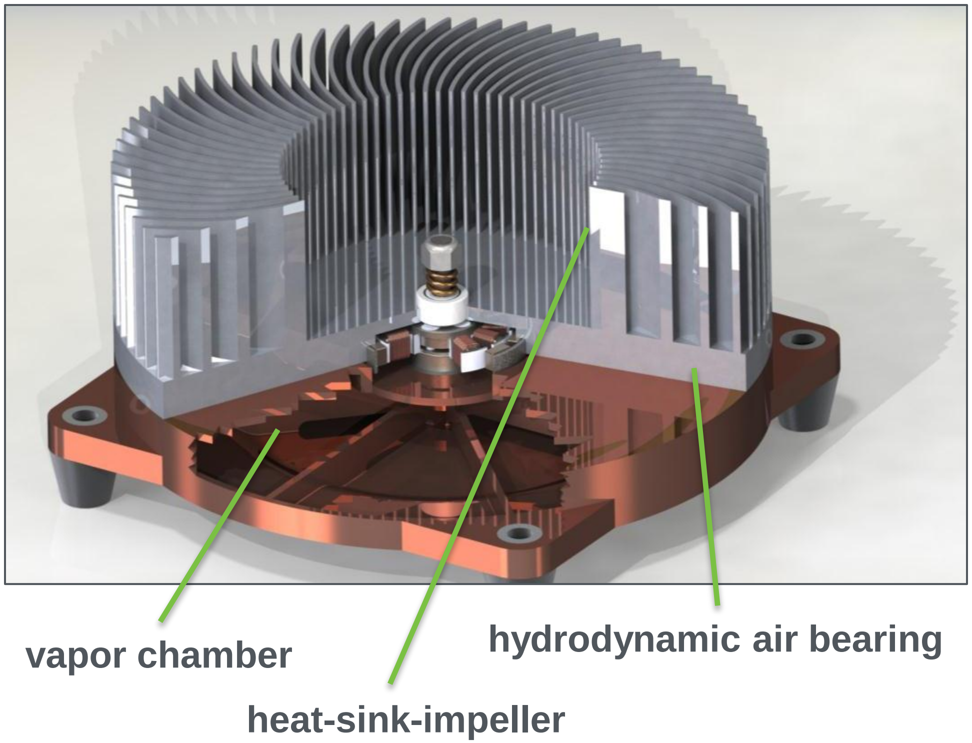
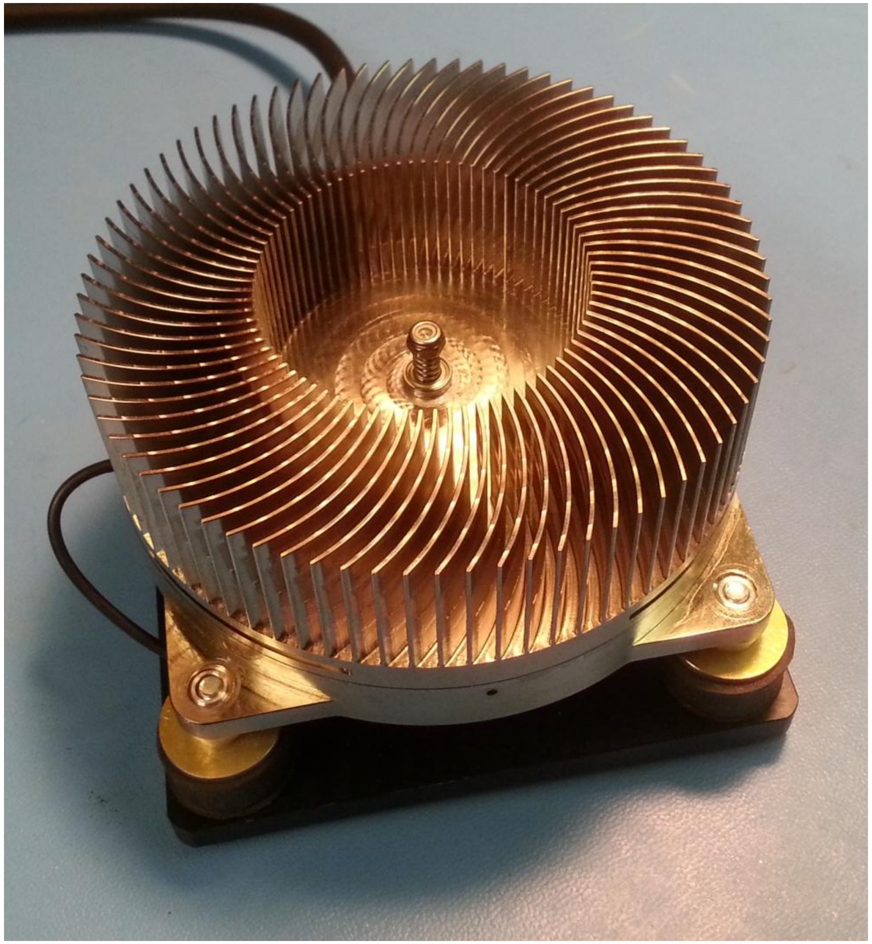
Sandia's Radial Flow Air Bearing Heat Exchanger

2014 Building Technologies Office Peer Review

Sandia's TRL 5 Air Bearing Heat exchanger technology (a. k. a. The Sandia Cooler)





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Sandia National Laboratories

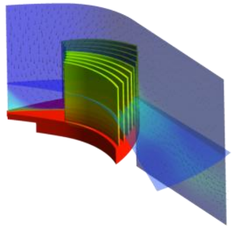
Project Summary

Timeline:

Start date: 2/2/2010

Planned end date: TBD

Key Milestones

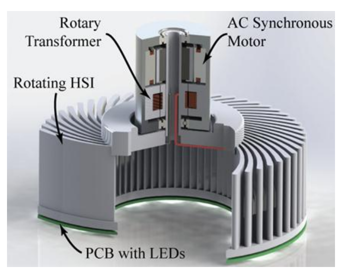


1. Mature Sandia Cooler to a TRL 5 technology platform suitable for refrigerators, LED lighting, and appliances, and fabricate 10 demo units for industry; 6/30/2014
2. End use application of the radial flow Sandia Cooler in a refrigerator condenser; 6/30/2014
3. Develop highly scalable device architecture suitable for building HVAC applications (RVCC); 9/30/2014

Budget:

Total DOE $ to date: $5,472k

Total future DOE $: TBD



Target Market/Audience:

Target markets in the energy sector include air conditioning, heat pumps, refrigeration, appliances and LED lighting. Target audience: high-volume manufacturers of such devices.

Key Partners:

DOE	Tribologix
UTRC	University of MD
Oak Ridge Nat Lab	Trane
Whirlpool/ Aavid Thermalloy	Optimized Thermal Systems

Project Goal:

Development of the radial flow Sandia Cooler to TRL 5 for (1) immediate applications in refrigerators, thermoelectric heat pumps, and LED lighting, (2) transfer of this new disruptive technology to industry (via TRL 5 demo units loaned from Sandia), and (3) development of a highly scalable device architecture for building HVAC.

The role of Sandia Org. 8366 is to invent breakthrough technologies for the energy sector, prove their viability and practicality at TRL 5, and then hand them off to industry.

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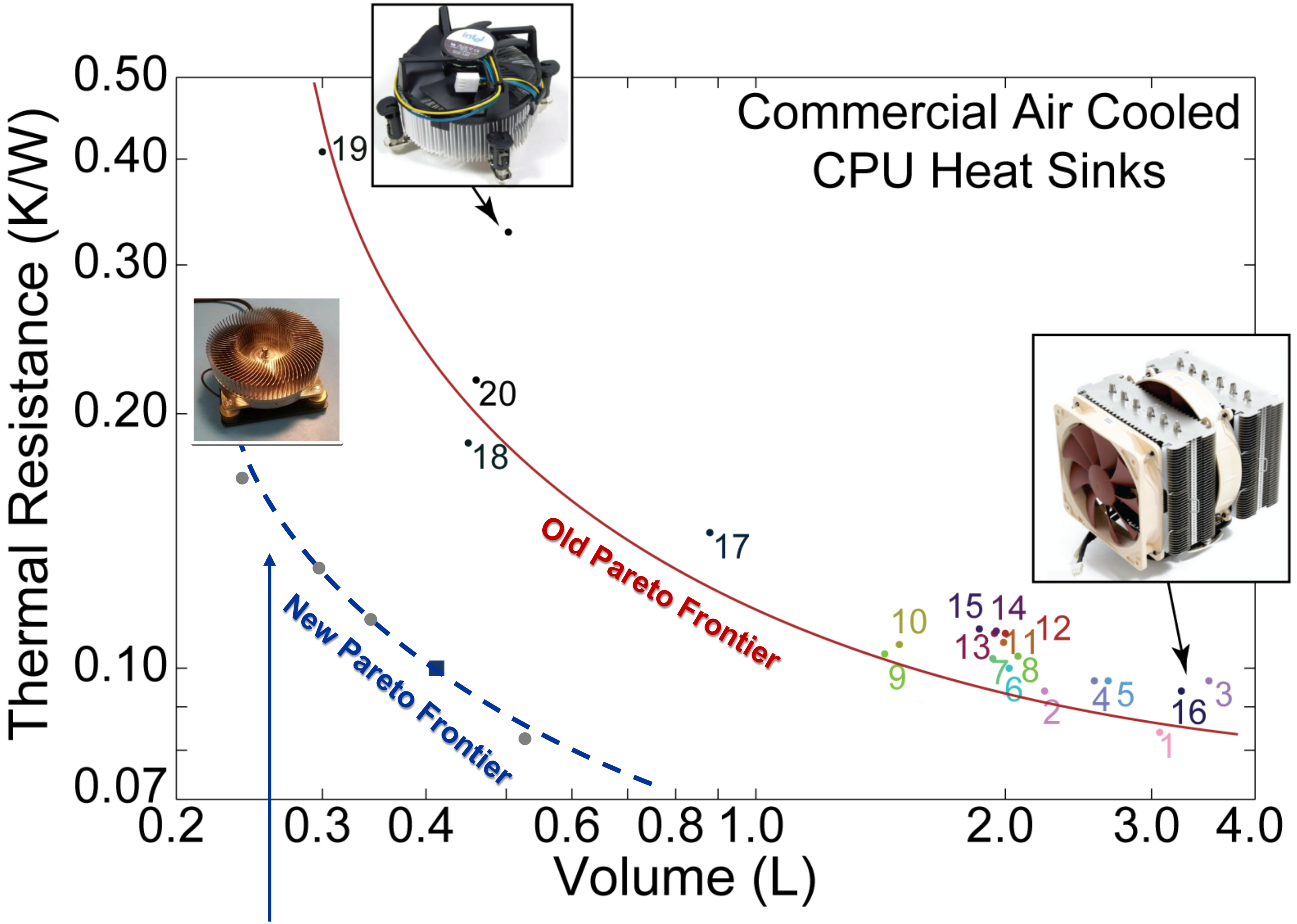
Crossing over to a new Pareto Frontier curve



Our role is to devise the next better idea and convincingly demonstrate its feasibility.
The private sector can now explore this new Pareto Frontier.
The private sector can take this new technology down the price/performance learning curve.

Purpose and Objectives

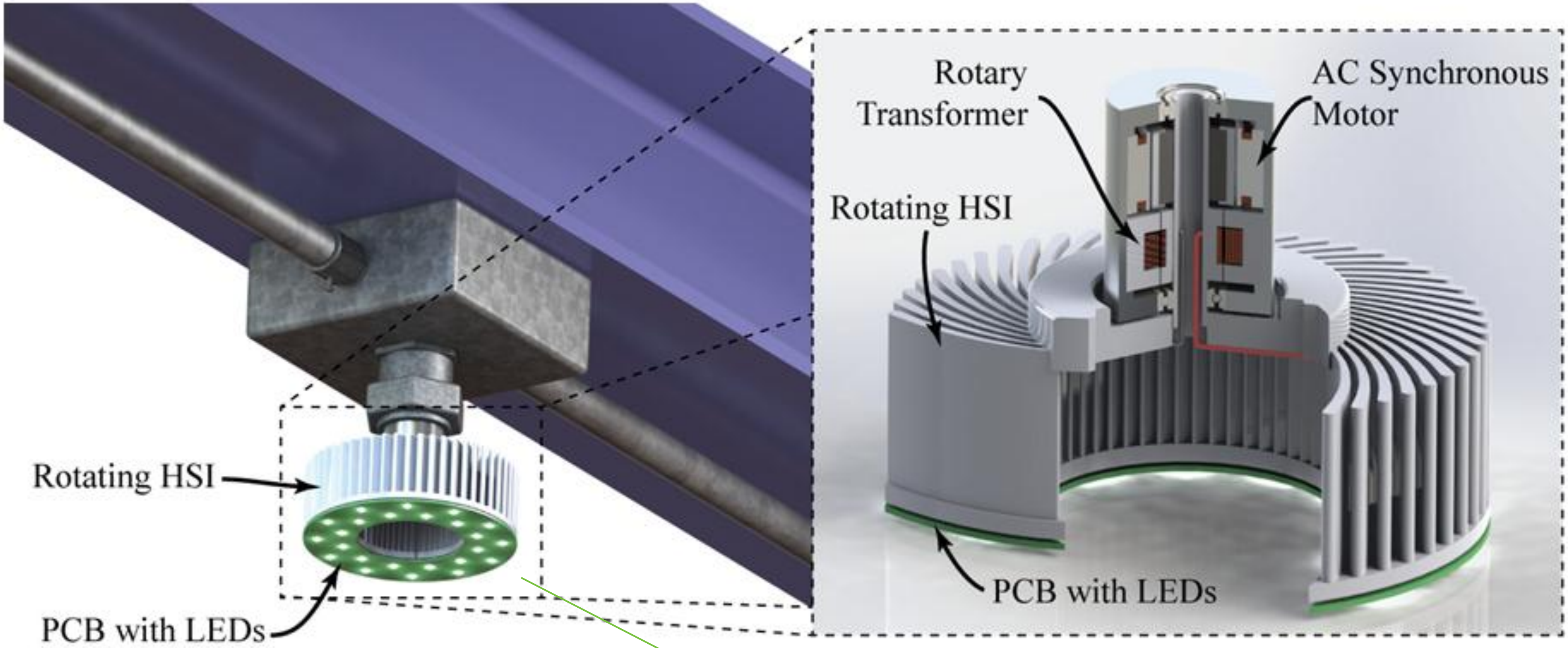
Problem Statement: *Questions* -- How well will this radically different heat exchanger technology perform? Can it be manufactured in high volume at low cost? How big an impact will it make in short term applications? How can the same principles be scaled up to address building HVAC?

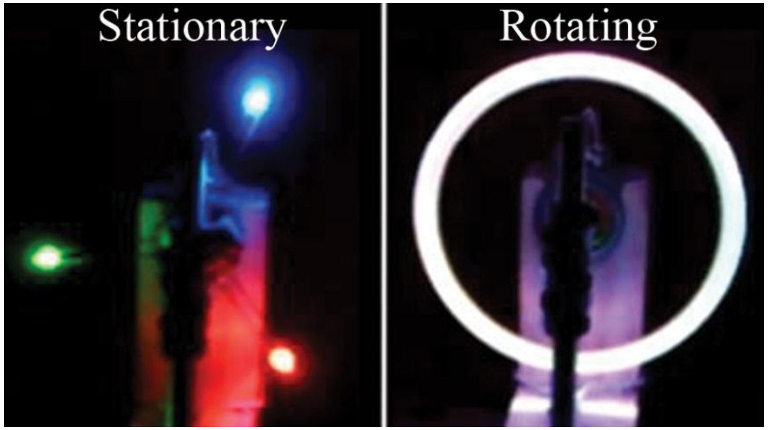
Target Market and Audience: Short term target markets in the energy sector include refrigeration, thermoelectric heat pumps, appliances, and LED lighting (total potential energy savings estimated to be 2 quads, dominated by LED lighting). Long term markets include building-scale air conditioners and heat pumps (total potential energy savings estimated to be 0.5 quads).

Impact of Project:

1. Final products: (1) TRL 5 technology maturation, (2) ten demo units for loan to industry to facilitate tech transfer, (3) scalability path for building HVAC.
2. Measuring achievement towards these goals:
   a. Near-term: number of demo units loaned to industry & licenses signed, ability to obtain funding for a 10-kW proof-of-concept RVCC heat pump.
   b. Medium term: Success of RCSSL technology, success of RVCC prototype.
   c. Long-term: Net energy savings and market presence of Sandia Cooler technologies.

Rethinking LED lighting (and the payoff for developing *technology platforms*)





highly effective, direct, lossless color mixing

12,000 lumen high bay light fixture demonstration unit under construction (completion date: 09/14)

10X improvement in LED thermal management
Direct red + green + blue synthesis of white light
Imperceptible flicker frequency of 120 Hz
Underscores importance of investing in red and green LED R&D
Currently applicable to white (phosphor converted blue) LEDs
Low operating temperature enables 100,000 hour lifetime
No LED derating: many fewer LEDS required, lower up-front cost
Motor power consumption for 12,000 lumen device: 1.2 watt
Sandia-Cooler-like performance but no requirement for air bearing

Approach

Approach: Scale the learning curve of this new technology (see **"Key Issues"**, below) emphasizing (1) performance relative to state-of-the-art, (2) device optimization and design rules, (3) design for high-volume, low-cost manufacturability, (4) low-noise operation, and (5) cost-effective routes to scalability. TRL 5 demo units used to make tech transfer objectives materialize.

Key Issues: Air gap engineering, fin optimization, cold forged fabrication, advanced motor controller development, high endurance anti-friction coating, elimination of air gap in some applications (e.g. LED lighting, thermoelectric heat pumps, and building HVAC), and rotary transformer technology.

Distinctive Characteristics:

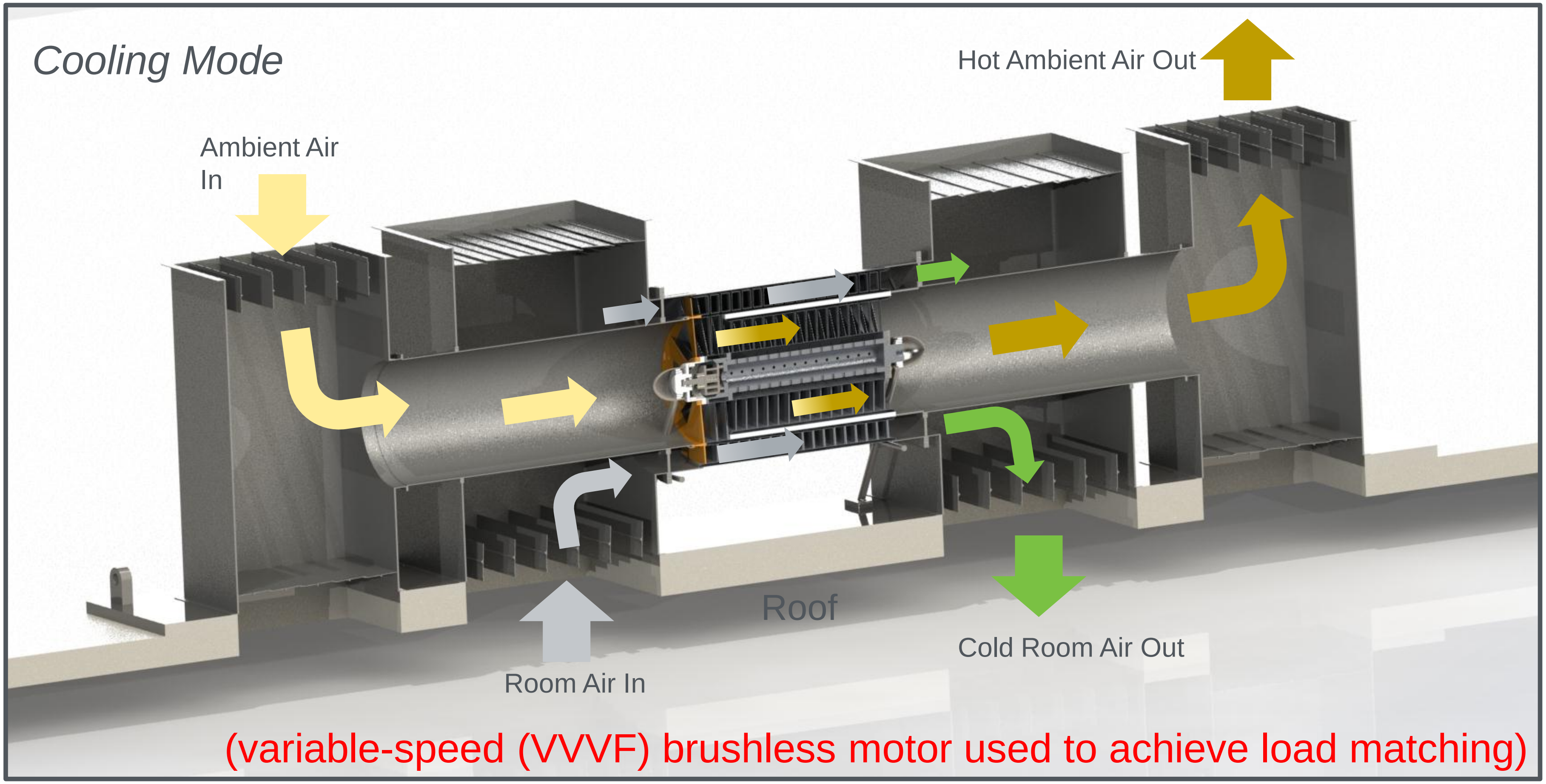
Radial Flow Sandia Cooler (e.g. for refrigerator condensers): use of air gap

LED lighting: elimination of air gap, zero-insertion-loss RGB color mixing

IGBT/transistor cooling (e.g. microwave ovens): high volumetric efficiency

Building scale air conditioning and heat pumps: elimination of air gap, rotating-frame-two-phase-flow effects, elimination of superheating losses, elimination of evaporator frosting.

RVCC roof top heat pump unit in cooling mode:

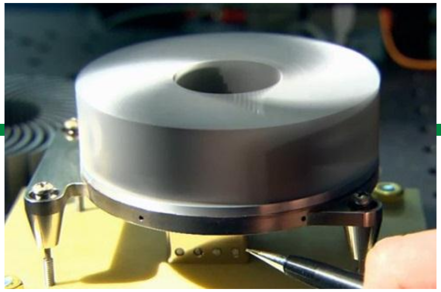


RVCC: Rotary Vapor Compression Cycle Technology

Key to low-cost manufacturing: cold pressure welded assembly

Estimated efficiency improvement: 16%

Progress and Accomplishments



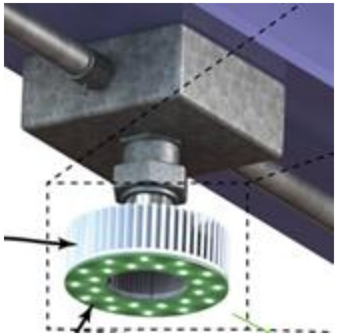
Lessons Learned: (1) degree of difficulty for CFD optimization. (2) R&D strategy constrained by design for manufacturability.

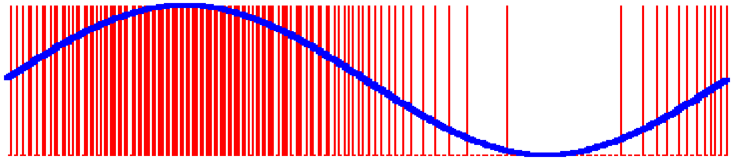
Accomplishments: Maturation to TRL 5 while attaining goals for thermal performance, low power consumption, low noise, and manufacturability. Fabrication of ten demonstration units for loan to industry (nearly completed). Invention of RVCC technology to address specific challenges of building HVAC.

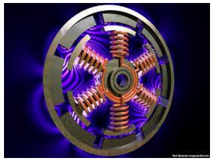
Market Impact: Market impact will truly be felt when the ten evaluation units are delivered to the prospective industry partners awaiting them (see next slide). To date >100 companies have contacted Sandia to inquire about commercialization of the Radial Flow Sandia Cooler. Demonstration of our 12,000-lumen RCSSL fixture later this year is also expected to generate significant commercial interest.

Awards/Recognition:

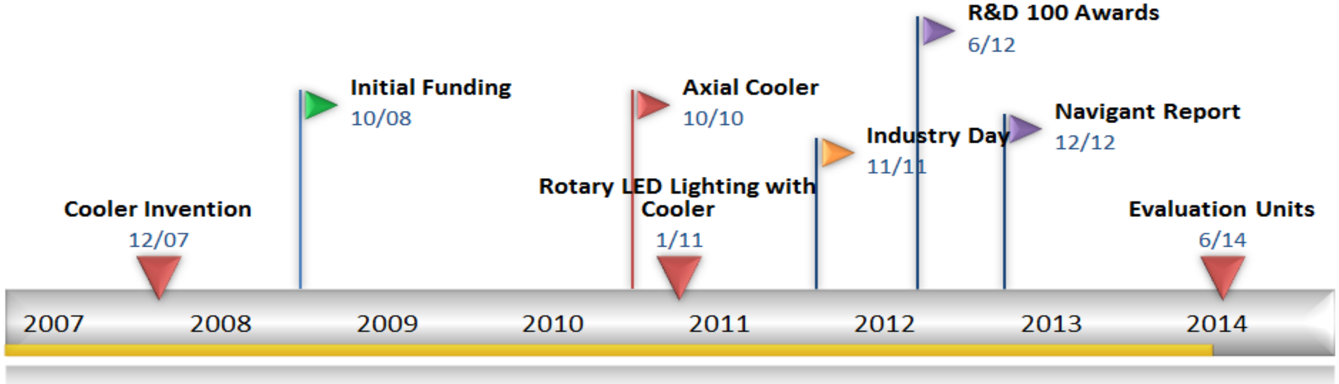
2011 MIT Clean Energy Competition Grand Prize
2012 R&D 100 Award (top 100 inventions of 2012)
2012 R&D 100 Editors Choice Award (top 3 inventions of 2012)
Briefing to Secretary Steven Chu by Tony Bouza
Navigant study on commercialization of Radial Flow Sandia Cooler







Sandia Cooler Technology Development Time Line



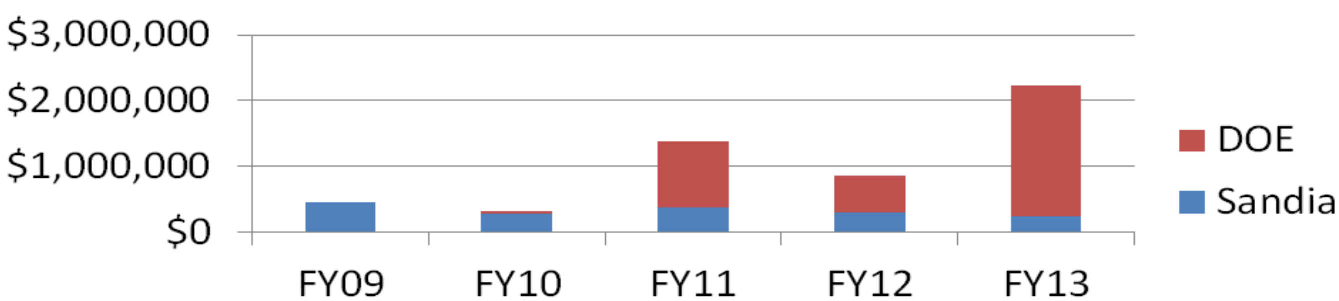
Invention
- TRL 1-2
- Lab bench system
- Follow-on Inventions
- Patent Protection
  - US + World

Proof of Concept
- TRL 3
- Industry Day
  - Lots of outreach
- Wide Press Coverage
- Interest ~ 20 companies

Development
- TRL 4-5
- Licenses to 2 Startups
  - 3 License Options
- Industry Waits for Prototypes
- Interest > 50 companies

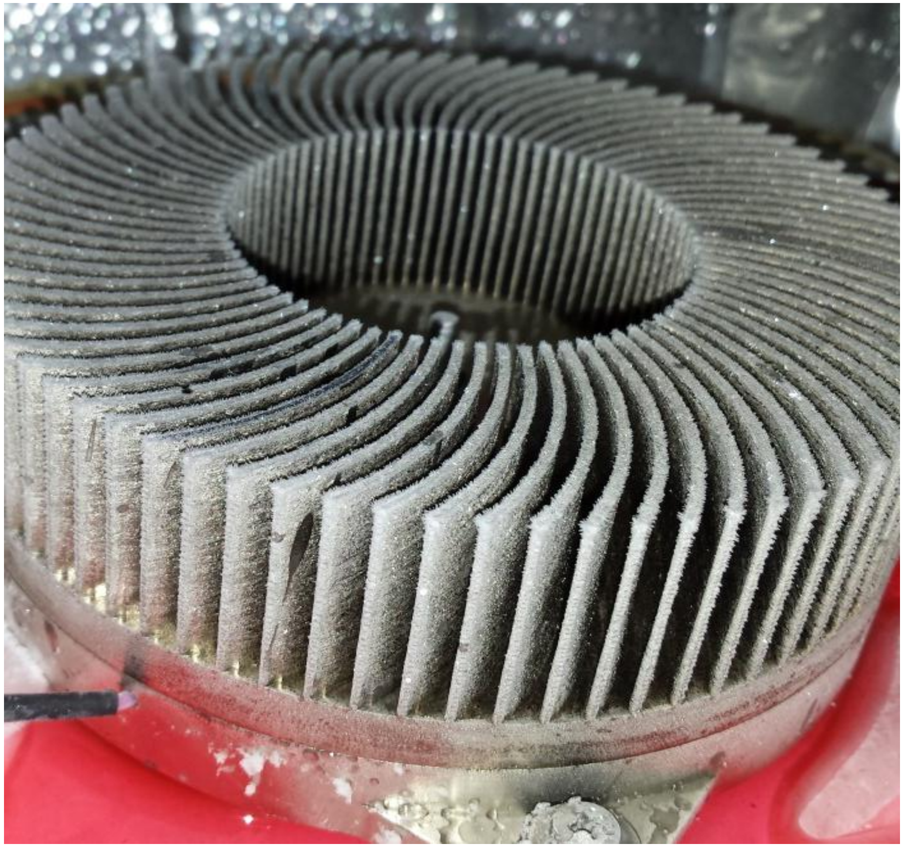
Deployment
- Evaluation Units
- Partnerships
- Application Specific R&D
  - Refrigerators
  - HVAC
  - LED Lighting

Funding



Elimination of heat exchanger fouling has driven industry interest

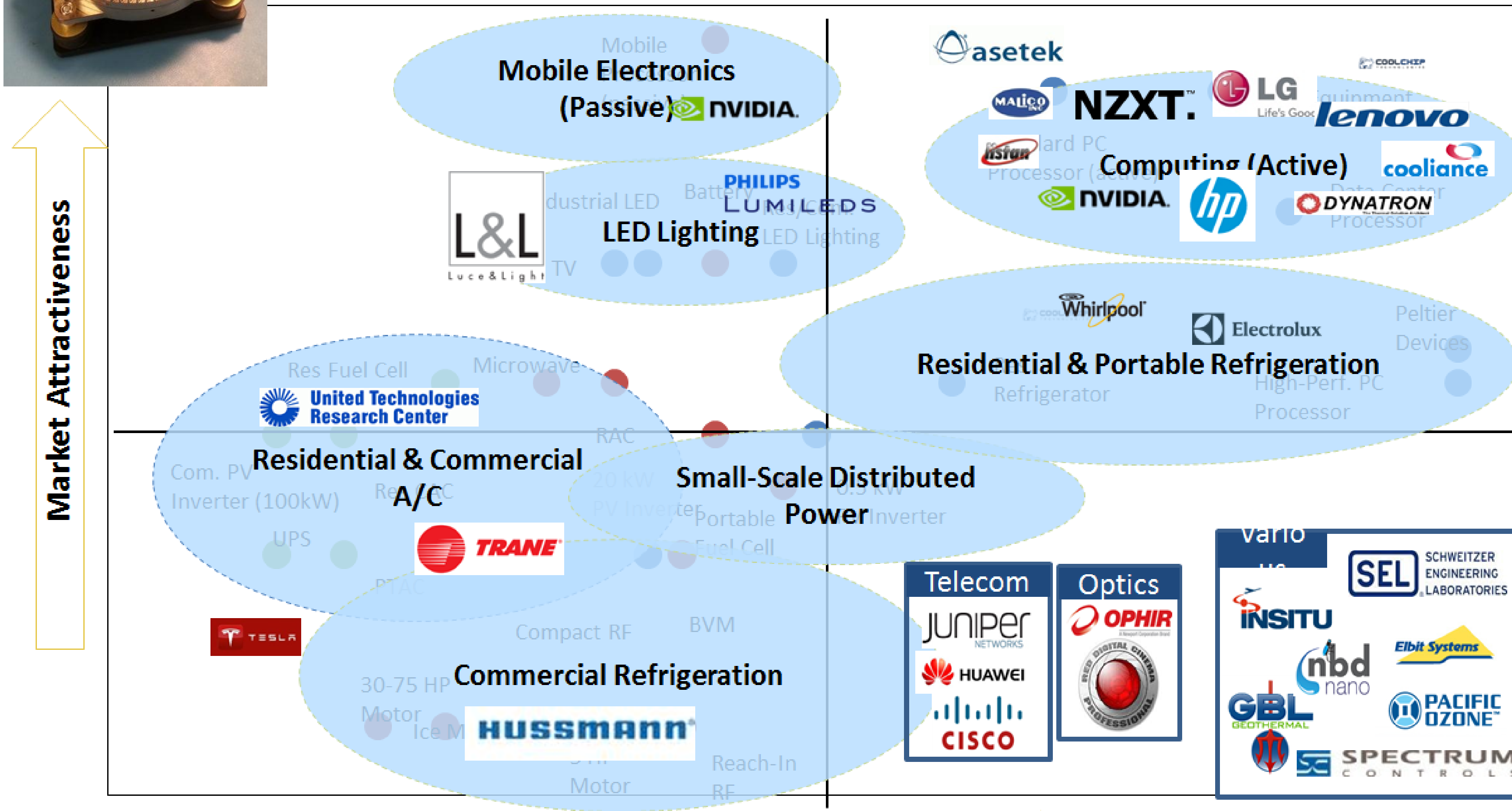
dust



ice

Heat transfer performance does not degrade over time.

Radial Flow Sandia Cooler Markets and Commercial Interest



Technology Attractiveness

"Market Assessment and Commercialization Strategy for the Radial Sandia Cooler"
http://energy.gov/sites/prod/files/2014/02/f8/Radial%20Sandia%20Cooler%20Final%20Public%20Report.pdf

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Project Integration and Collaboration

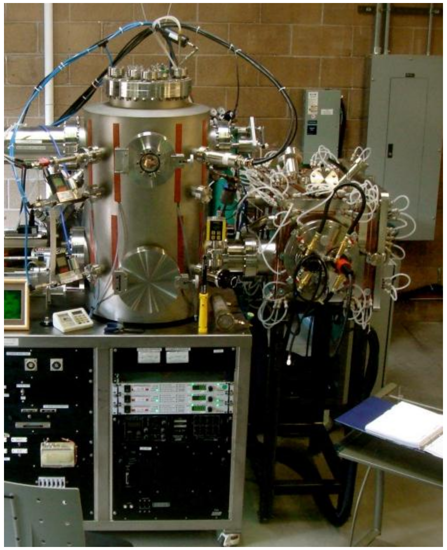
Project Integration: Collaborations (e.g. Univ. MD, UTRC) are mostly based on technology demonstrations for specific end use applications. The key to accelerating interaction with industry is (1) laboratory visits, and (2) the availability of demonstration units that can be loaned out for independent testing. For example, Whirlpool is now partnering with Aavid Thermalloy to map out a detailed manufacturing plan for applications in appliances.

Partners, Subcontractors, and Collaborators:

Key Partners
University of MD
UTRC
Oak Ridge National Laboratory
Tribologix
DOE
Trane
Optimized Thermal Systems
Whirlpool/ Aavid Thermalloy

Key advisors:

Omar Abdelaziz (Oak Ridge National Labs)
Reinhard Radermacher (University of MD)
Tom Radcliffe (United Technologies)
John Doyle (Whirlpool)
Andras L. Korenyi-Both (Tribologix)

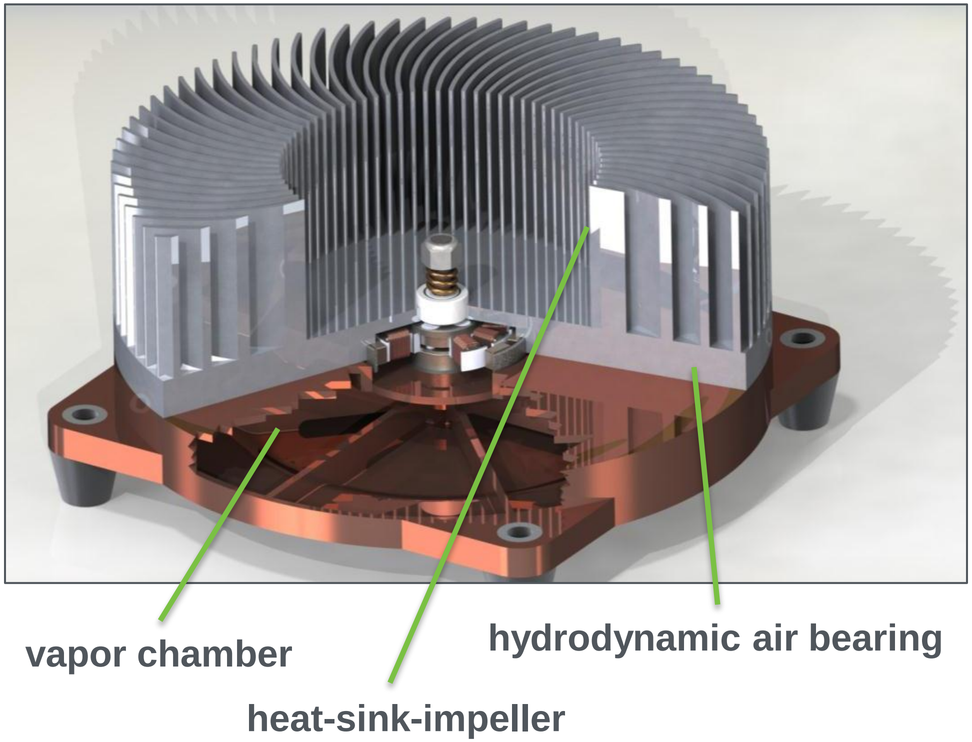


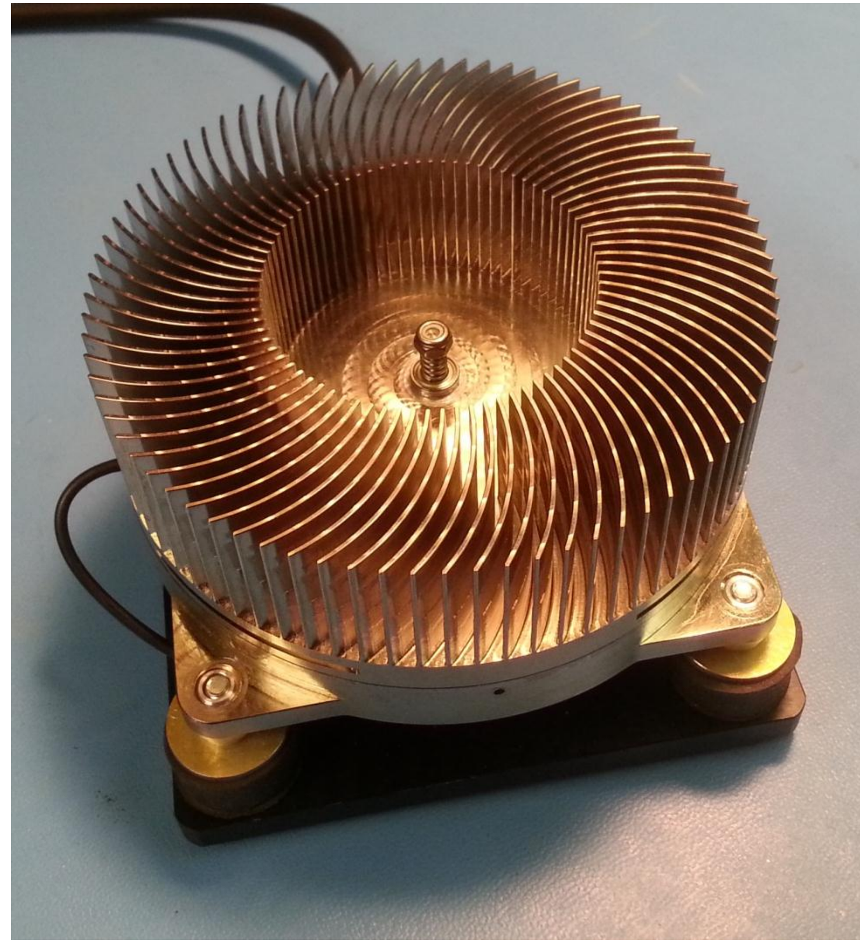
Dry anti-friction coating deposition at Tribologix

Communications: ASHRAE conference, Summer Heat Transfer Conference, University of MD workshop, Sandia Industry Day, Wall Street Journal

Next Steps and Future Plans

Sandia's TRL 5 Air Bearing Heat exchanger technology (a. k. a. The Sandia Cooler)





Radial Flow Sandia Cooler (TRL 5):
Now being taken over by industry

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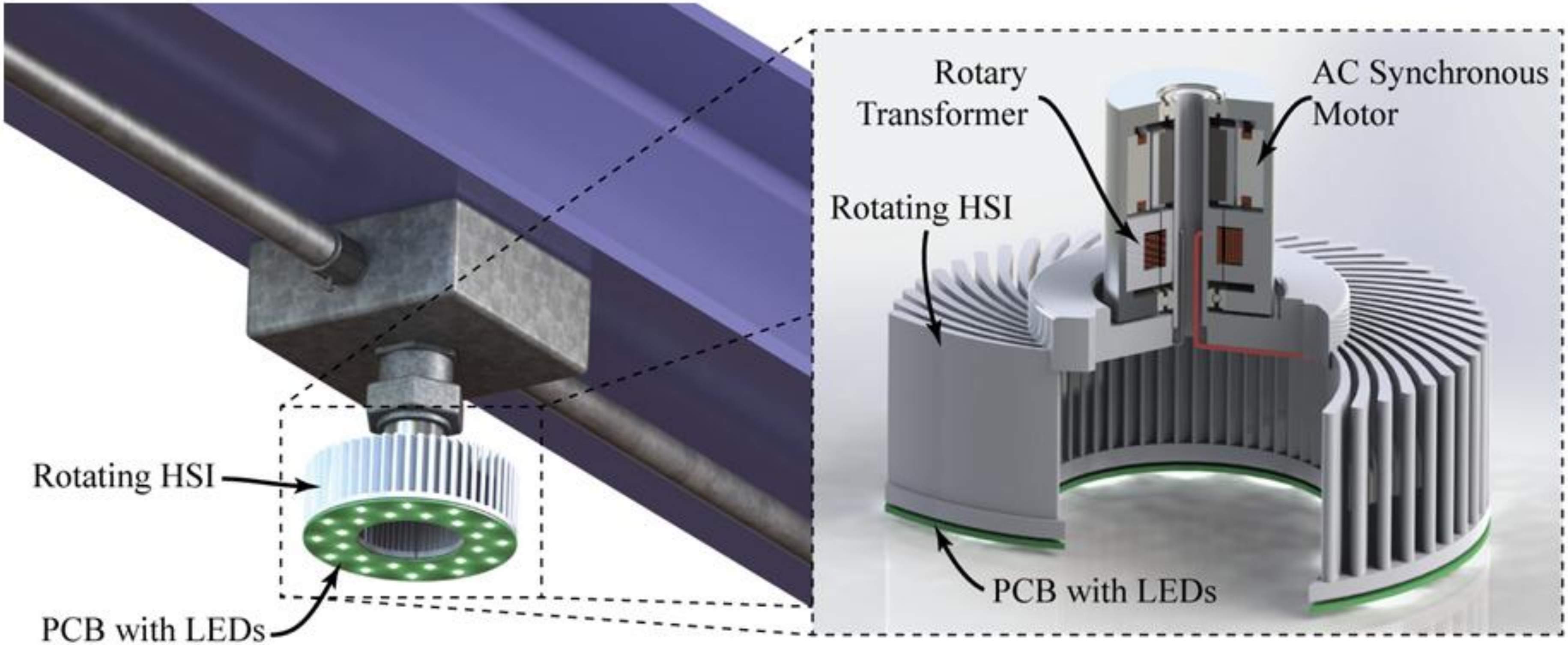
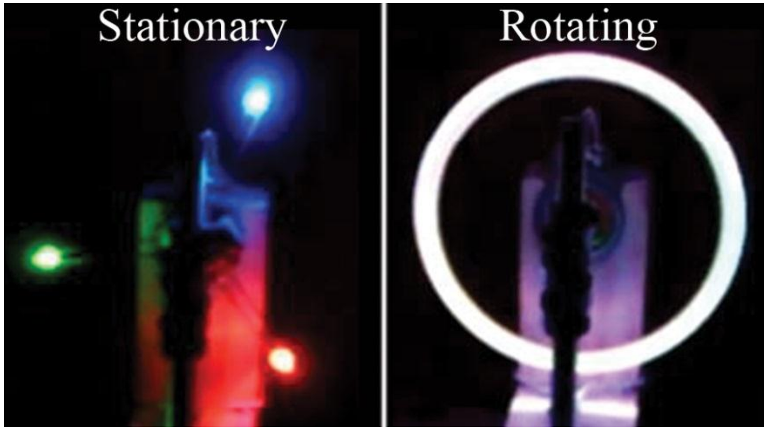
Next Steps and Future Plans





highly effective, direct, lossless color mixing

RCSSL technology (TRL 3):
12,000 lumen proof-of-concept device being built in FY14 using Sandia LDRD funds.

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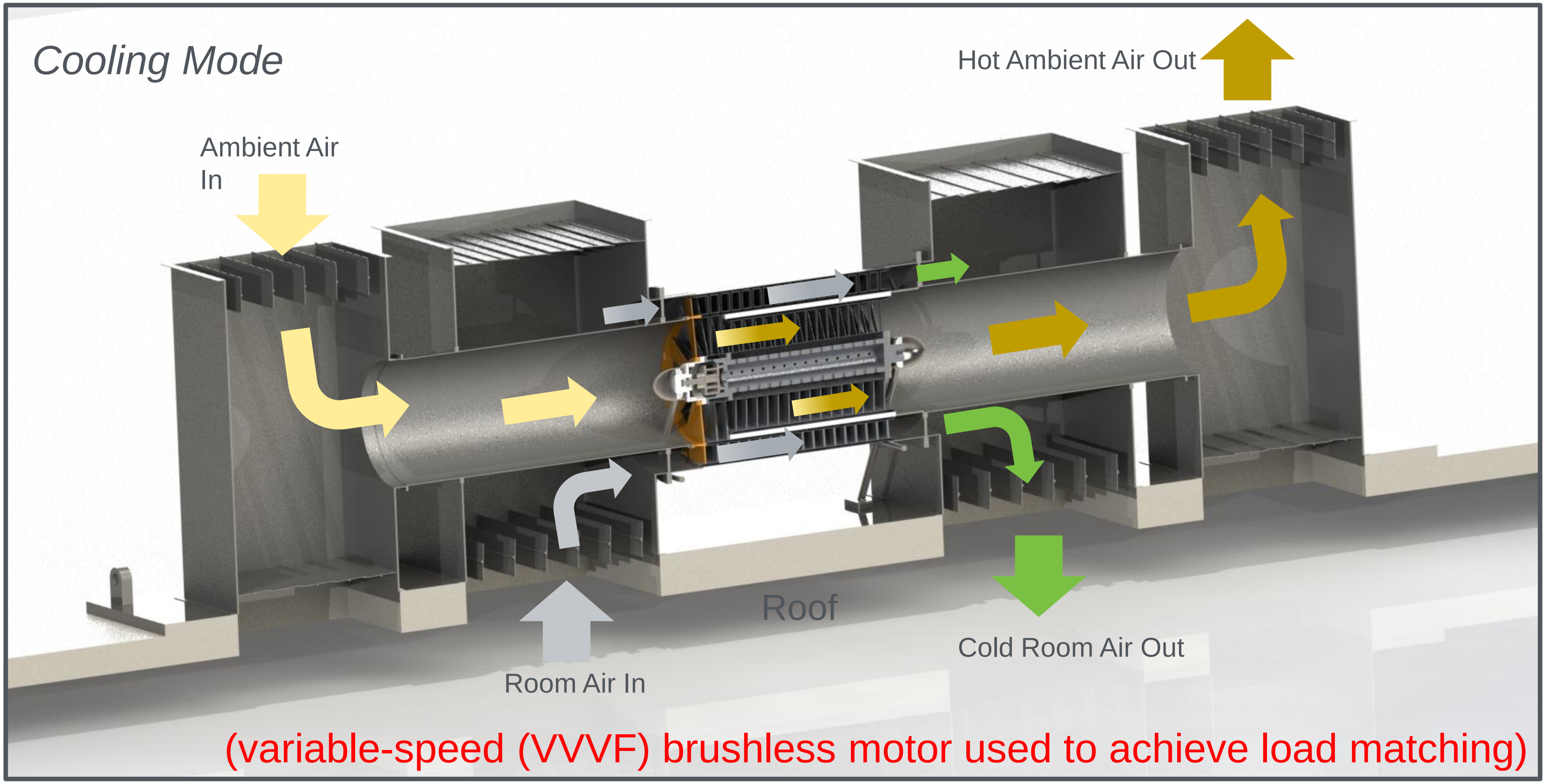
Next Steps and Future Plans



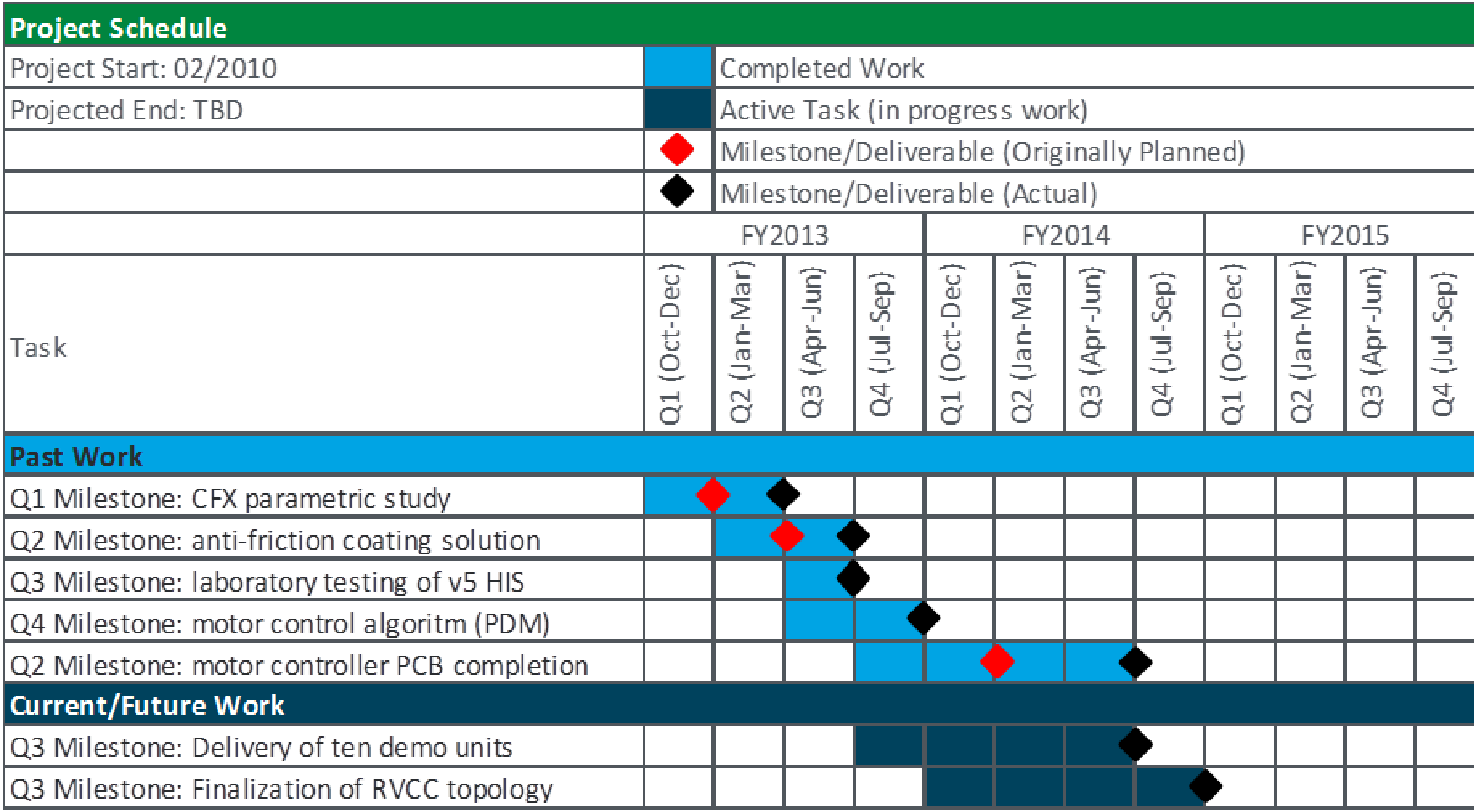
Rotary Vapor Compression Cycle Technology (TRL 2):
Seeking funding for 10 kW proof-of-concept demonstration

Project Budget

Project Budget: Average of $1.1M/year since 2010
Variances: Delivery of demo units delayed until 06/30/14 by motor controller development work.
Cost to Date: $4,660k
Additional Funding: Laboratory-Directed Research and Development funding; Total of $1740k since 2009, average of $290K/year

Budget History					
FY2010– FY2013 (past)		FY2014 (current)		FY2015 – (planned)	
DOE	*Cost-share*	*DOE*	*Cost-share*	*DOE*	*Cost-share*
$4,047,285	N/A	$1,425,000	$91,873	TBD	TBD

Project Plan and Schedule



Main driver behind slipped milestones: unanticipated complexity of motor controller development

Future work: RVCC technology (only if FY15 funding can be obtained)

Future work: RCSSL technology (FY15 program development contingent on FY14 results)