**Exhibit A**
**SCOPE OF WORK**

## TECHNICAL TASK LIST

| Task # | CPR | Task Name |
|---|---|---|
| 1 | N/A | Administration |
| 2 | | Develop Detailed Specification of the System and its Components |
| 3 | | Design, Build and Test Compute Module |
| 4 | | Design, Build and Test a Single Blade and Deflection Mechanism |
| 5 | | Design and Build Heat Risers |
| 6 | | Design and Build Cooling CRate and Housing, Test with Heat source |
| 7 | | Design and Build RAck with Integrated Refrigerant Distribution System |
| 8 | | Build 12 Shelves and Integrate with Rack, Test with Standard Liebert XDP Pump and Heat Exchanger System Connected to a Chiller |
| 9 | | Test System with Full Complement of Blades |
| 10 | | Test System with ChillerLess System |

## KEY NAME LIST

| Task # | Key Personnel | Key Subcontractor(s) | Key Partner(s) |
|---|---|---|---|
| 1 | Phil Hughes & Bob Lipp & Mike Martin | | Clustered Systems |
| 2 | Phil Hughes & Bob Lipp & Mike Martin | | Clustered Systems |
| 3 | Phil Hughes & Bob Lipp | ODM1 | Clustered Systems |
| 4 | Phil Hughes & Bob Lipp | | Clustered Systems |
| 5 | Phil Hughes & Bob Lipp | | Clustered Systems |
| 6 | Phil Hughes & Bob Lipp & Douglas Werner | | Clustered Systems & Emerson/Cooligy |
| 7 | Douglas Werner | | Emerson/Cooligy |
| 8 | Phil Hughes & Bob Lipp & Douglas Werner | ODM3 | Clustered Systems & Emerson/Cooligy |
| 9 | Phil Hughes & Bob Lipp & Douglas Werner | | Clustered Systems & Emerson/Cooligy |
| 10 | Phil Hughes & Bob Lipp & Mike Martin & Douglas Werner | | |

**Exhibit A**
**SCOPE OF WORK**

## GLOSSARY

*Specific terms and acronyms used throughout this scope of work are defined as follows:*

| Term/ Acronym | Definition |
|---|---|
| ARRA | American Recovery and Reinvestment Act of 2009 |
| CPR | Critical Project Review |
| CPU | Central Processing Unit |
| DCiE | Data center infrastructure efficiency |
| DIMM | Dual in line memory module |
| DOE | Department of Energy |
| Gbps | Gigabits per second |
| HPC | High Performance Computing |
| IC | Integrated Circuit |
| IT | Information Technology |
| Key partner 1 | Clustered Systems |
| Key partner 2 | Emerson |
| Key partner 3 | Cooligy |
| KW | kilowatt |
| PAC | Project Advisory Committee |
| PIER | Public Interest Energy Research |
| PRD | Product Requirement Document |
| RD&D | Research, Development and Demonstration |
| U | Rack unit (1.75 inches) |

**Problem Statement:**

The electricity consumed in data center and telecom systems is 3 percent of the U.S. total and growing rapidly. Historically, the energy used to provide cooling for data centers is upwards of 45% of the total facility power. Over the last several years, there have been significant efforts to improve the energy used for information technology (IT) cooling by making small improvements to the cooling equipment and the control of air movement. However, moving air is energy intensive because air circuits have a high thermal resistance; hot and cold air mix in unpredictable ways; and air is simply incompatible with high density systems that are required for High Performance Computing (HPC). The approach of technology improvements to date has been to push air through ever decreasing gap sizes, but the energy required is becoming unacceptably large. Liquid circulation for cooling, on the other hand, requires only 0.5% of the 20% of IT load for air circulation, and on average less than 1/3 of the 20% to 30% of IT load used by air conditioning systems.

**Exhibit A**
**SCOPE OF WORK**

The objective of this project is to design and develop a prototype very high-density compute platform with 100% liquid cooling, using commodity components and high volume manufacturing techniques. The system will be powerful enough for HPC applications and cost-effective enough for general enterprise applications. The target is 300-400 Central Processing Units (CPU) per standard data center rack with a performance of 25 petaFLOPS (floating point operations per second) in 2010 and 50 petaFLOPS in 2011. The components to be developed include a 2 CPU compute module, a 3 rack unit (U) shelf with built in cooling, and rack plumbing. A Liebert XD pumped refrigerant platform connected to an existing cold water system will supply the coolant. When this very dense, liquid cooled computing system is coupled with a standard data center high efficiency cooling system, it will:

- Achieve a data center infrastructure efficiency (DCiE) of better than 0.85 compared to today's average DCiE of approximately 0.61.
- Be capable of effectively supporting HPC applications yet have a manufacturing cost that makes it cost-effective for mainstream applications.
- Have the capability of being cooled without the use of refrigeration systems for most of the year in the majority of U.S. locations.

The design will culminate in the construction of a prototype evaluation system consisting of two racks containing the cooling systems and approximately 350 compute modules. Development is expected to take 9-12 months. Thereafter the system will be installed at a test site and used to run production applications. Installation will be 3-4 months. All key parameters will be recorded over a 6-9 month period. In addition, system breakdowns (if any) and causes will be logged. This data will be available to the Department of Energy (DOE) and the public. As part of the commercialization phase, the site will be available for customer outreach.

**Goals of the Agreement**:
The goal of this agreement is to help develop a fundamentally new HPC architecture based upon liquid cooling and encompassing both infrastructure and equipment. It will be low cost, have a small carbon footprint, and have a design that comprehends board layout for heat transfer from the servers' internal components to ultimate dissipation of the heat to the ambient environment. Existing components, technologies and work practices will be used wherever possible. This will be done in concert with the United States Department of Energy's "Energy Efficient Information and Communication Technology" American Reinvestment and Recovery Act (ARRA) program (DE-FOA-0000107). Since this agreement has already begun with ARRA funding, this agreement will be for partial funding of Task 9.

**Objectives of the Agreement:**
The objectives of this Agreement are to accomplish the following:

- Design, build and test a compute module, blade and deflection mechanism.
- Integrate and test compute module and deflection system.
- Design and build rack with integrated refrigerant system.

- Test system without chiller at the Stanford Linear Accelerator (SLAC).

**Product Guidelines:**
For complete product guidelines, refer to Section 5 in the Terms and Conditions.

## TASK 1 ADMINISTRATION

### Task 1.1 Attend Kick-off Meeting

The goal of this task is to establish the lines of communication and procedures for implementing this Agreement.

**The Recipient shall:**

- Attend a "Kick-Off" meeting with the Commission Project Manager, the Grants Officer, and a representative of the Accounting Office. The Recipient shall bring its Project Manager, Agreement Administrator, Accounting Officer, and others designated by the Commission Project Manager to this meeting. The administrative and technical aspects of this Agreement will be discussed at the meeting. Prior to the kick-off meeting, the Commission Project Manager will provide an agenda to all potential meeting participants.

  The administrative portion of the meeting shall include, but not be limited to, the following:
  - Discussion of the terms and conditions of the Agreement
  - Discussion of Critical Project Review (Task 1.2)
  - Match fund documentation (Task 1.6)
  - Permit documentation (Task 1.7)

  The technical portion of the meeting shall include, but not be limited to, the following:
  - The Commission Project Manager's expectations for accomplishing tasks described in the Scope of Work
  - An updated Schedule of Products
  - Discussion of Progress Reports (Task 1.4)
  - Discussion of Technical Products (Product Guidelines located in Section 5 of the Terms and Conditions)
  - Discussion of the Final Report (Task 1.5)

  The Commission Project Manager shall designate the date and location of this meeting.

**Recipient Products:**

- Updated Schedule of Products
- Updated List of Match Funds

- Updated List of Permits

**Commission Project Manager Product:**

- Kick-Off Meeting Agenda

**Task 1.2 Critical Project Review (CPR) Meetings**

The goal of this task is to determine if the project should continue to receive Energy Commission funding to complete this Agreement and to identify any needed modifications to the tasks, products, schedule or budget.

CPRs provide the opportunity for frank discussions between the Energy Commission and the Recipient. CPRs generally take place at key, predetermined points in the Agreement, as determined by the Commission Project Manager and as shown in the Technical Task List above. However, the Commission Project Manager may schedule additional CPRs as necessary, and any additional costs will be borne by the Recipient.

Participants include the Commission Project Manager and the Recipient and may include the Commission Grants Officer, the Public Interest Energy Research (PIER) Program Team Lead, other Energy Commission staff and Management as well as other individuals selected by the Commission Project Manager to provide support to the Energy Commission.

If DOE is conducting similar meetings, the Recipient shall notify and invite the Commission Project Manager to participate, either by teleconference or by actual meeting attendance. The DOE required meetings can be used in place of the Commission's CPR meetings, at the discretion of the Commission Project Manager.

**The Commission Project Manager shall:**

- Determine the location, date, and time of each CPR meeting with the Recipient. These meetings generally take place at the Energy Commission, but they may take place at another location.
- Send the Recipient the agenda and a list of expected participants in advance of each CPR. If applicable, the agenda shall include a discussion on both match funding and permits.
- Conduct and make a record of each CPR meeting. One of the outcomes of this meeting will be a schedule for providing the written determination described below.
- Determine whether to continue the project, and if continuing, whether or not modifications are needed to the tasks, schedule, products, and/or budget for the remainder of the Agreement. Modifications to the Agreement may require a formal amendment (please see the Terms and Conditions). If the Commission Project Manager concludes that satisfactory progress is not being made, this conclusion will be referred to

the Energy Commission's Research, Development and Demonstration (RD&D) Policy Committee for its concurrence.

- Provide the Recipient with a written determination in accordance with the schedule. The written response may include a requirement for the Recipient to revise one or more product(s) that were included in the CPR.

**The Recipient shall:**

- Prepare a CPR Report for each CPR that discusses the progress of the Agreement toward achieving its goals and objectives. This report shall include recommendations and conclusions regarding continued work of the projects. This report shall be submitted along with any other products identified in this scope of work. The Recipient shall submit these documents to the Commission Project Manager and any other designated reviewers at least 15 working days in advance of each CPR meeting.
- Present the required information at each CPR meeting and participate in a discussion about the Agreement.
- Recipient will provide copies of any DOE correspondence (emails, reports, letters, etc.) that relate to the project status. This includes copies of project performance reviews on Recipient work and summaries and results of project review meetings with DOE.

**Commission Project Manager Products:**

- Agenda and a list of expected participants
- Schedule for written determination
- Written determination

**Recipient Product:**

- CPR Report(s)
- DOE correspondence and reporting

**Task 1.3 Final Meeting**

The goal of this task is to closeout this Agreement. If DOE is conducting a similar final meeting, the Recipient shall notify and invite the Commission Project Manager to participate, either by teleconference or by actual meeting attendance. The DOE required meeting can be used in place of the Commission's final meeting, at the discretion of the Commission Project Manager. However, all items listed in this task will need to be covered in the meeting.

**The Recipient shall:**

- Meet with Energy Commission staff to present the findings, conclusions, and recommendations. The final meeting must be completed during the closeout of this Agreement.

This meeting will be attended by, at a minimum, the Recipient, the Commission Grants Office Officer, and the Commission Project Manager. The technical and administrative aspects of Agreement closeout will be discussed at the meeting, which may be two separate meetings at the discretion of the Commission Project Manager.

The technical portion of the meeting shall present an assessment of the degree to which project and task goals and objectives were achieved, findings, conclusions, recommended next steps (if any) for the Agreement, and recommendations for improvements. The Commission Project Manager will determine the appropriate meeting participants.

The administrative portion of the meeting shall be a discussion with the Commission Project Manager and the Grants Officer about the following Agreement closeout items:

- What to do with any equipment purchased with Energy Commission funds (Options)
- Energy Commission's request for specific "generated" data (not already provided in Agreement products)
- Need to document Recipient's disclosure of "subject inventions" developed under the Agreement
- "Surviving" Agreement provisions, such as repayment provisions and confidential Products
- Final invoicing and release of retention
- Prepare a schedule for completing the closeout activities for this Agreement.
- Copies of all correspondence and reports discussing DOE's findings on the project, and future disposition of the project, if applicable. When directed by the Commission project manager, recipient will provide copies of any DOE correspondence (emails, reports, letters, etc.) that relate to project performance.

**Products:**

- Written documentation of meeting agreements
- Schedule for completing closeout activities
- DOE correspondence on project findings and results

**Task 1.4 Quarterly Progress Reports**

The goal of this task is to periodically verify that satisfactory and continued progress is made towards achieving the research objectives of this Agreement on time and within budget.

The objectives of this task are to summarize activities performed during the reporting period, to identify activities planned for the next reporting period, to identify issues that may affect performance and expenditures, and to form the basis for determining whether invoices are consistent with work performed.

With Commission Project Manager approval, the Recipient can submit a DOE Progress Report in lieu of the required Commission report if contains the information listed in Attachment 1 of the Terms and Conditions.

**The Recipient shall:**

- Prepare Quarterly Progress Reports which summarize all Agreement activities conducted by the Recipient for the reporting period, including an assessment of the ability to complete the Agreement within the current budget and any anticipated cost overruns. Each progress report is due to the Commission Project Manager within 10 days of the end of the reporting period. The recommended specifications for each progress report are contained in Exhibit A, Attachment A-2.
- Unless otherwise directed by the Commission Project Manager, each Progress Report must contain any reports made to DOE, including summaries of meetings with DOE, as they relate to the project outcome and performance. The Progress Report must include names and contacts of DOE representatives.

**Product:**

- Copies of all Quarterly Progress Reports that were submitted to DOE before the execution of this Agreement
- Quarterly Progress Reports submitted to DOE subsequent to execution of this Agreement
- Copies of DOE reporting and meeting summaries

**Task 1.5 Final Report**

The goal of the Final Report is to assess the project's success in achieving its goals and objectives, advancing science and technology, and providing energy-related and other benefits to California.

The final report shall describe the following at a minimum: a) original purpose, approach, activities performed, results and conclusions of the work done under this Agreement; b) how the project advanced science and technology to the benefit of California's ratepayers and the barriers overcome; c) assessment of the success of the project as measured by the degree to which goals and objectives were achieved; d) how the project supported California's economic recovery in the near term and number of jobs created or sustained; e) how the project results will be used by California industry, markets and others; f) projected cost reduction impact and other benefits resulting from the project; g) discuss

the project budget, including the total project cost and all the funding partners and their cost share; h) discuss how the Energy Commission funding was spent on the project, including any unique products and benefits; i) observations, conclusions and recommendations for further RD&D projects and improvements to the PIER project management process.

If a final report is required by DOE, the Recipient will include a copy of it along with the Energy Commission's final report requirements. In addition, the Recipient shall submit the draft final DOE report to the Energy Commission for review at the same time it submits it to DOE.

The Final Report shall be a public document. If the Recipient has obtained confidential status from the Energy Commission and will be preparing a confidential version of the Final Report as well, the Recipient shall perform the following activities for both the public and confidential versions of the Final Report.

**The Recipient shall:**

- Provide a draft copy of the Final Report including a copy of the draft submitted to the U.S. DOE in response to the American Recovery and Reinvestment Act Funding Opportunity Notice for which an award was received. The Final Report must be completed on or before the end of the Agreement Term.
- Submit written correspondence from DOE regarding acceptance of the final report.

**Products:**

- Draft Energy Commission Final Report, including a copy of the draft report submitted to DOE
- Energy Commission Final Report, including a copy of the final report submitted to DOE
- Written correspondence from DOE regarding acceptance of final report

**Task 1.6 Identify and Obtain Matching Funds**

The goal of this task is to ensure that the match funds planned for this Agreement are obtained for and applied to this Agreement during the term of this Agreement.

The costs to obtain and document match fund commitments are not reimbursable through this Agreement. Although the PIER budget for this task will be zero dollars, the Recipient may utilize match funds for this task. Match funds shall be spent concurrently or in advance of PIER funds for each task during the term of this Agreement. Match

funds must be identified in writing and the associated commitments obtained before the Recipient can incur any costs for which the Recipient will request reimbursement.

**The Recipient shall:**

- Prepare a letter documenting the match funding committed to this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. The letter needs to identify the following at a minimum:
  - Amount of each cash match fund, its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied.
  - Amount of each in-kind contribution, a description, documented market or book value, and its source, including a contact name, address and telephone number and the task(s) to which the match funds will be applied. If the in-kind contribution is equipment or other tangible or real property, the Recipient shall identify its owner and provide a contact name, address and telephone number, and the address where the property is located.
- Provide a copy of the letter of commitment from an authorized representative of each source of cash match funding or in-kind contributions that these funds or contributions have been secured.
- Discuss match funds and the implications to the Agreement if they are reduced or not obtained as committed, at the kick-off meeting. If applicable, match funds will be included as a line item in the progress reports and will be a topic at CPR meetings.
- Provide the appropriate information to the Commission Project Manager if during the course of the Agreement additional match funds are received.
- Notify the Commission Project Manager within 10 days if during the course of the Agreement existing match funds are reduced. Reduction in match funds must be approved through a formal amendment to the Agreement and may trigger an additional CPR.

**Products:**

- A letter regarding match funds
- Copy(ies) of each match fund commitment letter(s)
- Letter(s) for new match funds (if applicable)
- Letter that match funds were reduced (if applicable)

**Task 1.7 Identify and Obtain Required Permits**

The goal of this task is to obtain all permits required for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track.

Permit costs and the expenses associated with obtaining permits are not reimbursable under this Agreement. Although the PIER budget for this task will be zero dollars, the Recipient shall budget match funds for any expected expenditures associated with obtaining permits. Permits must be identified in writing and obtained before the Recipient can make any expenditures for which a permit is required.

**The Recipient shall:**

- Prepare a letter documenting the permits required to conduct this Agreement and submit it to the Commission Project Manager at least 2 working days prior to the kick-off meeting. If there are no permits required at the start of this Agreement, then state such in the letter. If it is known at the beginning of the Agreement that permits will be required during the course of the Agreement, provide in the letter:
  - A list of the permits that identifies the:
    - Type of permit
    - Name, address and telephone number of the permitting jurisdictions or lead agencies
  - The schedule the Recipient will follow in applying for and obtaining these permits.
- Discuss the list of permits and the schedule for obtaining them at the kick-off meeting and develop a timetable for submitting the updated list, schedule and the copies of the permits. The implications to the Agreement if the permits are not obtained in a timely fashion or are denied will also be discussed. If applicable, permits will be included as a line item in the Progress Reports and will be a topic at CPR meetings.
- If during the course of the Agreement additional permits become necessary, provide the appropriate information on each permit and an updated schedule to the Commission Project Manager.
- As permits are obtained, send a copy of each approved permit to the Commission Project Manager.
- If during the course of the Agreement permits are not obtained on time or are denied, notify the Commission Project Manager within 5 working days. Either of these events may trigger an additional CPR.

**Products:**

- Letter documenting the permits or stating that no permits are required
- A copy of each approved permit (if applicable)
- Updated list of permits as they change during the term of the Agreement (if applicable)
- Updated schedule for acquiring permits as changes occur during the term of the Agreement (if applicable)

## TECHNICAL TASKS

The Recipient has completed Tasks 2 through 8 which were funded by ARRA. The Recipient must complete Tasks 9 through 10. This Agreement will fund Task 9.

## TASK 2.0 DEVELOP DETAILED SPECIFICATION OF THE SYSTEM AND ITS COMPONENTS

Task 2.0 has already been completed. The goal of this task was to create a product requirement document (PRD) and an engineering specification, which was derived from the former. The PRD involved key partner 1 (Clustered Systems) interviewing a sample set of customers with different applications requirements as well as soliciting input from CPU and dual in line memory module (DIMM) vendors.

**The Recipient Has:**

- Created two documents, a product requirement document (PRD) and an engineering specification.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

## TASK 3.0 DESIGN, BUILD AND TEST COMPUTE MODULE

Task 3.0 has already been completed. The goal of this task was to design and build a test compute module (blade server), which is a card approximately 5” x 16” with 2 CPUs and 4 memory slots.

**The Recipient Has:**

- Designed and built a test compute module (blade server). The CPUs are the latest Intel Xeon models and were loaned to the program for three years by key partner 1. The board has a Gigabit Ethernet network connection and Infiniband. The elimination of air as the heat removal medium offers another degree of freedom to the designer, permitting components to be in closer proximity. This may create other issues such as noise interference between integrated circuits (IC). The CPU and memory segment are the most sensitive to these effects. Besides developing the card, a set of design rules were developed for future projects. Other issues addressed include DIMM configuration (standard or custom) and positioning. As they are potentially the tallest devices on the board, special sockets are required to lower them. Testing required heat risers attached to the CPUs and a cold plate impressed on top to remove the heat. Key partner 1 supplied a simple water-based cold plate to provide adequate cooling while the board was “brought up” and debugged.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

## TASK 4.0 DESIGN, BUILD AND TEST A SINGLE BLADE AND DEFLECTION MECHANISM

Task 4.0 has already been completed. The goal of this task was to apply the flexible plate technology employed in the 1U servers (previously funded in the PIER Energy Innovation Small Grant project 06-03-24) to the compute module, or blade server, built in Task 3.

**The Recipient Has:**

- Applied the flexible plate technology employed in the 1U servers. The main difference with the 1U servers is a much higher heat load per plate. Measurements have shown that the tubing used in current projects have sufficient capacity. Some experimentation was required to determine the optimum pressures and configuration in order to minimize space and maximize the number of modules in a 3U shelf.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

## TASK 5.0 DESIGN AND BUILD HEAT RISERS

Task 5.0 has already been completed. The goal of this task was to design the heat risers from blocks of aluminum to conduct heat from ICs to the cooling plate.

**The Recipient Has:**

- Designed the heat risers from blocks of aluminum to conduct heat from ICs to the cooling plate. Aluminum heat pipes could also be designed if Original Equipment Manufacturer's wished to save weight during volume production.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

## TASK 6.0 DESIGN AND BUILD COOLING CRATE AND HOUSING, TEST WITH HEAT SOURCE

Task 6.0 has already been completed. The goal of this task was to assemble the cooling plates and associated deflection mechanisms into the crate, then pressure test and charge with refrigerant.

**The Recipient Has:**

- Assembled the cooling plates and associated deflection mechanisms into the crate, then pressure tested and charged with refrigerant. Testing of single daughter card positions was done in a key partner 1 facility and full load testing

at the key partner 2 (Emerson) lab. A cooling capability of one kilowatt (KW) per daughter card position was demonstrated and the refrigerant was evenly distributed to all positions.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**Task 6.1 Test crate with modules and switch cards**

Task 6.1 has been completed. The goal of this task was to perform a bench test of a single shelf at key partner 1 and then key partner 2 labs.

**The Recipient Has:**

- Performed a bench test of a single shelf at two key partner's labs.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**Task 6.2 Integrate compute module and deflection mechanism with crate**

Task 6.2 has been completed. The goal of this task was to test the compute module separately and then in conjunction with the deflection mechanism to confirm operation.

**The Recipient Has:**

- Tested the compute module separately and then in conjunction with the deflection mechanism to confirm operation. MILESTONE: Passing this test was necessary prior to releasing the next build of modules and mechanisms.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**TASK 7.0 DESIGN AND BUILD RACK WITH INTEGRATED REFRIGERANT DISTRIBUTION SYSTEM**

Task 7.0 has already been completed. The goal of this task was to construct a rack integrated with the refrigerant distribution system.

**The Recipient Has:**

- Constructed a rack integrated with the refrigerant distribution system. The issue was the piping diameter and fitting the pipes within the rack. MILESTONE: A successful test of a single crate (chassis) and 12 cold plates. The cooling plates and crate (chassis) were integrated and heaters attached to each cooling plate.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**TASK 8.0 BUILD 12 SHELVES AND INTEGRATE WITH RACK, TEST WITH STANDARD LIEBERT XDP PUMP AND HEAT EXCHANGER SYSTEM CONNECTED TO A CHILLER**

Task 8.0 has already been completed. The goals of this task were to build 12 compute modules with deflection mechanisms and heat riser kits and test the system.

**The Recipient Has:**

- Built 12 compute modules, deflection mechanisms and heat riser kits.
- Manufactured a 1 gigabit per second (Gbps) switched backplane card and midplane card.
- Integrated the deflection mechanisms with the chassis and loaded the modules and 1Gbps switch into an integrated rack.
- Installed a Liebert XDP and chiller at a key partner 3 (Cooligy) site.
- Tested the integrated rack system connected to a chiller with dummy loads to confirm that refrigerant is evenly distributed among all the shelves. A capacity of 160KW was demonstrated. MILESTONE: The rack was built out chassis by chassis and tested. The rack consists of 144 compute modules (blades), volume heat risers, twelve 1 Gbps cards, and one bulk 208 VAC to 350 VDC converter.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**Task 8.1 Acquire bulk converter for power supply**

Task 8.1 has already been completed. The goal of this task was to complete the rack connected to a chiller.

**The Recipient Has:**

- Adapted the power supply to be cooled by contact. 120 KW is required.

**Products:**

- Note: Progress Reports Submitted to the Energy Commission per Task 1.4

**TASK 9.0 TEST SYSTEM WITH FULL COMPLEMENT OF BLADES**

The goal of this task is to confirm a cooling energy reduction of at least 20% compared with a traditional 1U system of the same compute capability. In addition, due to the use of right sized power supplies, power supply efficiency should increase by 1-2%. Using the Liebert XDP with chiller set at minimum temperature will allow the potential for over clocking to be explored. At the other end of the spectrum, refrigerant temperatures

could be allowed to increase to 30$^{o}$C in order to simulate hot day operation without chiller.

**The Recipient Shall:**

- Test the fully constructed rack system for energy reduction compared to a traditional 1U system with the same compute power at a key partner 1 facility.

**Task 9.1 Build and test second rack**

The goal of this subtask is to confirm the results of the test at a key partner 1 facility. A second rack with a Liebert XDP and chiller will be built and tested at key partner 2 lab.

**The Recipient Shall:**

- Build a second rack to be transferred to the key partner 2 lab.
- Test the fully constructed rack system for energy reduction compared to a traditional 1U system with the same compute power at key partner 2 lab.
- Prepare rack system test reports from the key partner's facilities.

**Products:**

- Rack system test reports from the key partner 1facility (no draft)
- Rack system test report from the second key partner 2 lab (no draft)

**TASK 10.0 TEST SYSTEM WITHOUT CHILLER**

**The Recipient Shall:**

- Test the system at a site that does not use chillers. Optimally the test should last one year during which time it can be monitored, debugged and improved if necessary. Totally eliminating the chiller could reduce cooling energy by 22% to 36%.
- Prepare a test report on chillerless system.

**Products:**

- Test report on chillerless  system (no draft)