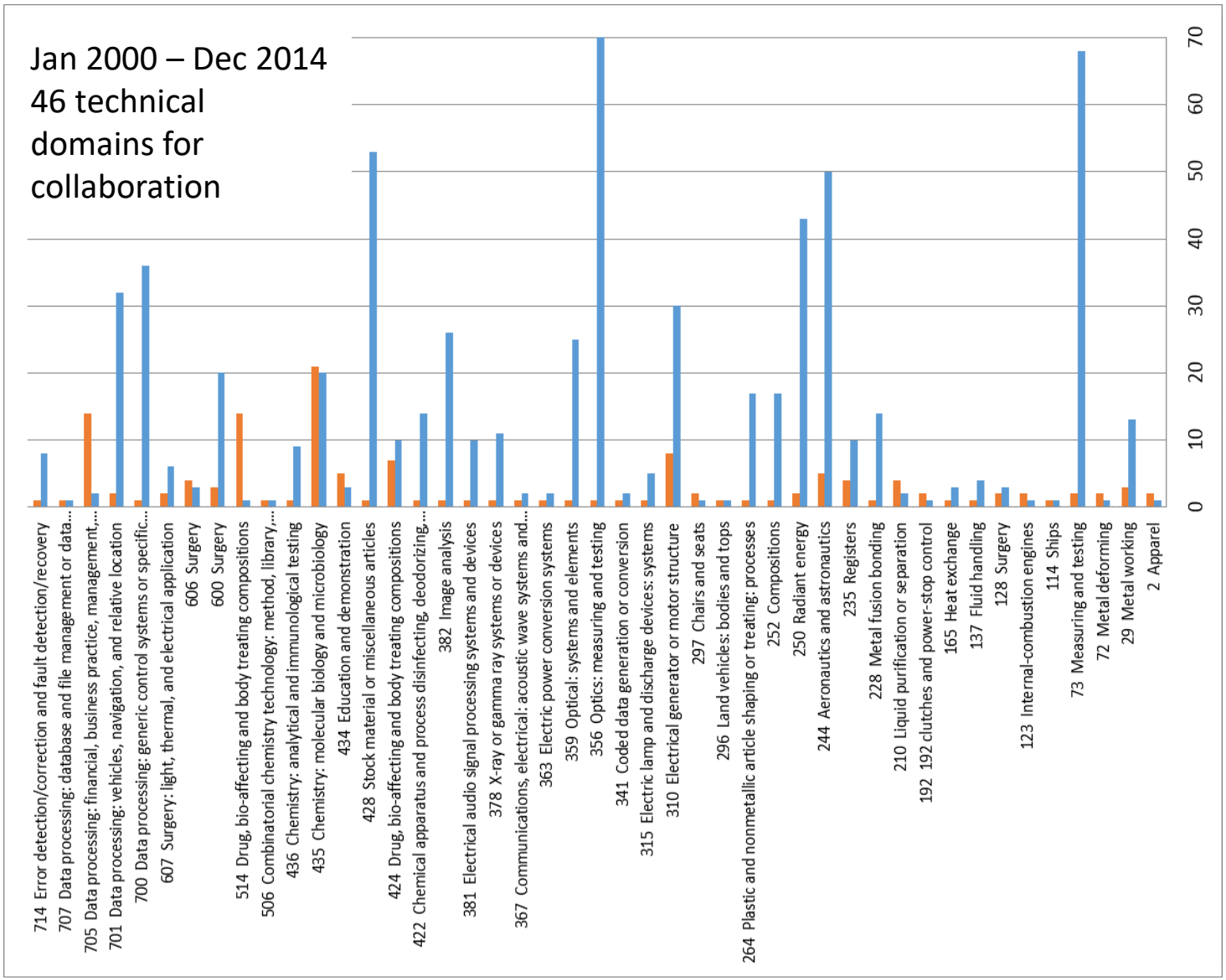
Serendipity as a Service*

- Bring people together based on their similarities
  - Similarities engender trust
- Innovate based on their differences
  - Differences challenge mental models
- Greater Trenton Region Data Sector Example
  - Similarity – All of the inventors understand data technology
  - Differences – Each inventor brings a different mental model for the use of data from their individual market segments that span software, to finance, training, pharmaceuticals and healthcare.
  - Opportunities for noncompetitive risk pooling and common platform innovations

* Krebs, Valdis, "BIF 8: Getting Technology and Sociology to Match", the Business Innovation Factory.

Collaboration with Federal Laboratories

Intersection of NASA and Norfolk Private Sector



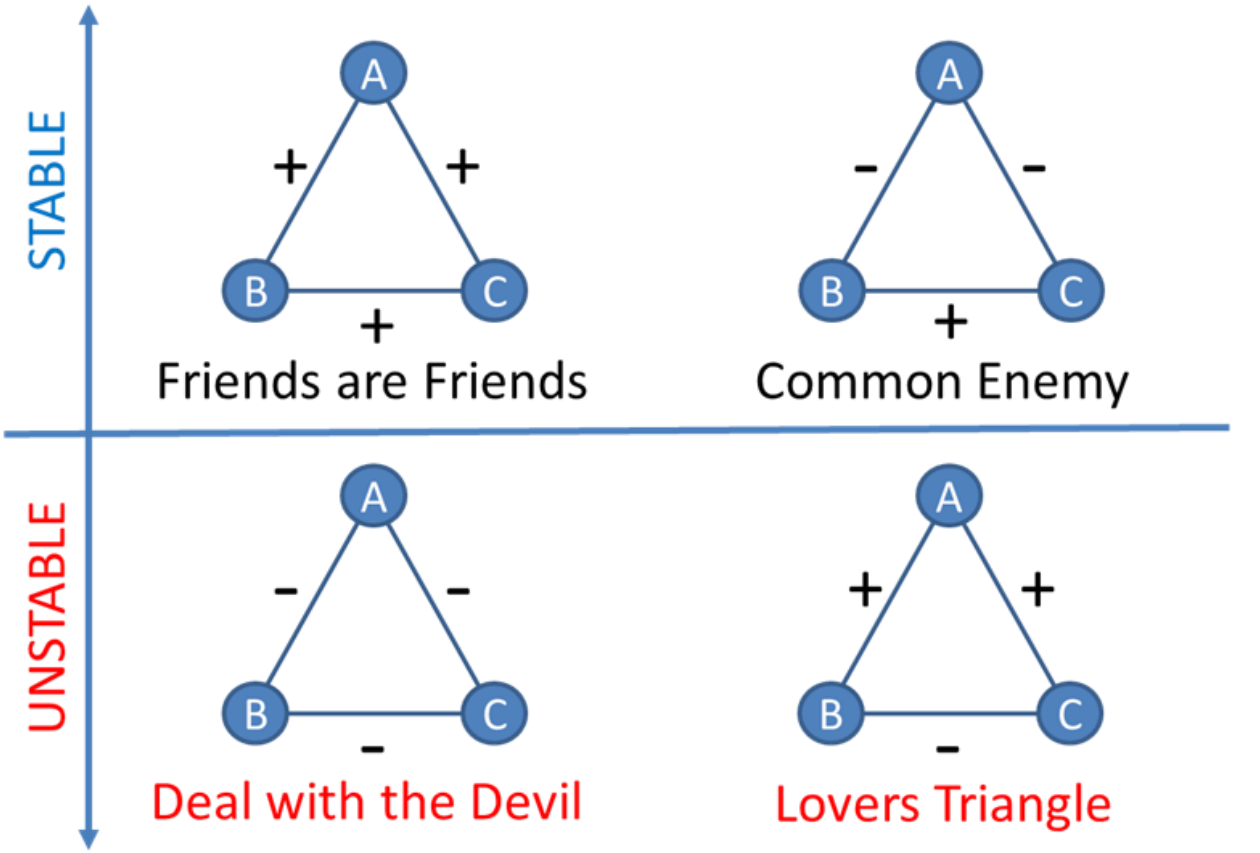
Genetic Engineering, Attractions, Mergers, and Acquisitions

Uses of the Innovation Genotype™

- Regional Genetic Engineering – Compare current genotype to desired future regional genotype and construct an economic development plan to achieve it
- Attraction – Given the desired future genotype scour the globe for candidates that match portions of the desired genotype and consider them candidates for attraction
- Organization Genetic Engineering – Identify desired emerging markets/technologies and required genes
- M&A – Identify target companies with desired genes for merger or acquisitions
- Identify Universities and Federal Labs with desired genes for collaboration or candidate hires

Triadic Policy Analysis

The Four Triadic Configurations



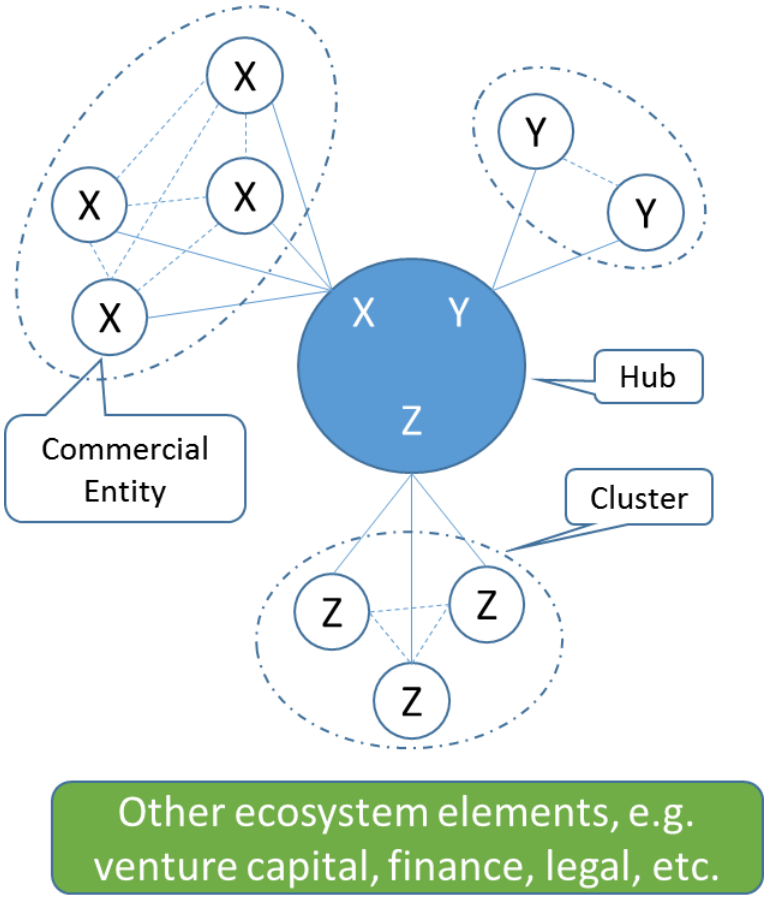
Unintended Consequences

- Well intended policies can produce negative unintended consequences that can degrade an organization's capacity for innovation
  - Block funding versus Working Capital Fund
  - Naval Innovative Science and Engineering funding
  - Different colors of money
  - NRL Institute of Nanoscience
  - Post Watson IBM*

* "Managed by the Markets: How Finance Re-Shaped America" by Gerald F. Davis, Oxford University Press, 2009.

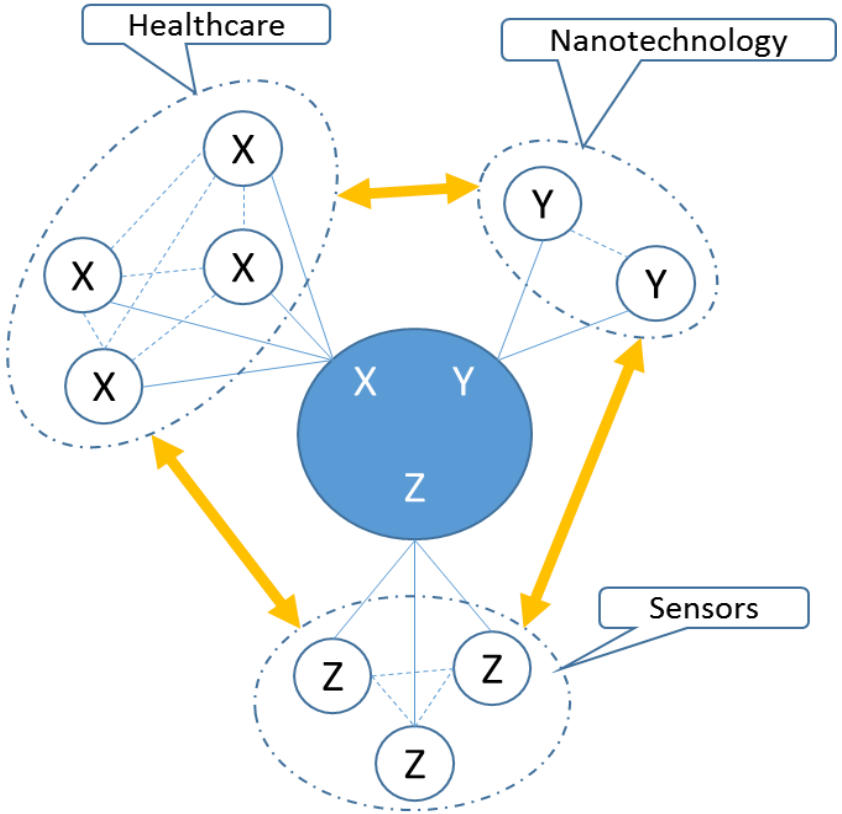
Regional Mechanisms for Economic Growth

Collective Intelligence Clusters



- Connecting intelligent people based on similarities and innovating based upon differences
- Hub provides neutral ground with expertise in X, Y, and Z
- Informal to formal structure
- From risk pooling to client specific R&D
- Generation and transfer of knowledge and skills

Innovations at the Intersections



Other ecosystem elements, e.g. venture capital, finance, legal, etc.

- Hub is in a unique position to see the opportunities for innovation at the intersection of multiple domains (X, Y, Z)
- Increases probability of generating radical or disruptive innovations in the region served by the Hub – growth and prosperity

Meta-Ideas

- A normal idea addresses a need by producing a new functional capability with desirable attributes obtained by a combination of elements and relationships, which if novel, nonobvious, and useful is patentable:

$$I(N) = f_a(E,R)_{nnu}$$

- A meta-idea is an idea that helps to generate and propagate new ideas*
- Romer believes the nations that capture meta-ideas will be the winners in the innovation economy
- Examples of meta-ideas are dense urban cities, venture capital, and allowing market forces to guide decisions – collective intelligence

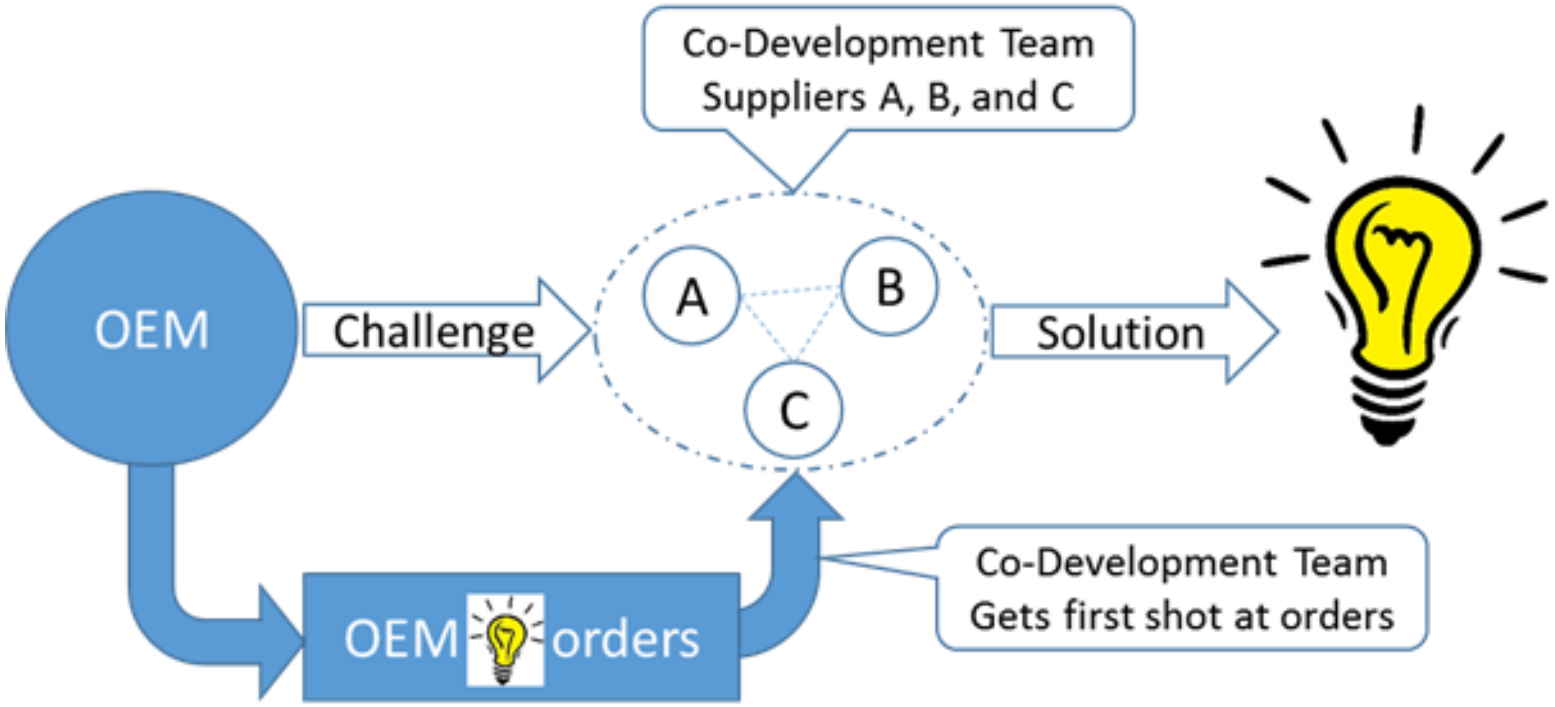
"Economic Growth" by Paul Romer, Liberty Fund, Inc., 2008.

Insight Driven Innovation™

- IDI Front End
  - Focusing on the Right Problem
  - Designing Quality into your Innovation Process
- IDI Back End
  - Solving the problem the Right Way
  - Leveraging the World's Knowledge Networks
- Navy Pilot
  - 4 teams, 4 problems, 10 weeks, 3 hours per week
  - Navy estimated 2 years & $10 million of R&D saved
  - Patent applications 50x site average
  - Increased morale

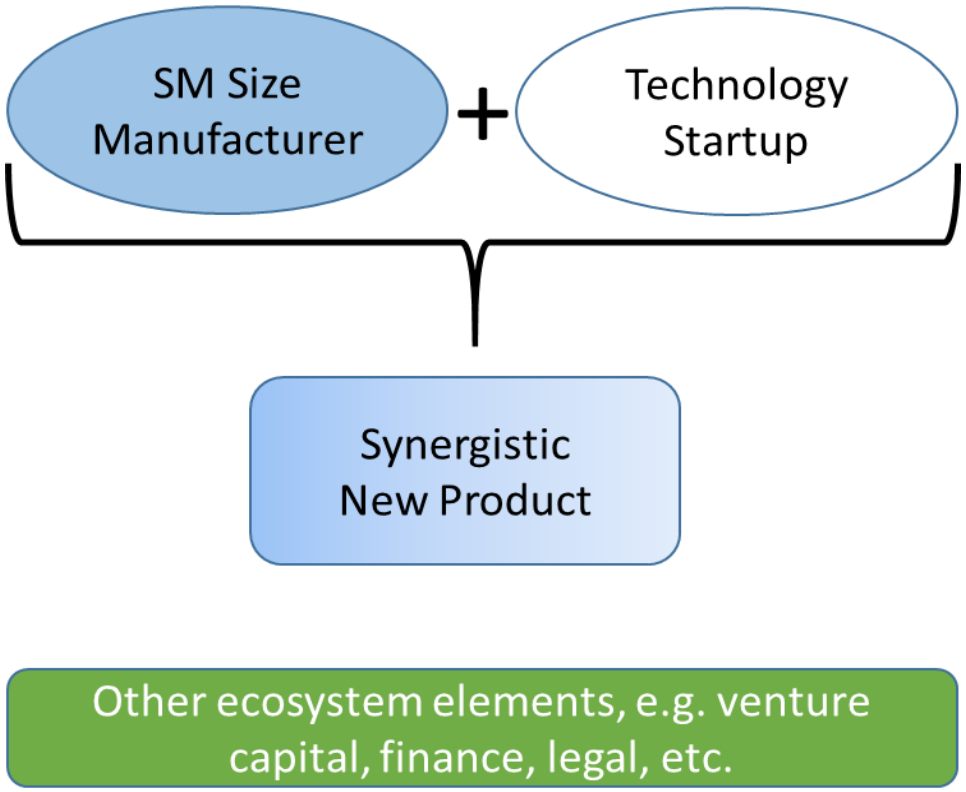
"Bridging Small Worlds to Accelerate Innovation", by Markovits, et al, Defense AT&L: September-October 2005.

Co-Development Teams



"Nike's Extended Co-Development Network", Featured Practice of the Corporate Executive Board, 2003.

Technology Enhanced Manufacturing



- Leverage the different strengths of regional small to medium size manufacturers and technology startups
- Allows different relationships from collaboration, to joint product, to formal merger
- An SME could have relationships with multiple Startups
- A Startup could have relationships with multiple SMEs

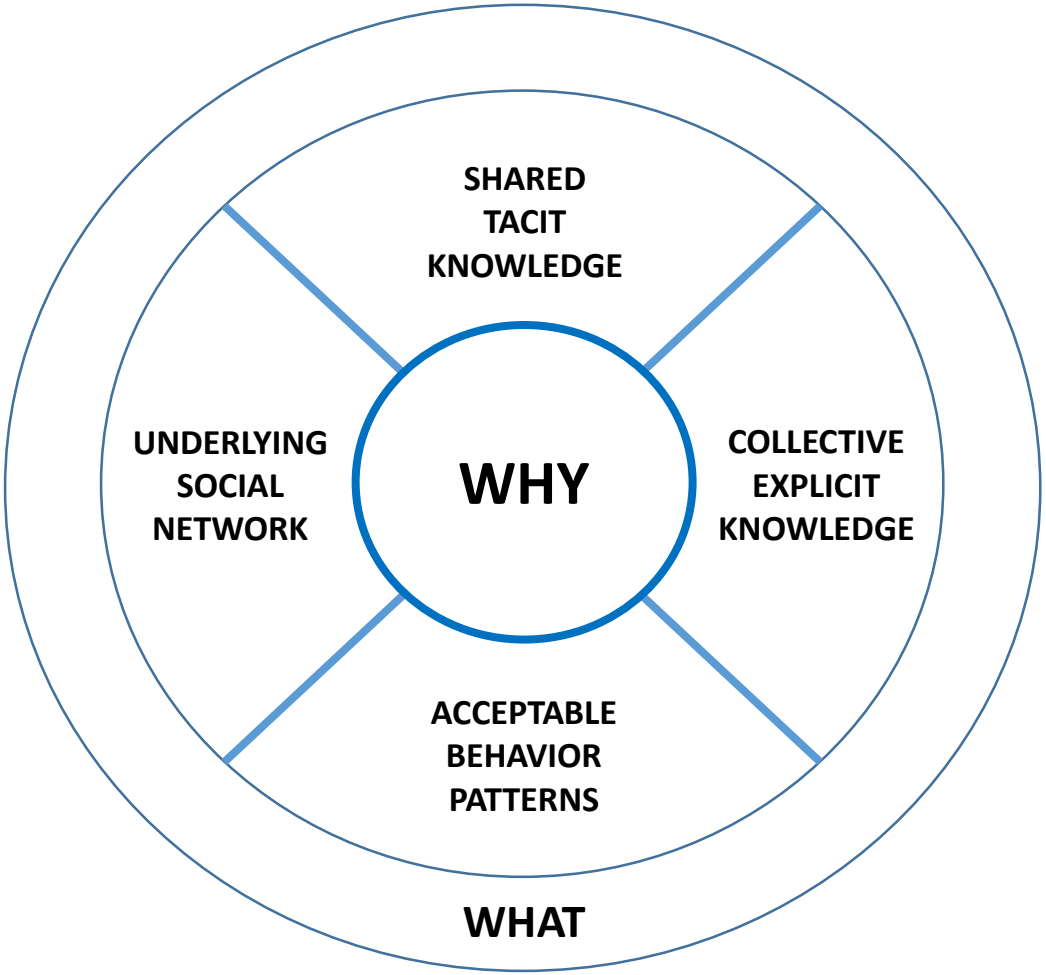
Measuring Innovation

Gen 1: 1950s-60s	Gen 2: 1970s-80s	Gen 3: 1990s	Gen 4: 2000+
R&D Expenditure	Patents	Surveys	Intangibles
S&T Personnel	Publications	Indexing	Networks
Capital	Products	Benchmarks	System Dynamics
Tech Intensity	Quality Change		Knowledge
			Demand
			Clusters
			Mgmt Techniques
			Risk/Return

- Generations are cumulative
- Innovation Network Mapping and Genotype Analysis provide critical data for 4th generation

Creating a Culture of Innovation

The power of organizational culture lies in its ability to create a collective intelligence that can acquire and apply knowledge and skills at a rate that far exceeds that of the individual.



The collective intelligence of an organization arises from its shared tacit knowledge, collective explicit knowledge, and the acceptable behavior patterns that determine the structure of its underlying social network.

Conclusions

- It is our collective human intelligence that enables us to survive and thrive in the global innovation economy
- We need policies and programs that promote and facilitate the tacit-explicit dialogue between government, universities, and industry
- We need a coherent body of policies and programs at the regional, organization, group and individual levels
- Network science, Innovation Network Mapping, and Genotype Analysis can provide insights into designing policies with more positive effects and less unintended negative consequences
- Our ultimate goal should be to create a national culture of innovation

The GUIRR Opportunity – Offer

- GUIRR provides a forum like no other
- Its membership represents a formidable collective intelligence from government, academia, and industry
- GUIRR can be the National Collective Intelligence Cluster
- The opportunity, and challenge for GUIRR is to lead the nation in developing and implementing the policies and programs that will create a national collective intelligence to ensure our security and prosperity
- To facilitate tackling this challenge Innovation Business Partners is offering a limited number of free Innovation Genotype analyses to GUIRR members – ideally a collection of GUIRR members with the potential to form a national Collective Intelligence Center