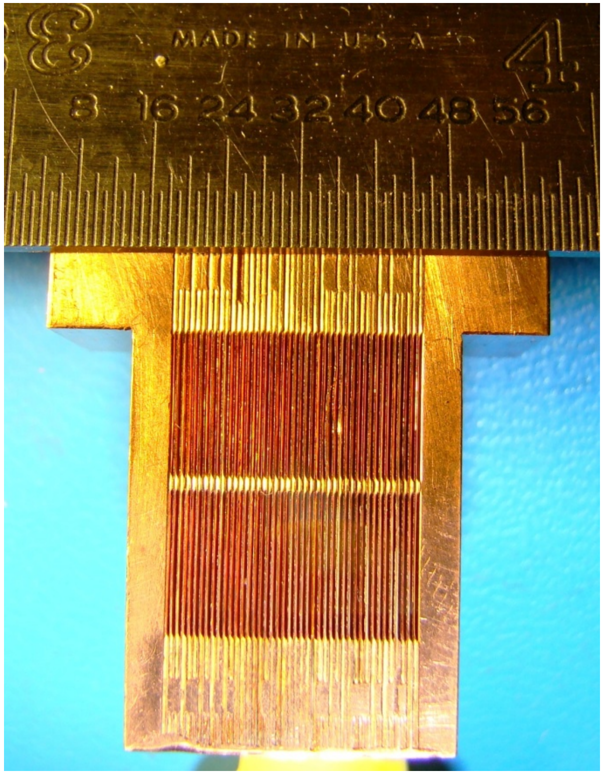
Air Cooling Technology for Power Electronics Thermal Control



Desikan Bharathan
Email: desikan_bharathan@nrel.gov
Phone: 303-887-4215
Organization: National Renewable Energy Laboratory

Team members:
Charlie King
Ken Kelly
Sreekant Narumanchi

Project Duration: FY06 to FY09

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Advanced Power Electronics and
Electric Machines Projects
FY08 Kickoff Meeting

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This presentation does not contain any proprietary or confidential information

NREL/PR-540-42340

The Problem

- Eliminate liquid coolant loops.
- Enable heat rejection directly to the sink, namely, ambient air. Simplify.
- Maintain die temperature below specified operating limits for long-term reliability.
- Reduce cost and meet other FreedomCAR goals for year 2020 ($8/kW for a 55 kW traction system).

Description of Technology

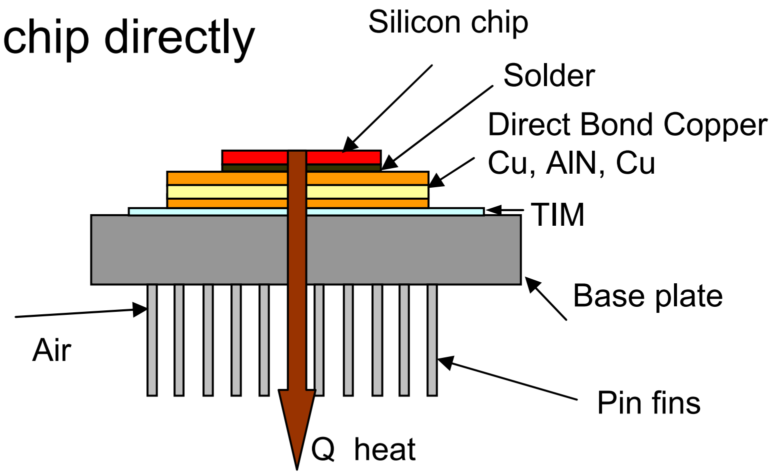
Advantages

Air is the ultimate sink

Rejecting heat to air can eliminate intermediate fluid loops

Air is benign and need not be carried

Air is a dielectric, and can contact the chip directly



Drawbacks

Air has a low specific heat

Air is a poor heat-transfer fluid

Air density is low

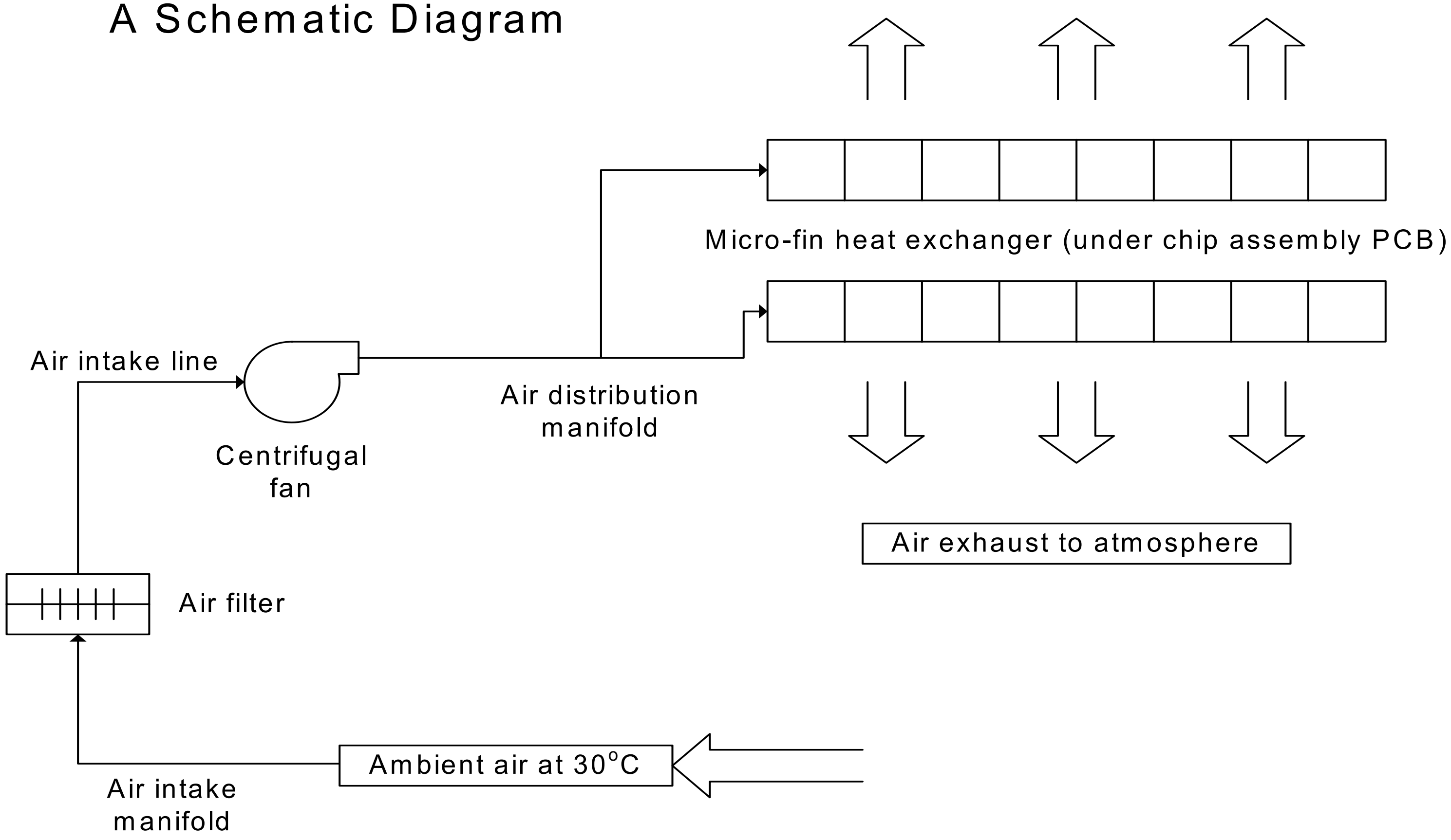
Uniqueness of Project and Impacts

- Approach looks at simple thermal solutions.
- Offers viable heat rejection directly to the sink.
- Air cooling offers simplicity and least number of components.
- Air cooling offers high degree of reliability.

Accomplishments to Date

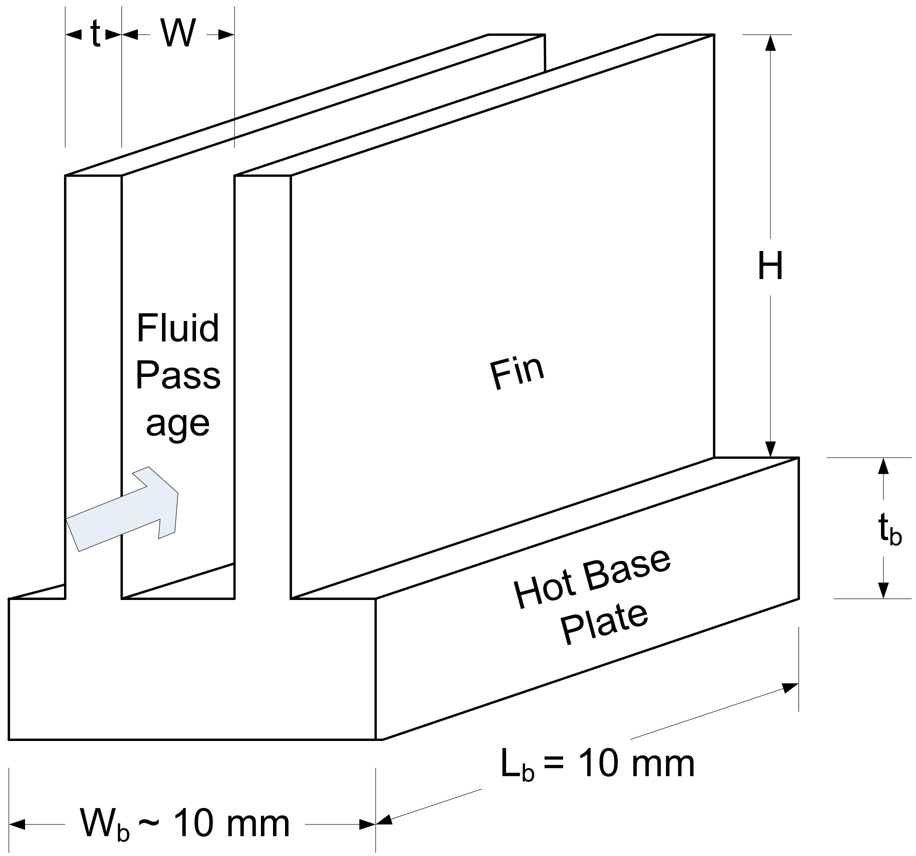
Air-Cooling System for
Power Electronics

A Schematic Diagram



Accomplishments to Date

Micro-fin array geometry



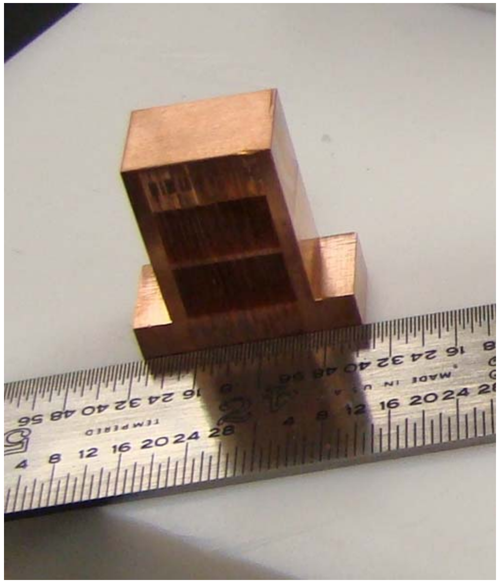
<u>Typical values are</u>:

W=130 μm

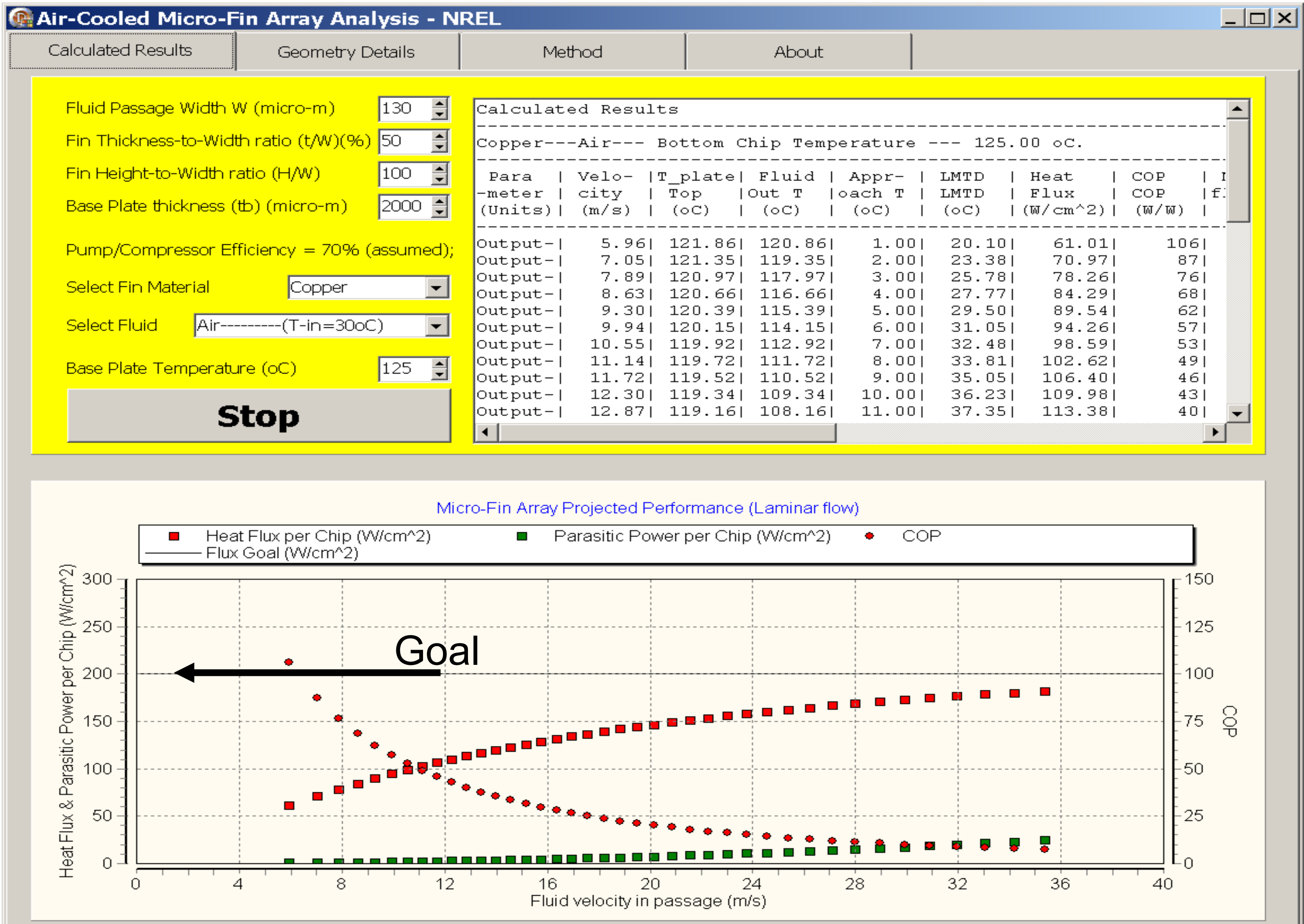
t = 65 μm

H = 13 mm and

t_b = 1 mm



Accomplishments to Date



Accomplishments to Date

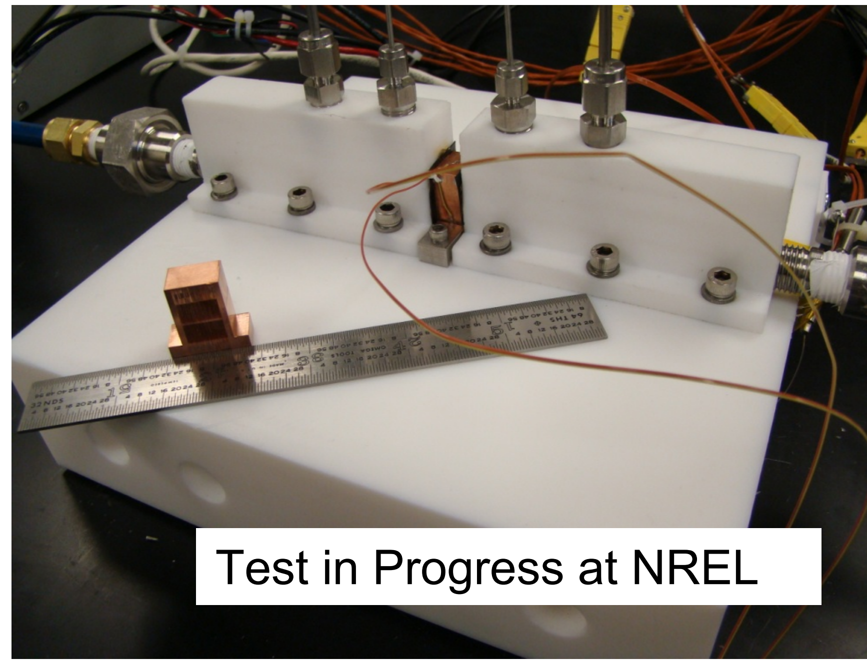
<u>Models show that:</u>

• Air cooling can remove fluxes up to 150 W/cm^2 for Silicon-based devices.

• Higher chip operating temperatures will increase the flux close to programmatic goal of 200 W/cm^2.

<u>Comparison with the use of an intermediate liquid cooling loop indicate that:</u>

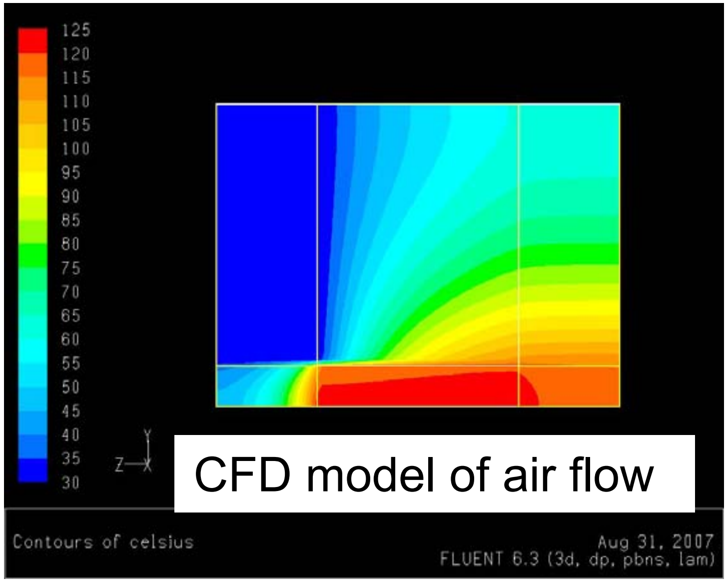
• Air cooling is simple, less costly, and reliable.



Test in Progress at NREL

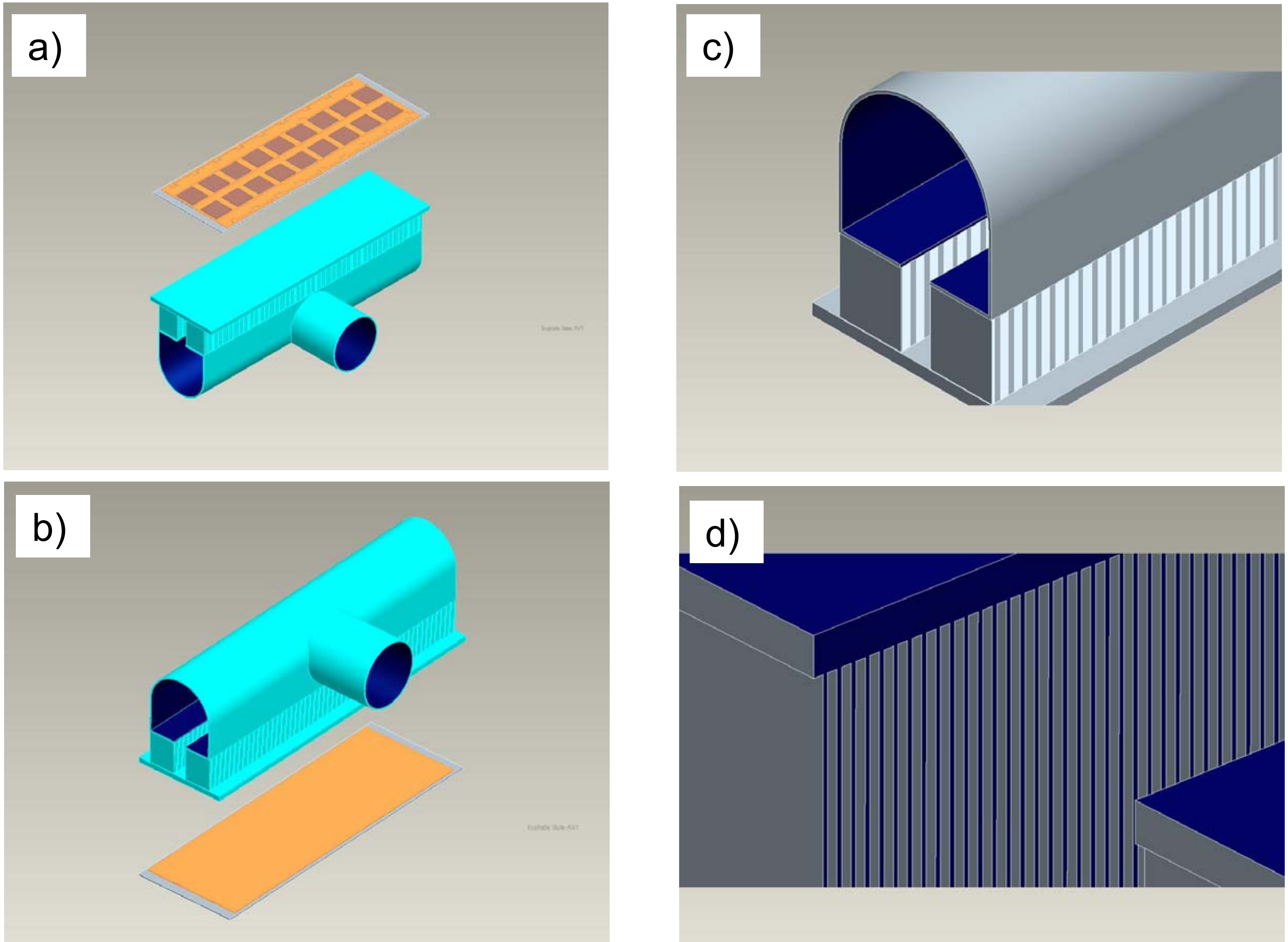
Project Objectives for FY08

- Implement air cooling
  - Work with an industrial partner to accommodate technology on a working inverter module to meet FreedomCAR goals.
- Validate models and design approach.
- Contribute to advanced PE development cooling options
  - Work closely with ORNL in development efforts to meet programmatic goals.



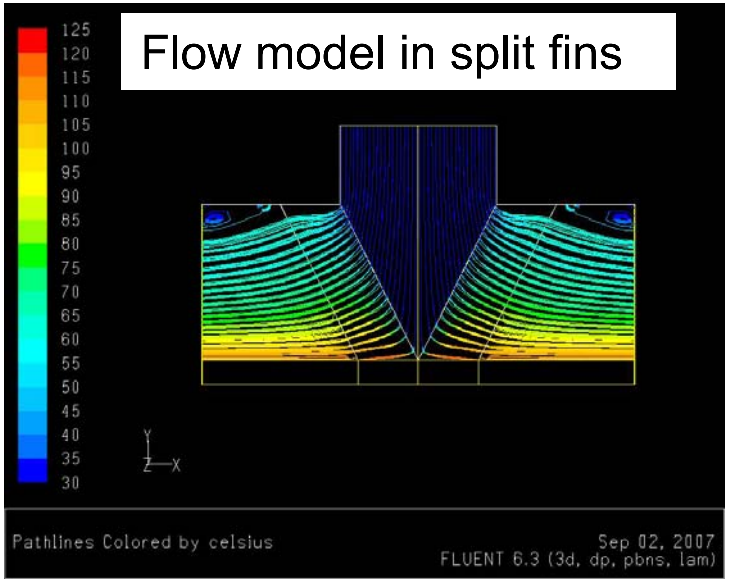
CFD model of air flow

Technical Approach for FY08

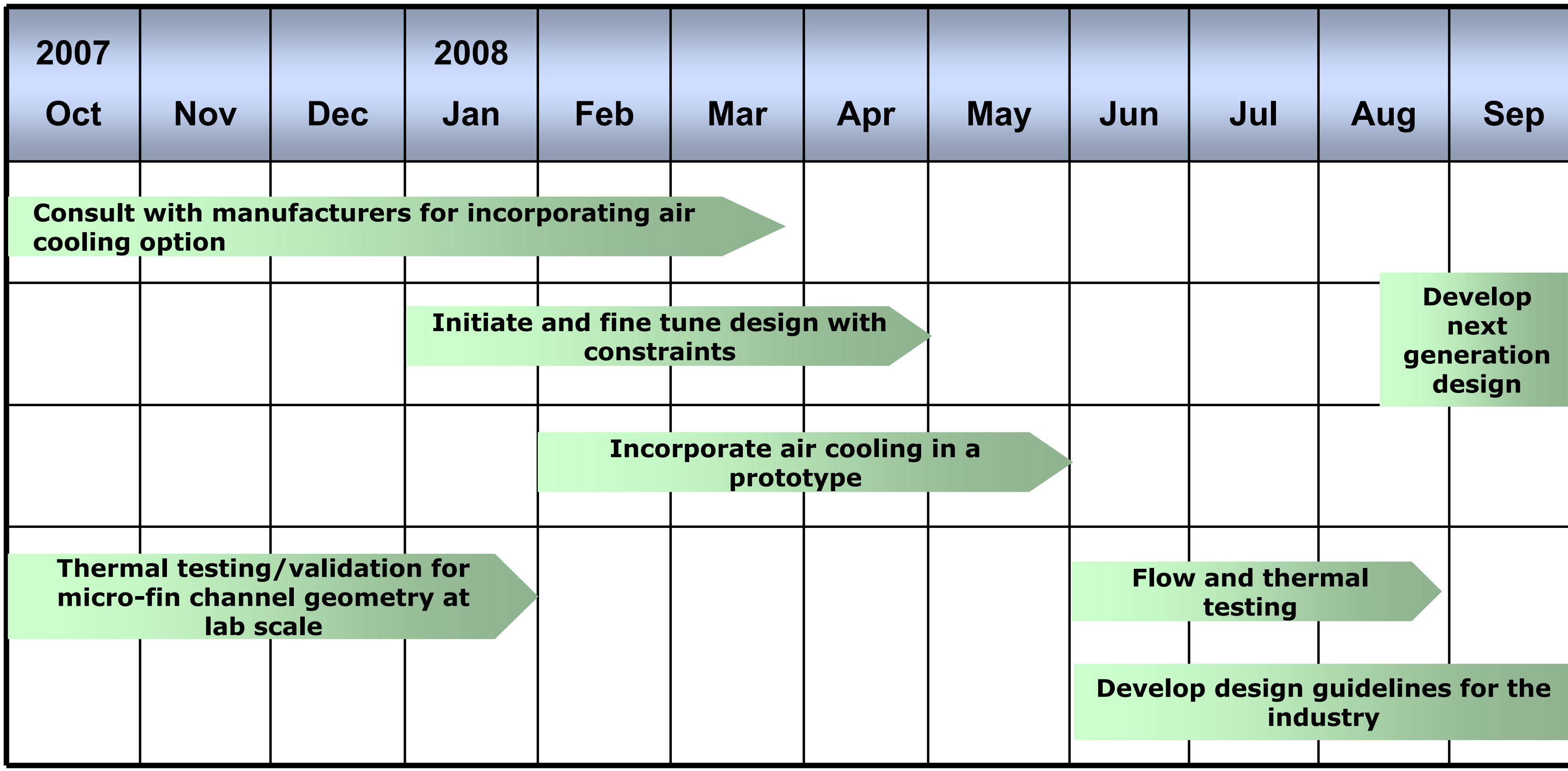


Technical Approach for FY08

1. **Design an air cooled micro-channel fin heat exchanger for an inverter module**
   - **in close collaboration with a chosen industrial manufacturer that meets the performance goals and other manufacturing constraints.**
2. **Incorporate air cooling device in a production model as a prototype.**
3. **Test performance of the module under realistic working conditions.**
4. **Validate design with test data.**
5. **Develop guidelines for performance estimation, cost, volume, weight and other measures for air cooling for use by the industry.**
6. **Develop second iteration design and demonstrate air-cooling as a viable option.**



Timeline



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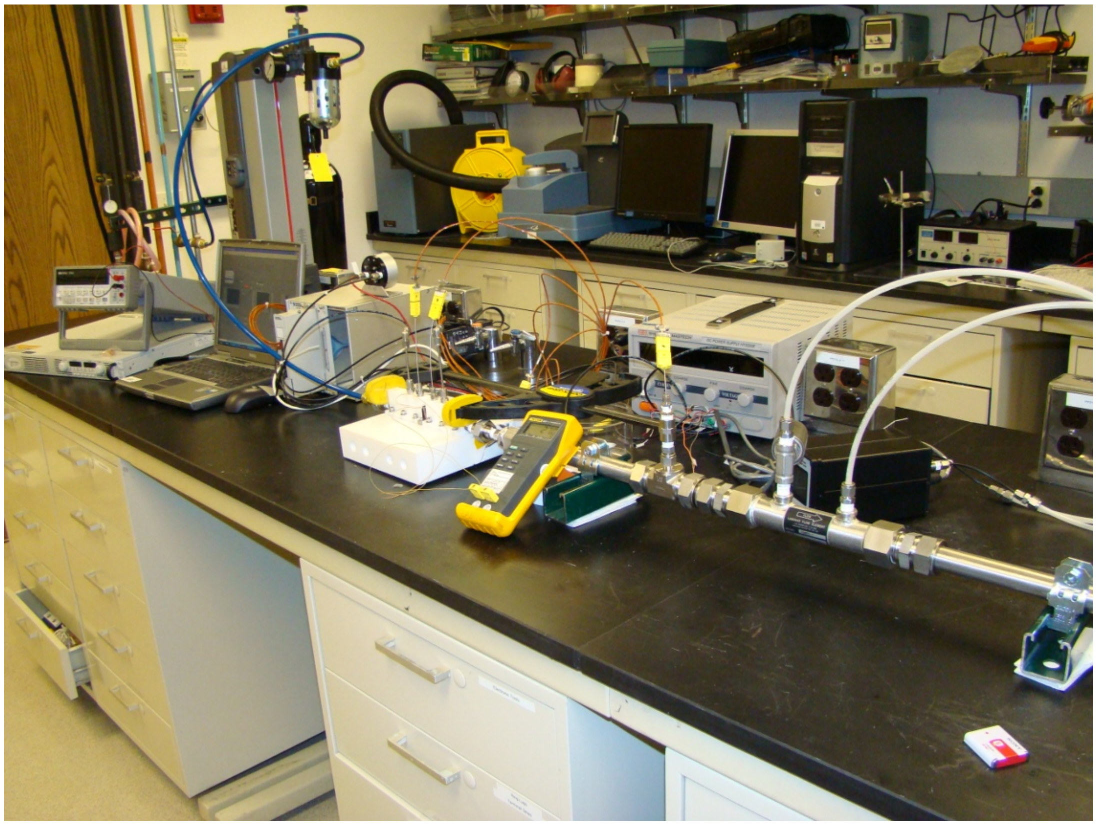
Consult with manufacturers for incorporating air cooling option
Initiate and fine tune design with constraints
Develop next generation design
Incorporate air cooling in a prototype
Thermal testing/validation for micro-fin channel geometry at lab scale
Flow and thermal testing
Develop design guidelines for the industry

The Challenges/Barriers

<u>To be addressed</u>:

- Erosion concerns -- due to coolant impingement and long term effects of jet impingement on copper fins.
- Potentially low blower efficiency.
- Potential noise generation due to air flow on fins.
- Difficulties with differential thermal expansions and resulting stresses.
- Convince industry this is a viable technology with advantages, while long-term reliability issues are addressed.

Beyond FY08 -- Integrate the developed thermal control technology with reliability tasks based on a systems level approach



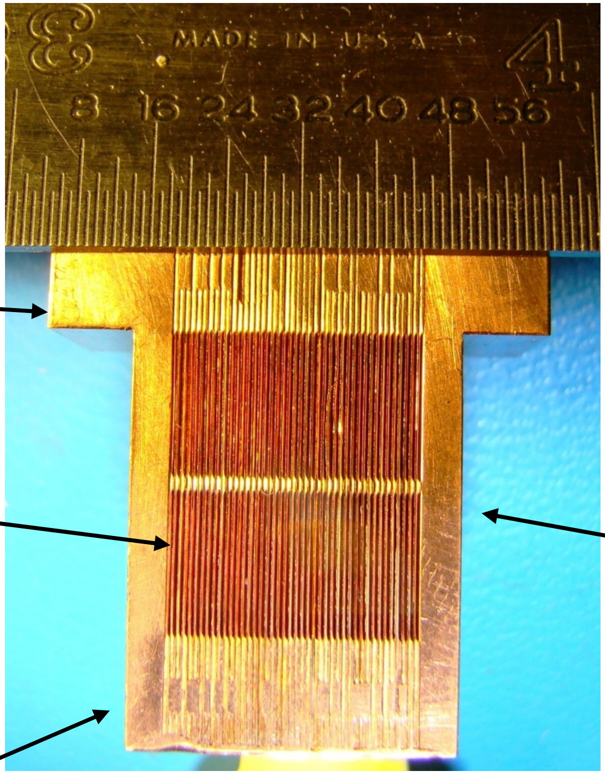
- Analyze pulsed systems to power
- Generate a design tool for air cooling
    - Provide industry with an easy-to-use tool to evaluate all aspects of performance and specifications.

Questions

Base plate

Copper micro-fins

Bottom enclosure



Channel enclosure