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**Rockwell
Automation**



Magnetic Refrigeration Applied to Electronic Systems

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Advisor: Dr. Lili Dong

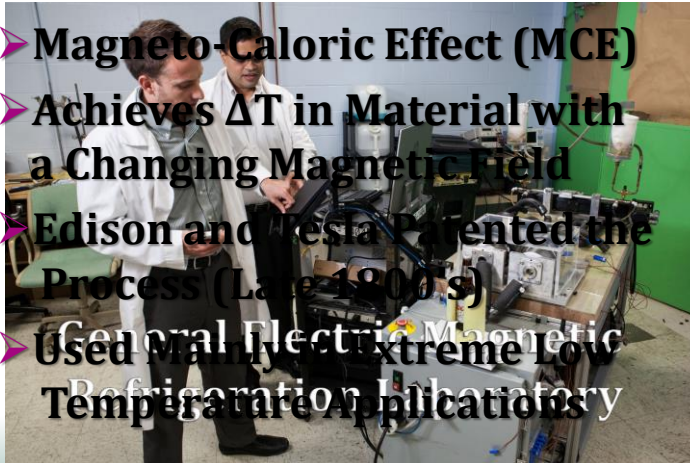
Sponsor: Rockwell Automation
Fred M. Discenzo, Ph.D.
Manager, R&D, Advanced Technology



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What is Magnetic Cooling ?

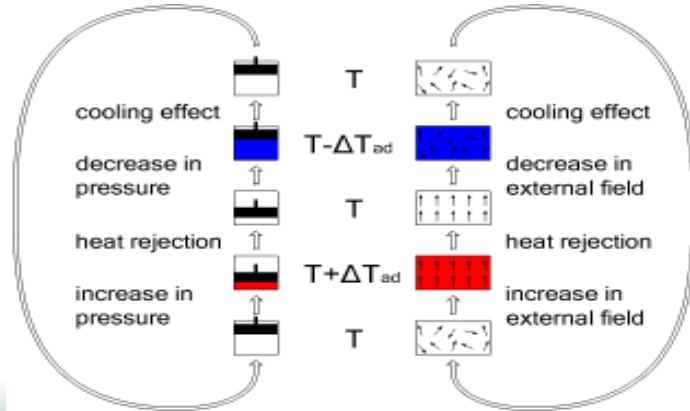
- **Magneto-Caloric Effect (MCE)**
- **Achieves ΔT in Material with a Changing Magnetic Field**
- **Edison and Tesla Patented the Process (Late 1800's)**
- **Used Mainly for Extreme Low Temperature Applications**





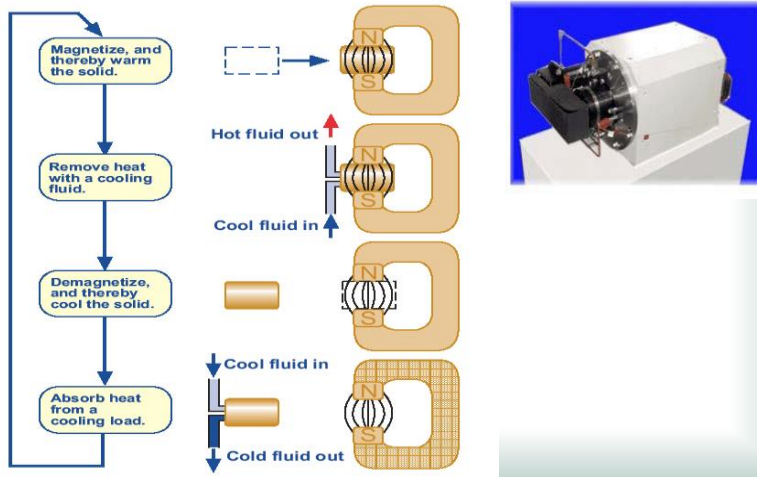
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Conventional Liquid / Vapor Coolant vs. Magneto-Caloric Solid Materials



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Magnetic Refrigerator Operation





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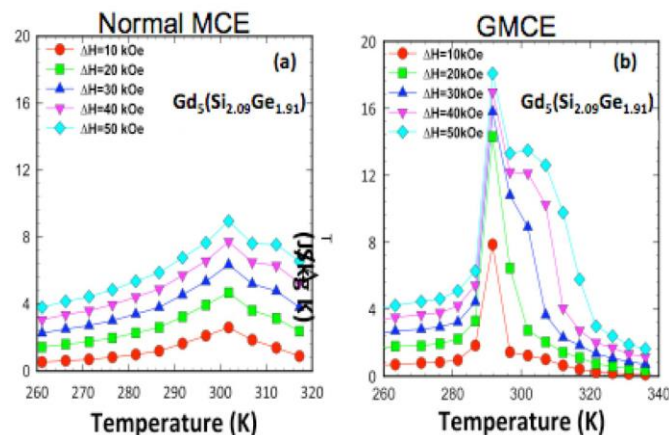
Why Magnetic Cooling ?

- ▶ Material Science Advances
 - New Gadolinium (Gd) Alloys
 - Improved Rare Earth Magnets
- ▶ Engineered Materials - *GIANT* MCE at Room Temps (GMCE)
- ▶ Higher Efficiency 75% vs. 60%
- ▶ Environmentally Friendly
 - Replace Harmful CFCs / HFCs



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Material Science Advancements AMES Lab Material Data

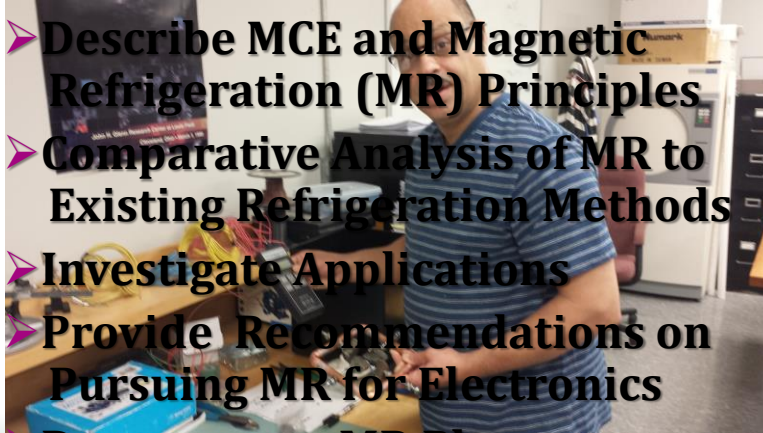




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Project Scope - Deliverables

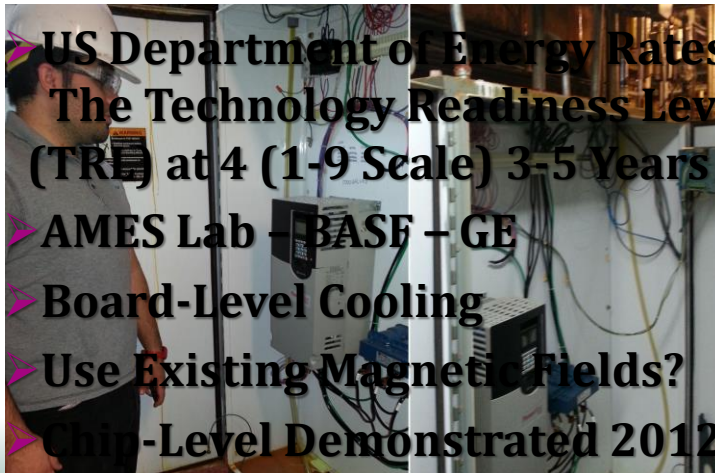
- Describe MCE and Magnetic Refrigeration (MR) Principles
- Comparative Analysis of MR to Existing Refrigeration Methods
- Investigate Applications
- Provide Recommendations on Pursuing MR for Electronics
- Demonstrate MR Phenomenon



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Market Potential

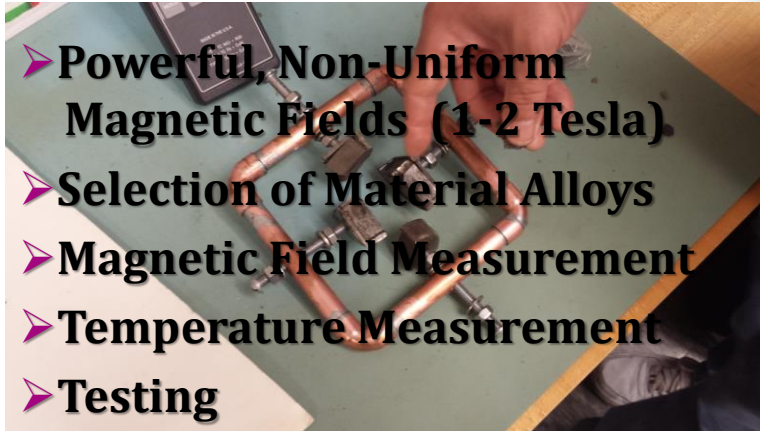
- US Department of Energy Rates The Technology Readiness Level (TRL) at 4 (1-9 Scale) 3-5 Years
- AMES Lab - BASF - GE
- Board-Level Cooling
- Use Existing Magnetic Fields?
- Chip-Level Demonstrated 2012





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Challenges



- **Powerful, Non-Uniform Magnetic Fields (1-2 Tesla)**
- **Selection of Material Alloys**
- **Magnetic Field Measurement**
- **Temperature Measurement**
- **Testing**



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Timeline

<u>TARGET</u>	<u>TASK</u>
11/2015	Research and Literature Review
12/2015	Conduct Experiments to Demonstrate Magnetic Refrigeration Phenomenon
02/2016	Correlate Strength of Magnetic Field to the Material Temperature Change
04/2016	Comparative Analysis of Magnetic Cooling vs. Existing Cooling Techniques
05/2016	Senior Design Presentation - Final Report