Commercialization Report
for Zalman
Thermal management for high density power PCs and servers using nano-MEMS technologies

Enterprise Innovation Institute
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Report Summary

The Georgia Institute of Technology’s Enterprise Innovation Institute (EI²) was tasked with the project of market commercialization for Zalman, Cool Innovations Co.’s Two-Phased Loop Heat Pipe System through the Korean Government’s KIAT program. In addition to identifying the appropriate U.S. commercial markets, EI² was also tasked with identifying field testing opportunities for the Two-Phased Loop Heat Pipe system. The Zalman point of contact for this effort is Dr. Jeehoon Choi and the EI² point of contact is Lynne Henkiel. This report encompasses activities and efforts from August 1, 2012 through November 30, 2012.

Introduction

Zalman has developed a prototype miniature Loop Heat Pipe system that dissipates heat fluxes as high as 150 kW. Cloud infrastructures today are “ultra high density” environments that generate 15 to 30 kW per rack. Current trends in cloud computing show an increasing demand for cooling technologies that dissipate and transfer large amounts of heat, while consuming less power. Zalman’s mLHP shows potential in capturing and capitalizing on this growing trend.

This report outlines the potential for the mLHP system in the US market. The commercialization group at EI² has performed market research (size, competition and market trends) and identified a potential partner for prototype testing and validation.

Initial Investigation

EI² has used the Technology Readiness Level (TRL) standard that is commonly used by some U.S. government agencies and many of the world’s major companies to assess evolving technologies prior to incorporating them into a system or subsystem. New technologies are usually subjected to experimentation, refinement and increasingly realistic testing.
Figure 1. Classification system that was used to identify the readiness level of mLHP

Zalman’s mLHP (miniature Loop Heat Pipe) technology can be classified as:

**TRL Level 4 – component and/or breadboard validation in laboratory environment**

The prototype and development schedule for the product as indicated in Zalman’s proposal is outlined in the table below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Prototype phase</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
<td>1st prototype (CASE1)</td>
<td>For workstation and desktop PC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compact condensers with centrifugal fan can be mounted inside and/or on the upper/rear panel of a chassis</td>
</tr>
<tr>
<td><strong>Year 2</strong></td>
<td>2nd prototype (CASE2)</td>
<td>Server rack mount</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compact condensers with centrifugal fans can be mounted inside a server rack mount</td>
</tr>
<tr>
<td><strong>Year 3</strong></td>
<td>3rd prototype (CASE3)</td>
<td>Server system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hybrid system; 2nd model combined with a water and/or aero cooling system</td>
</tr>
</tbody>
</table>

The 1st prototype has been developed and has successfully dissipated heat fluxes as high as 150 kW. Current efforts are being focused on characterizing thinner and lighter weight LHPs for higher heat loads and long distances using nano-technology.
Product/Service

Product forms
There are 3 different models of the product, each for a separate application:

Table 1. Product forms

<table>
<thead>
<tr>
<th>Model for workstation and desktop PC</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model for server rack mount</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Figure 1: 1st prototype of Zalman LHP
Model for server system (multiple racks)

Cost to Produce

Table 2. Cost estimate and capital investment to produce the product

<table>
<thead>
<tr>
<th>Cost to Produce</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Equipment and Facility</td>
<td>459,600</td>
<td>437,600</td>
<td>443,600</td>
</tr>
<tr>
<td>• Reagents and materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Testing and analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Prototyping</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Capital Investment                                   |         |         |         |
| • Equipment and Facility                             | 303,100 | 279,600 | 275,600 |
| • Reagents and materials                             |         |         |         |

Customer Desirability/Value Proposition

What problem in the market does this product address?

There is a need for highly effective and energy efficient thermal management for hardware cooling in data centers. Most cloud infrastructures today are ultra-high density environments (15 to 30 kW power in each rack) with significantly greater rack-level power requirements compared to conventional data centers.
Current methods for cooling include air cooling and liquid cooling, both of which are energy inefficient and require significant capital expenditure.

**Air cooling**

The most common hot aisle-cold aisle configuration produces convection currents that generate a cooling, continuous flow of air. This method increases air circulation and works great for racks up to 15 kW. Used by itself, it is incapable of coping with the heat produced by large cloud infrastructures.

**Liquid cooling**

This method is more economical for racks above 15-20 kW. Liquid cooling methods use water or oil to remove heat from the racks. The former could employ rear door heat exchangers that attach to the back of the server enclosures. The heat from the rack mounted equipment is transferred to the water and ejects cool air out of the rear door heat exchanger.
“Green Revolution Cooling” makes immersive liquid cooling server racks using oil as the medium of heat transfer. The company claims a reduction in power consumption of 90-95% and reduction in server power by 10-20%. A significant disadvantage of this method is the maintenance and repairs of these oil-immersed servers.

**Pain in the Market**

Looking at existing technologies, there is clearly a need for a simple, elegant solution that will achieve large amounts of heat transfer over considerable distances, at the same time reducing power consumption.

Energy efficient cooling is a sought out solution for data centers:

- There is a high demand for economizer and free cooling technologies (e.g.: having data centers in cool climates).
• High growth is expected for green cooling technologies that can be used in areas with warmer climates (opportunity for Zalman’s product).

Market Research

Market sizing

The market for cooling technologies has been broken down based on the number of desktop PCs and servers in the United States. These numbers are for 2012 and are approximate.

• **Total Area Market (TAM):** TAM consists of all the desktop PCs, home theater PCs and servers (rack mount and blade) in the US. The approximate numbers obtained for these segments are:
  - DTPC+HTPC=2500 million units
  - Total TAM = 2512 million units

• **Subject Area Market (SAM):** SAM consists of the portion of TAM that Zalman’s mLHP will focus on. Considering the growth potential in the server market and the demand for greener cooling technologies (please see “Data center expansion plans”, Figure 6), we will target the server market (12 million units)

• **Target Market (TM):** TM will consist of a subset of SAM that we can realistically reach. This will include servers currently being manufactured or in OEM assembly since mLHP is not an “add on” technology and has to be integrated during the manufacturing process. Although exact numbers were not available as on date, a guesstimate of 1 million servers in production has been used.
Current trends and focus areas

In 2010, investment in greener data center technologies was 7.5 billion dollars, and is expected to be at 41.4 billion dollars by 2015. Almost half of the market, 46 percent, for greener data center technologies will be in new cooling technologies. These market projections came in 2010 before the cloud computing craze came about in 2011, and we expect the numbers for greener data center technology investments to be a lot higher than predicted in coming years.

The figure below shows the data center expansion plans for the major players in the cloud computing/data management space: Google, Facebook, Microsoft and IBM.
Looking at past trends (1996-2010) there has been a linear rise in the spending on power and cooling technologies, while the number of servers has remained relatively constant.

In a study of 300 companies by Digital Realty Trust (http://knowledge.digitalrealtytrust.com/wp-content/uploads/2011-Whats-Driving-the-US-Datacenter-Market.pdf), the average number of data centers a company owns is 4 and nearly 1 in 5 companies has 6 or more data centers. Two in five respondents in this study had definite plans to expand in 2012, and nearly one in three had
expanded in the 2011-2012 period. This study shows tremendous growth in this sector and significant opportunity for success in the data center cooling industry.

**Competitors**

The desktop PC cooler market is fragmented with several companies selling fans, heat sinks and other cooling equipment. Zalman holds 11% of the market share in CPU cooling.

![CPU Cooler Market Share Chart](image)

**Figure 9. Market share for CPU cooling companies**

EI² has identified several players in the data center cooling technology space and is currently investigating the size and market share of these companies.

**Table 3. Competitors in data center cooling technologies**

<table>
<thead>
<tr>
<th>Provider</th>
<th>General Product Strategy</th>
<th>How this provider competes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DegreeC</td>
<td>Underfloor and overhead air cooling. Dynamic management of flow of cool air to IT racks.</td>
<td>DegreeC’s system dynamically manages airflow, thus eliminating hotspots and saves 30% of cooling energy - <strong>Air cooling</strong></td>
</tr>
<tr>
<td>Coolcentric</td>
<td>Rear door heat exchanger (RDHx) water cooling</td>
<td>Uses a passive system and requires no electricity at the RDHx, thus reducing electricity consumption by 90%</td>
</tr>
<tr>
<td>42U</td>
<td>Several cooling solutions available: In-row cooling, in-rack cooling, economizer/free cooling, high density cooling and hot/cold air aisle containment</td>
<td>Served several Fortune 500 companies (eg: Bank of America, GE, AT&amp;T) - <strong>Air cooling</strong></td>
</tr>
<tr>
<td>Thermacore</td>
<td>Loop Heat Pipe removes heat directly from the processor</td>
<td>High heat removal capacity, high efficiency, long heat removal distance and low cost to build and operate. Ability to cool data centers with no chillers. – LHP cooling system/air</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Captherm Systems</td>
<td>Multiphase cooling where refrigerant changes state from liquid to vapor</td>
<td>2000x more efficient than air cooling &amp; 500x more efficient than liquid cooling</td>
</tr>
</tbody>
</table>

**Potential Test Bed Partnership**

**CEETHERM data center visit**

EI²’s commercialization group visited a data center at Georgia Tech to identify a potential partnership for prototype testing of the Zalman mLHP. The data center, run by Dr. Yogendra Joshi, has two areas consisting of:

1. Low power racks (4-24 kW) for testing, experiments and simulation
2. High performance (HPC) racks (24 kW) that serve the computing needs at Georgia Tech.

Dr. Yogendra Joshi has obliged to share the simulator/tester racks for Zalman’s work. He suggested testing the prototype on a single rack and use savings in power consumption as a metric for measuring effectiveness of the product.

Currently, the data center uses hot aisle-cool aisle configuration and is cooled and maintained using computer room air conditioning (CRAC) units. These CRAC units are extremely noisy and use 30-50% of the data center’s power. These cooling units not only increase power consumption significantly, but don’t effectively cool the source of heat – the computer processors. During our discussion, it was noted that a system level solution such as mLHP is highly desirable.

The racks in Area 2 (HPC racks) use rear door heat exchangers which cost $5000 per door.

Both these methods, air cooling and rear door heat exchangers, drive up the costs of cooling a data center. These costs become prohibitive in large data centers with hundreds of thousands of servers spread over an average area of 15,400 sq.ft.

Figure 9 shows a HPC rack with several blade servers. Each server has a dual processor blade unit with a copper heat sink. Zalman’s system level solution, the mLHP, will replace the copper heat sink.
Future Plan of Action

An initial investigation and market analysis has been conducted and a potential test bed partnership has been identified. EI² would like to help make this partnership successful and aid Zalman to test its product in a data center setting. A better understanding of the product through a prototype demo and product validation in a real world setting will help EI² move forward to the next proposed phase of commercialization. Zalman’s cooperation in this regard will help accelerate this process.

Going forward, EI² will identify demo venues and partnerships with companies that can incorporate the mLHP in their OEM process. These include server companies like IBM, Dell, HP, Microsoft and Fujitsu. EI² will also clarify patent ownership and arrange meetings with Georgia Tech legal entities to establish IP ownership and licensing options. Once the product is in TRL 7 or 8 (Actual system completed and qualified for use in data center environment through test and demonstration), we can identify and participate in trade shows and niche participation events to market the product to server companies.