

---

# “Development of Functional Nanostructures for the Conversion of Thermal to Electrical Energy”

Dana W. Clarke, Sr.,  
Applied Innovation Alliance, LLC

---

Dr. Gafur Zainiev,  
Fluid Insights, LLC

# Objective / Approach

---

- Objective: Accelerate the development and optimization of thermal-to-electric generators (TEGs)
- Approach: Develop a technological system, Industrial-Scale MicroReactor™, capable of conducting high-throughput screening with immediate transition to production
- Our team:
  - PhDs in Chemistry / Chemical Processes / Cell Biology
  - Masters in Physics
  - 8 experts in Structured Innovation; including 5 experts in TRIZ, The Theory of Inventive Problem Solving
  - Experts in design of experiments, mathematics, computer science, mechanical engineering, alternative energy, electronics

# Keys to Realization of High TEG efficiency

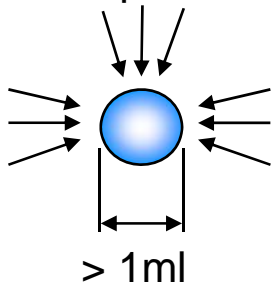
- Highly accelerated discovery, development and optimization challenges
  1. Rapid innovation and problem resolution via the use of structured approaches to innovation
  2. Automated self-assembly and measurement of micro-droplets containing chemical reactions
  3. Smooth transition to high production

## Structured Innovation

- The abstraction of knowledge from the human experience and structuring of that knowledge for efficient and effective use

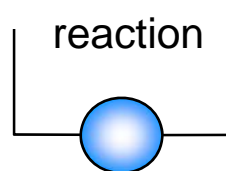
**Methods / Tools / Techniques:**  
Ideality, contradictions, resources, resource profiling, integration of innovation / mathematics, evolutionary sequencing, evolution of systems, inventive strategies, et al

Injection of chemicals / nanoparticles



Spherical micro-droplet, an Ideal system for chemical reaction

Thermal, electrical, magnetic and/or electromagnetic measurement probes for evaluation of results of chemical reaction



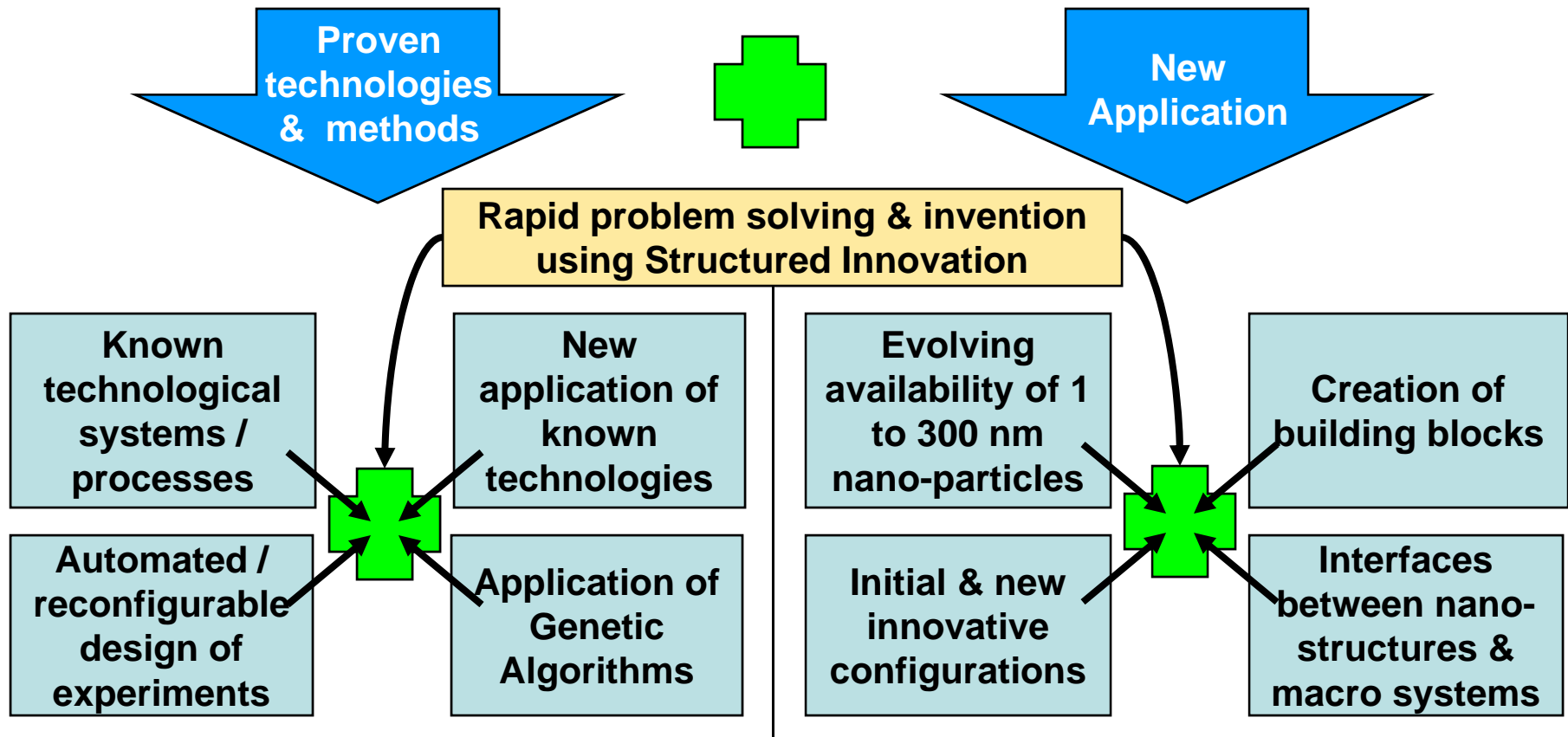
## Applied Innovation Alliance

# Industrial-Scale MicroReactor™ & TEG

## Invention with the intent of commercialization

Industrial-Scale MicroReactor™

Direct conversion of thermal-to-electric



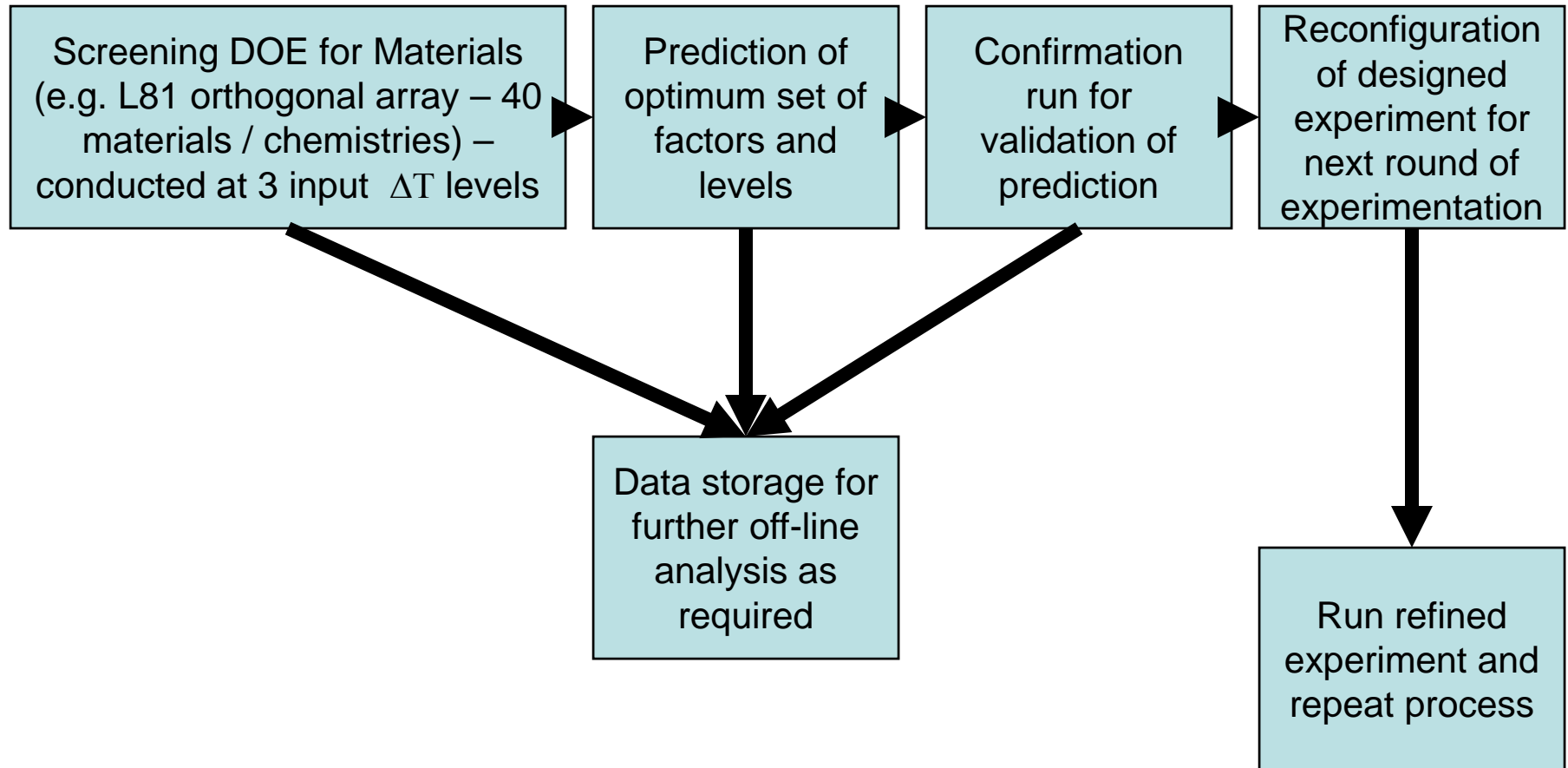
Applied Innovation Alliance

# Materials / Configurations Optimization

---

- Reconfigurable designed experiments (DOEs)
  - Inputs: initial discoveries by reputable labs, researchers and organizations plus in-depth research
  - Broadening on early findings to expand on discoveries
    - Ability to combine numerous different chemistries and types of nano-particles
  - Drilling toward new levels of optimization
    1. Experimentation and prediction of optimum
    2. Confirmation runs
    3. Reconfiguration of experiments
      - Repetition of 1, 2, 3 for continued optimization
- Utilization of Genetic Algorithms
  - Supports optimization of formula variables and tolerances
  - Proprietary Genetic Algorithm and Design of Experiments optimization processes
  - Development and optimization of new formulas using resource profiling and empirical data

# Automated Reconfigurable Designed Experiments



# Scalability: Lab Success-to-Production

---

## Invention with the intent of commercialization

- Industrial-Scale MicroReactor™
  - Discovery and production with the same system
  - Immediate transition from discovery to production

Performing the functionality of a research lab using a high-speed automated system

# References (paper & poster presentation)

---

1. G.S. Nolas, J. Sharp, H.J. Goldsmid, Thermoelectrics- Basic Principles and New Materials Developments, Springer, NY 2001
2. D.M. Rowe, Thermoelectric Handbook from Macro to Nano, CRC, NY 2005
3. Safa Kasap, Thermoelectric Effects in Metals: Thermocouples, CA 2001
4. J.M.O. Zide, D. Vashaee, "Demonstration of Electron Filtering to Increase the Seebeck Coefficient in  $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}/\text{In}_{0.53}\text{Al}_{0.28}\text{As}_{0.19}$  Superlattices," 2006
5. Till Huesgen, "Design and Fabrication of MEMS Thermoelectric Generators with High Temperature Efficiency," Sensors and Actuators, Vols. 145-146, Jul.-Aug. 2008
6. M. S. Dresselhaus, "Nanostructures and Energy Conversion," Rohsenow Symposium on Future Trends in Heat Transfer," 16 May 2003
7. Feng Xiao, "Recent Progress in Electrodeposition of Thermoelectric Thin Films and Nanostructures," Electrochimica Acta, Vol. 53, Issue 28, Nov 2008
8. Jianhua Zhou, "Quantum Confinement Effects on Thermoelectric Nanowires" 2008
9. Gehong Zeng, "Power Generator Modules of Segmented  $\text{Bi}_2\text{Te}_3$  and  $\text{ErAs}:(\text{InGaAs})_{1-x}(\text{InAlAs})_x$ ," Journal of Electronic Materials 2001
10. Thomas A. Keim, Ivan Celanovic, "Direct Conversion of Heat to Electricity," – Convergence Transportation Electronics Association 2008