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Grant Application Package

Opportunity Title:	Recovery Act: Energy Efficient Information and
Offering Agency:	Golden Field Office
CFDA Number:	81.086
CFDA Description:	Conservation Research and Development
Opportunity Number:	DE-FOA-0000107
Competition ID:	
Opportunity Open Date:	06/02/2009
Opportunity Close Date:	07/21/2009
Agency Contact:	Anne Elkins Grants & Agreements Specialist E-mail: ITP_ITC@go.doe.gov

This electronic grants application is intended to be used to apply for the specific Federal funding opportunity referenced here.

If the Federal funding opportunity listed is not the opportunity for which you want to apply, close this application package by clicking on the "Cancel" button at the top of this screen. You will then need to locate the correct Federal funding opportunity, download its application and then apply.

☐ **I will be submitting applications on my behalf, and not on behalf of a company, state, local or tribal government, academia, or other type of organization.**

*** Application Filing Name:** Hewlett-Packard

Mandatory Documents		Mandatory Documents for Submission
	Move Form to Complete	Application for Federal Assistance (SF-424) Project/Performance Site Location(s) Other Attachments Form
	Move Form to Delete	

Optional Documents		Optional Documents for Submission
	Move Form to Submission List	Disclosure of Lobbying Activities (SF-LLL)
	Move Form to Delete	

Instructions

1 Enter a name for the application in the Application Filing Name field.

- This application can be completed in its entirety offline; however, you will need to login to the Grants.gov website during the submission process.
- You can save your application at any time by clicking the "Save" button at the top of your screen.
- The "Save & Submit" button will not be functional until all required data fields in the application are completed and you clicked on the "Check Package for Errors" button and confirmed all data required data fields are completed.

2 Open and complete all of the documents listed in the "Mandatory Documents" box. Complete the SF-424 form first.

- It is recommended that the SF-424 form be the first form completed for the application package. Data entered on the SF-424 will populate data fields in other mandatory and optional forms and the user cannot enter data in these fields.

- The forms listed in the "Mandatory Documents" box and "Optional Documents" may be predefined forms, such as SF-424, forms where a document needs to be attached, such as the Project Narrative or a combination of both. "Mandatory Documents" are required for this application. "Optional Documents" can be used to provide additional support for this application or may be required for specific types of grant activity. Reference the application package instructions for more information regarding "Optional Documents".

- To open and complete a form, simply click on the form's name to select the item and then click on the => button. This will move the document to the appropriate "Documents for Submission" box and the form will be automatically added to your application package. To view the form, scroll down the screen or select the form name and click on the "Open Form" button to begin completing the required data fields. To remove a form/document from the "Documents for Submission" box, click the document name to select it, and then click the <= button. This will return the form/document to the "Mandatory Documents" or "Optional Documents" box.

- All documents listed in the "Mandatory Documents" box must be moved to the "Mandatory Documents for Submission" box. When you open a required form, the fields which must be completed are highlighted in yellow with a red border. Optional fields and completed fields are displayed in white. If you enter invalid or incomplete information in a field, you will receive an error message.

3 Click the "Save & Submit" button to submit your application to Grants.gov.

- Once you have properly completed all required documents and attached any required or optional documentation, save the completed application by clicking on the "Save" button.
- Click on the "Check Package for Errors" button to ensure that you have completed all required data fields. Correct any errors or if none are found, save the application package.
- The "Save & Submit" button will become active; click on the "Save & Submit" button to begin the application submission process.
- You will be taken to the applicant login page to enter your Grants.gov username and password. Follow all onscreen instructions for submission.

OMB Number: 4040-0004
Expiration Date: 01/31/2009

Application for Federal Assistance SF-424

Version 02

* 1. Type of Submission:
- [ ] Preapplication
- [x] Application
- [ ] Changed/Corrected Application

* 2. Type of Application:
- [x] New
- [ ] Continuation
- [ ] Revision

* If Revision, select appropriate letter(s):

* Other (Specify)

* 3. Date Received: Completed by Grants.gov upon submission.

4. Applicant Identifier:

5a. Federal Entity Identifier:

* 5b. Federal Award Identifier:

State Use Only:

6. Date Received by State:

7. State Application Identifier:

8. APPLICANT INFORMATION:

* a. Legal Name: Hewlett-Packard Company

* b. Employer/Taxpayer Identification Number (EIN/TIN): REDACTED EXEMPTION 4

* c. Organizational DUNS: 134303192

d. Address:

* Street1: 11445 Compaq Center Drive West
Street2:
* City: Houston
County: Harris
* State: TX: Texas
Province:
* Country: USA: UNITED STATES
* Zip / Postal Code: 77070

e. Organizational Unit:

Department Name: Shared Engineering Services

Division Name: Industry Standard Servers

f. Name and contact information of person to be contacted on matters involving this application:

Prefix: Mr.
* First Name: Ron
Middle Name:
* Last Name: Mann
Suffix:

Title: Director, Enterprise Infrastructure Solutions

Organizational Affiliation: Enterprise Servers and Storage

* Telephone Number: 281-514-2976
Fax Number: 281-518-1560

* Email: ron.mann@hp.com

OMB Number: 4040-0004
Expiration Date: 01/31/2009

Application for Federal Assistance SF-424 Version 02

9. Type of Applicant 1: Select Applicant Type:

Q: For-Profit Organization (Other than Small Business)

Type of Applicant 2: Select Applicant Type:

X: Other (specify)

Type of Applicant 3: Select Applicant Type:

* Other (specify):

App 2: for-profit org.

*** 10. Name of Federal Agency:**

Golden Field Office

11. Catalog of Federal Domestic Assistance Number:

81.086

CFDA Title:

Conservation Research and Development

*** 12. Funding Opportunity Number:**

DE-FOA-0000107

* Title:

Recovery Act: Energy Efficient Information and Communication Technology

13. Competition Identification Number:

Title:

14. Areas Affected by Project (Cities, Counties, States, etc.):

Houston, Harris County, Texas
Raleigh, Wake County, North Carolina
Columbus, Franklin County, Ohio
Milwaukee, Milwaukee County, Wisconsin
St. Louis, St. Louis County, Missouri

*** 15. Descriptive Title of Applicant's Project:**

Adaptive Environmentally Contained Power and Cooling IT Infrastructure for the Data Center

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

OMB Number: 4040-0004
Expiration Date: 01/31/2009

Application for Federal Assistance SF-424

Version 02

16. Congressional Districts Of:

* a. Applicant: TX-007

* b. Program/Project: TX-007

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 01/04/2010

* b. End Date: 01/06/2012

18. Estimated Funding ($):

* a. Federal	7,432,100.00
* b. Applicant	1,858,025.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	9,290,125.00
* g. TOTAL	18,580,250.00

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on .

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes", provide explanation.)**

☐ Yes ☒ No Explanation

21. *By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

Authorized Representative:

Prefix: Mr. * First Name: Michael

Middle Name: J.

* Last Name: Mason

Suffix:

* Title: Public Sector - Contracts Manager

* Telephone Number: 321-252-6406 Fax Number: 866-205-5390

* Email: michael.mason@hp.com

* Signature of Authorized Representative: Completed by Grants.gov upon submission. * Date Signed: Completed by Grants.gov upon submission.

OMB Number: 4040-0004
Expiration Date: 01/31/2009

Application for Federal Assistance SF-424 Version 02

*** Applicant Federal Debt Delinquency Explanation**

The following field should contain an explanation if the Applicant organization is delinquent on any Federal Debt. Maximum number of characters that can be entered is 4,000. Try and avoid extra spaces and carriage returns to maximize the availability of space.

Other Attachment File(s)

*** Mandatory Other Attachment Filename:** Project.pdf

Add Mandatory Other Attachment | Delete Mandatory Other Attachment | View Mandatory Other Attachment

To add more "Other Attachment" attachments, please use the attachment buttons below.

Add Optional Other Attachment | Delete Optional Other Attachment | View Optional Other Attachment

OMB Number: 4040-0010
Expiration Date: 08/31/2011

Project/Performance Site Location(s)

Project/Performance Site Primary Location ☐ I am submitting an application as an individual, and not on behalf of a company, state, local or tribal government, academia, or other type of organization.

Organization Name: Hewlett-Packard Company

DUNS Number: 1343031920000

* Street1: 1501 Page Mill Rd.

Street2:

* City: Palo Alto County: Santa Clara

* State: CA: California

Province:

* Country: USA: UNITED STATES

* ZIP / Postal Code: 94304-1100 * Project/ Performance Site Congressional District: CA-014

Project/Performance Site Location 1 ☐ I am submitting an application as an individual, and not on behalf of a company, state, local or tribal government, academia, or other type of organization.

Organization Name: Hewlett-Packard Company

DUNS Number: 1343031920000

* Street1: 11445 Compaq Center Drive West

Street2:

* City: Houston County: Harris

* State: TX: Texas

Province:

* Country: USA: UNITED STATES

* ZIP / Postal Code: 77070-1433 * Project/ Performance Site Congressional District: TX-007

DISCLOSURE OF LOBBYING ACTIVITIES

Complete this form to disclose lobbying activities pursuant to 31 U.S.C.1352

Approved by OMB
0348-0046

1. * Type of Federal Action:
- [ ] a. contract
- [x] b. grant
- [ ] c. cooperative agreement
- [ ] d. loan
- [ ] e. loan guarantee
- [ ] f. loan insurance

2. * Status of Federal Action:
- [ ] a. bid/offer/application
- [x] b. initial award
- [ ] c. post-award

3. * Report Type:
- [x] a. initial filing
- [ ] b. material change

4. Name and Address of Reporting Entity:

[x] Prime [ ] SubAwardee

*Name: Hewlett-Packard Company - Not Applicable

*Street 1: Street 2:

*City: State: TX: Texas Zip:

Congressional District, if known:

5. If Reporting Entity in No.4 is Subawardee, Enter Name and Address of Prime:

6. * Federal Department/Agency:

7. * Federal Program Name/Description:

Conservation Research and Development

CFDA Number, *if applicable:* 81.086

8. Federal Action Number, *if known:*

9. Award Amount, *if known:*

$

10. a. Name and Address of Lobbying Registrant:

Prefix: *First Name: Middle Name:

*Last Name: Suffix:

*Street 1: Street 2:

*City: State: Zip:

b. Individual Performing Services (including address if different from No. 10a)

Prefix: *First Name: Middle Name:

*Last Name: Suffix:

*Street 1: Street 2:

*City: State: Zip:

11. Information requested through this form is authorized by title 31 U.S.C. section 1352. This disclosure of lobbying activities is a material representation of fact upon which reliance was placed by the tier above when the transaction was made or entered into. This disclosure is required pursuant to 31 U.S.C. 1352. This information will be reported to the Congress semi-annually and will be available for public inspection. Any person who fails to file the required disclosure shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

*** Signature:** Completed on submission to Grants.gov

***Name:** Prefix: *First Name: Middle Name:

*Last Name: Suffix:

Title: **Telephone No.:** **Date:** Completed on submission to Grants.gov

Federal Use Only:

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Standard Form - LLL (Rev. 7-97)

PROJECT SUMMARY/ABSTRACT

Name of Applicant: Hewlett-Packard Company (HP)

Project Director/Principal Investigators:
Ron M. Mann, PI for HP (281-514-2976); **Miguel E. Chavez**, Co-PI for Eaton (919 878-6080)

Project Title:
Adaptive Environmentally Contained Power and Cooling IT Infrastructure for the Data Center

Project Objective:
There have been a limited number of demonstrations of high voltage AC and high voltage DC power distribution systems in the data center—the most visible was the demonstration conducted by LBNL at a SUN data center. There have also been a limited number of demonstrations of high efficiency cooling systems— the most visible was the Chill-Off conducted by LBNL and the Silicon Valley Leadership Group. There are no known, published studies of the creation of a power and cooling monitoring and management software solution. The cited independent studies have revealed a number of issues related to safety, supply chain, implementation, commercialization, and market acceptance that currently hamper commercialization of these solutions. No known studies have conducted the necessary research to address the issues identified in these and other key studies related to power distribution and cooling in the data center that will allow for successful commercialization of these solutions.

HP and Eaton have teamed and are proposing to conduct the necessary R&D, testing, manufacturing, market analysis, and commercialization of a complete end-to-end power and cooling solution for data centers in the target size of 100 kW. The proposed solution targets the largest segment of the US data center market, i.e., the Small Medium Business segment. This strategy will allow the greatest impact on the energy consumption and greenhouse gas emissions by the US data center market.

Description of Project:

a. **Methods to be Employed:** The system will incorporate high voltage AC and chilled water as the primary inputs into the system, but will also accept alternative energy power sources, such as wind and solar. For maximum efficiency, the system will use distributed high voltage DC power internally from the power source to the IT loads. The management system will aggressively manage energy use to insure the best use of available power and cooling resources based on factors such as grid demand signals, peak demand usage times, and availability/strength of alternative sources of energy. The solution will also incorporate active management controls that not only optimize the system environment for the given dynamic IT loads and change system conditions, but also interface with data center management systems to provide a complete end-to-end view of the power and cooling chain.

b. **Project Results/Benefits:** The major deliverables for this proposal are:

- Modular/deployable mechanical infrastructure in 100KW increments
- High efficiency power distribution system
- High efficiency closed loop cooling system
- Alternative energy HW/SW interface
- DC battery back-up system
- Power and cooling management/control at the system and data center level

The major benefits of this solution are:

- Thirty eight (38%) reduction in energy use resulting in ~400 ton yearly reduction in C02 emissions.
- Ability to deploy high density IT rack instances (12-25KW/rack) up to 100KW per system.
- Ability for the customer to deploy in any type of compute environment
- Reduces overall energy consumption for current industry standard IT compute and storage equipment

c. **Major Participants (for collaborative projects):** HP and Eaton Corporation

DOE_PMP.mpp

ID	Task Name	Duration	Start	Finish	Predecessors
1	Program Start	0 days	Mon 1/4/10	Mon 1/4/10	
2					
3					
4					
5					
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54					
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56					
57					
58					
59					
60					58FS+1 wk
61					
62					
63					
64					
65					62,63,64
66					65
67					

ID	Task Name	Duration	Start	Finish	Predecessors
68					
69					
70					
71					
72					
73					
74					

REDACTED
EXEMPTION 4

Applicant Name: Hewlett-Packard Corporation

Announcement Number: DE-FOA-0000107

Representation of Limited Rights Data and Restricted Computer Software

(a) Any data delivered under an award resulting from this announcement is subject to the Rights in Data – General or the Rights in Data – Programs Covered Under Special Data Statutes clause (See Intellectual Property Provisions at http://www.gc.energy.gov/financial_assistance_awards.htm). Under these clauses, the Recipient may withhold from delivery data that qualify as limited rights data or restricted computer software. As an aid in determining the Government's need to include Alternate I and/or Alternate II in these clauses, which allow for delivery of limited rights data and/or restricted computer software, the applicant must complete paragraph (b) below to either state that none of the data involved in the proposed work effort qualify as limited rights data or restricted computer software, or identify, to the extent feasible, which of the data qualifies as limited rights data or restricted computer software. Any identification of limited rights data or restricted computer software in this application is not determinative of the status of such data should an award be made.

(b) The applicant has reviewed the proposed work effort and the requirements for the delivery of data or software and states:

☐ None of the data proposed for fulfilling such requirements qualifies as limited rights data or restricted computer software.

☒ Data proposed for fulfilling such requirements qualify as limited rights data or restricted computer software and are identified as follows:

– US Patent REDACTED EXEMPTION 4 **Other intellectual property:**

Note: "limited rights data" and "restricted computer software" are defined in provision "Rights in Data – General."

Applicant Name: Eaton Corporation

Announcement Number: DE-FOA-0000107

Representation of Limited Rights Data and Restricted Computer Software

(a) Any data delivered under an award resulting from this announcement is subject to the Rights in Data – General or the Rights in Data – Programs Covered Under Special Data Statutes clause (See Intellectual Property Provisions at http://www.gc.energy.gov/financial_assistance_awards.htm). Under these clauses, the Recipient may withhold from delivery data that qualify as limited rights data or restricted computer software. As an aid in determining the Government's need to include Alternate I and/or Alternate II in these clauses, which allow for delivery of limited rights data and/or restricted computer software, the applicant must complete paragraph (b) below to either state that none of the data involved in the proposed work effort qualify as limited rights data or restricted computer software, or identify, to the extent feasible, which of the data qualifies as limited rights data or restricted computer software. Any identification of limited rights data or restricted computer software in this application is not determinative of the status of such data should an award be made.

(b) The applicant has reviewed the proposed work effort and the requirements for the delivery of data or software and states:

☐ None of the data proposed for fulfilling such requirements qualifies as limited rights data or restricted computer software.

☒ Data proposed for fulfilling such requirements qualify as limited rights data or restricted computer software and are identified as follows:

See attached sheet.

EATON CORPORATION
COMPANY CONFIDENTIAL
19-Jul-09

This list has been compiled in advance of Eaton's partner's response to DOE Solicitation DE-FOA-0000107

The following contains proprietary information that Eaton Corporation requests not be released to persons outside the Government, except for purposes of review and evaluation.

List of Intellectual Property under development, expected to be disclosed and filed before 31-Oct-09. **Status**

REDACTED
EXEMPTION 4

Other Intellectual Property

REDACTED
EXEMPTION 4

List of Patents Applied for, not yet issued, that may be applicable to proposed project

PDS Number	Country	Filing Type	Application Number	Title	Status

REDACTED
EXEMPTION 4

Note: "limited rights data" and "restricted computer software" are defined in provision "Rights in Data – General."

List of Intellectual Property under development, expected to be disclosed and filed before 31-Oct-09.

1

2

3

4

REDACTED
EXEMPTION 4

Other Intellectual Property

1

2

3

4

5

REDACTED
EXEMPTION 4

Hewlett-Packard Company
20555 State Highway 249
Houston, TX 77070
www.hp.com

Ron Noblett
Vice President of Engineering
Shared Engineering Services

281.514.2976 Tel
281.536.5813 Mobile
Ron.Mann@hp.com

July 21, 2009

U.S. Department of Energy
Golden Field Office
1617 Cole Boulevard
Golden, Colorado 80401-3393
ITP_ITC@go.doe.gov

RE: Recovery Act: Energy Efficient Information and Communication Technology - Pre-application/Intent to Bid, Announcement DE-FOA-0000107

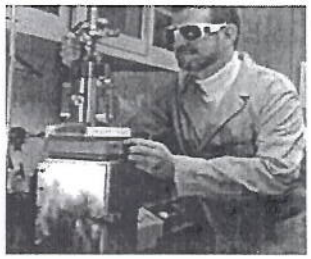
As requested on your FedConnect submittal site for this opportunity, I am providing a document with my signature to assure the DOE that I am in a position to contractually bind Hewlett-Packard (HP) on our bid with Eaton Corporation on the energy efficient information and technology funding opportunity provided through the Recovery Act by DOE.

Sincerely,

Ron Noblett
Vice President, Shared Engineering Services
Hewlett Packard Corporation

Hewlett-Packard's Proposal to the U.S. Department of Energy, Golden Field Office for the Recovery Act: Energy Efficient Information and Communication Technology Funding Opportunity





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Non Disclosure - FAR 52.215-1, Restriction on Disclosure and Use of Data (Oct 1997)

PROJECT NARRATIVE

1. Project Objectives

This program will research and develop a fully enclosed IT rack system that will provide it owns internal power and cooling with high voltage AC (400v-480v) and chilled water as the primary inputs into the system and will also accept alternative energy power sources such as wind and solar. For maximum efficiency, internal power to the IT equipment will use distributed high voltage DC power from the power source to the IT loads. The management scheme will aggressively control energy use to insure the best utilization of available power and cooling resources based upon factors such as grid demand signals, peak demand usage times, and availability/strength of alternative sources of energy. The solution will also incorporate internal active management controls that not only optimize the system environment for the given dynamic IT loads and changing system conditions, but also interface with data center management systems to provide a complete end-to-end view of power and cooling chain.

Elements from the above described systems have been under investigation by Eaton and HP over the past year. Due to current economic conditions, it is becoming increasingly difficult to perform this type of new research and development due to limited development funds and competition with other research and development areas related to current mainstream IT products for both companies. If awarded, these grant funds will accelerate the research and development of the specified elements in power and cooling by not only bringing the proposed solution to market within a two year program time frame, but also advancing general research and development in these key power and cooling areas.

The major deliverables for this proposal are:

- Modular/deployable mechanical infrastructure
- High efficiency power distribution system
- High efficiency closed loop cooling system
- Alternative energy Hardware/Software interface
- DC battery back-up system
- Power and cooling management/control at the system and data center level

Other Selection Factors (Reference: V.A.3.ii)

The technology outlined in this proposal will result in a 38% reduction in the amount of energy needed to support a 100KW IT load compared to current data center design. This will result in a 396 ton yearly reduction in CO2 emissions. If this technology is widely adopted by data centers in the United States, it would severely reduce the CO2 emissions associated with the current 60 billion kWh per year energy consumption of US data centers.

2. Merit Review Criterion Discussion

Criterion 1: Technical Merit

a. Overview

There have been many debates within the ICT industry with respect to improvement of data center energy efficiency. Industry stakeholders have made numerous comparisons illustrating relative efficiency improvements of one system over another. But a failure to examine the entire system has resulted in conflicting conclusions. One must examine the total conversion process from the utility voltage to the voltage needed by the server CPU with respect to cost, power distribution, safety isolation, backup, redundancy, cooling and total system reliability. Increased end-to-end power conversion and cooling efficiency will reduce energy losses, thereby improving overall data center efficiency and reduction in Greenhouse Gas emissions. For power this means reducing the total number of conversions to as few as possible and making those that remain as efficient as possible. For cooling, this means distributing the appropriate amount of air at the required temperature as close to the load as possible and removing the heat generated as efficiently as possible. Further, to be able to dynamically control those factors as load use changes.

1.1 Existing Environment

If we examine the total power conversion process from 480V delta utility voltage to the 1.x volts DC needed by the server CPU, we discover that higher distribution voltages will have lower I^2R losses resulting in higher efficiency. The low voltage and high current needed by the server CPU suggests the power conversion to 1.x volts will be logistically close to the CPU.

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EXEMPTION 4

The cooling system for this proposal builds on the technology developed for the HP Modular Cooling System and Performance Optimized Data Center container solutions and adapts it for use in this application. The basic concept is to use air in a closed-loop, contained environment and only supply what is needed for the IT equipment, thus preventing any cool air from being distributed where it is not needed and wasted.

Next is to use water with a dual heat exchanger configuration to cool the IT equipment hot air exhaust and remove the heat through a water return (see ***Figure 6***). The cooling unit will be located in the center of the unit, distributing cool air on either side. The number of rack bays on either side of the cooling unit can involve two, three, or four units, cooling a maximum of 100KW. The air and water flow will be dynamically controlled with a software control system that will automatically adjust based on the actual power demand of the installed IT equipment. This ensures optimized cooling by establishing a direct relationship between the IT loads and cooling system. To further optimize energy use, the air inlet temperature will be customer-configurable to allow for higher inlet air temperatures up to the specified IT equipment maximum temperatures (typically specified at 35 degrees Celsius). Studies show that raising chilled water temperature by 1C reduces the power consumption of the chiller plant by approximately 3.5%. Thus, significant reductions in data center energy consumption will be achieved if the ICT equipment inlet air temperature is raised above the ASHRAE TC9.9 recommended upper limit of 27C.

1.2 Statement of Project Objectives

The proposed R&D effort is aimed at dramatically raising the energy efficiency of the small and medium data center market., that make up the bulk of the US data center industry. For the targeted data centers, the baseline PUE is known to be 2.04 (Sullivan, 2009)[1], while the proposed effort aims to lower the PUE to 1.25. This will be accomplished via R&D in the following areas:

- High efficiency power distribution path from the utility through to the servers
- High efficiency cooling system
- Distributed power generation at the system unit level
- Dynamic Power and Cooling monitoring and control software for total system optimization

HP further proposes to develop an energy management system that will tie together demand/curtailment and Time of Use (TOU) pricing signals to the power states of the downstream IT loads as well as an alternative power interface for wind and solar. This is discussed in more detail in ***Sections 1.3.3*** and ***1.3.4***.

Further details of the specific areas for the proposed research and development are provided in the following section.

1.3 Proposed Research and Development

The proposed research and development will produce a complete closed loop 100KW power and cooling system incorporating high efficiency AC and DC power systems, a high efficiency closed loop cooling system, dynamic software management and control that will automatically adjust to changing IT load conditions, and compatibility for incorporation of alternative energy systems. Additionally, this system will be easily deployable in current data centers, Greenfield data centers, non raised floor environments, as well as remote locations. The IT rack elements will be independent of the power and cooling elements allowing for complete flexibility of IT configurations within the 100KW maximum system capacity.

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EXEMPTION 4

1.3.2 High Efficiency Cooling System

Develop a closely coupled cooling architecture that supports increments of up to 100KW in a single instance, and that is managed aggressively to lower fan energy needed to cool ICT, and water flow/consumption needed to transport the rejected heat of the ICT gear. HP will design a free-standing enclosure that can house up to eight (8) independent IT cabinets (fig.5), and includes a closely coupled cooling solution. Each IT cabinet can support up from 12.5KW to 25KW of IT load depending upon the number of IT racks utilized. Cooling will be integrated into the concept, and no outside cooling capacity would be needed. Key to this new design will be the management of cooling fan energy through the use of both temperature and differential pressure sensing which is used to manage cooling fan speed. By slowing the fan speeds to match the cooling needs of the IT load specifically, we expect to be able to lower energy consumption significantly (***Figure 6***). As all systems are entirely enclosed in a modular shell, no cooling losses to the outside can occur. This will significantly contribute to a much lower PUE score.

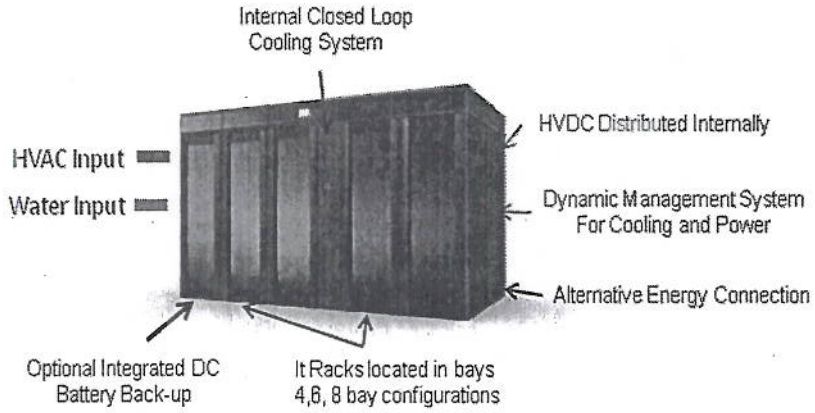

Figure 5. Contained Power and Cooling IT Infrastructure. *Complete system showing major components.*

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1.3.3 Energy Demand and Efficiency Management

Current datacenters represent fairly large, static loads to the upstream Utility provider. These loads are many times considered "Mission-Critical", and owners are generally risk averse when it comes to purposefully moving their loads from utility to generators in order to participate in Utility Demand Response/Curtailment programs. To address this issue, we propose to develop and energy management system that ties together demand/curtailment and Time of Use (TOU) pricing signals to the power states

of the downstream IT loads. This will allow load to be shed more reliably and safely. Further, by reacting to pricing signals, the system will be able to direct the use of stored energy sources. Another aspect of this management system would be the "on the fly" management capabilities of energy consumption by the cooling system, and the ICT hardware itself. We would research how to link the power management capabilities of the ICT hardware to the environmental management capabilities of the cooling solution, and the switching in of on-site generation capacity to further improve the overall energy efficiency and consumption of the solution.

1.3.4 Distributed Power Generation

Research has shown that with traditional central power plants, e.g., coal-fired plants, approximately 33% of the fuel input at the power plant arrives as useful energy at the data center (Scheihing, 2008) [2]. The 67% total losses are incurred through inefficiencies at the power plant, along with transmission and distribution losses as the electricity is delivered to the data center. This part of the research effort is focused on researching and developing a photovoltaic (PV) inverter with galvanic isolation

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. The galvanic isolation will minimize the arc fault danger associated with high voltage photovoltaic (PV) arrays. The galvanic isolation will also enable monitoring ground leakage to minimize danger to humans.

Inclusion of the grid-tie inverter will allow the data center to run off onsite generated power when back-up power is needed, when supplemental power is needed, or even to get the data center to run entirely off the grid. Ultimately, data centers running off the grid and using green power will enable the greatest increases in total energy efficiency (due to greatly reduced transmission and distribution losses) and significant reductions in the creation of Greenhouse Gases. Note that the proposing team has not taken credit for such energy efficiency gains, given that the DOE spreadsheet does not accommodate such scenarios.

1.3.5 Power and Cooling Monitoring/Management System

The Power and Cooling management system should provide the optimal balance between energy efficiency and resiliency for mission critical datacenter operations. The research and design portion of the management system will include options for full redundancy at all levels of operation but not necessarily require them for basic operation unless dictated by the specific deployment application. However, the most energy efficient operation will be inherent even in the most basic deployment application.

The Power and Cooling management and monitoring system should have a number of ways of integrating into new and existing datacenter operations.

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To achieve energy efficiency, a number of existing techniques as well as new research will be needed in the cooling system. Traditional datacenter cooling systems are inherently inefficient due to the inability to closely couple the cooling requirements of the managed equipment or better stated the consumers of the provided cooling medium.

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The potential savings in the cooling system alone will be in the three specific areas of Fan / motor electricity use, heat exchanger COP (coefficient of performance) and chilled water reduction. Fans and motors have a cubic relationship with the amount of energy used to drive them and the saving will be by a factor of 3 for each percent of fan / motor speed that can be reduced. Heat exchangers are most efficient

when the warmest air possibly can be returned to the heat exchanger within the specification. Lastly, with the most efficient use of the heat exchangers running at the highest possible temperature, chilled water consumption and production will be reduced which will in turn save energy in the entire chilled water production and distribution systems.

The power distribution management system will be capable of dynamically switching between various sources of energy based on predefined policies or real-time changes in the environment. The policies can be defined to more heavily weight the use of a specific energy source in a particular region of the country. For instance in areas where wind energy is more prevalent and stable this source can be more heavily weighted for consumption during peak usage times.

Since datacenter typically have at least 2 possible power feeds, the power distribution management system will continually monitor both feeds which could be supplied by different sources and balance the most efficient sources with a number of factors and polices that include the attributes of stability, redundancy and cost.

1.3.6 Energy Efficient Data Center: Target PUE of 1.25

As stated in the Overview (Section 2.a, above), the current average PUE for existing data centers is 2.04. The Technical Merit section of the proposal details a proposed research effort that will drive the average PUE down to 1.25 or lower. The PUE of 1.25, for the targeted 100 kW data center, was arrived at using the following values:

- Ninety seven percent (97%) efficiency for the power distribution path (see Section 1.3.1).
- An optimized cooling system with power consumption of 17.5 kW of power per 100kw of IT load (see ***Table 2***).

Establish the highest data room efficiency and flexibility from 480VAC to 1.X VDC for the server CPU. The integration of the individual elements outline above will produce higher efficiency over the baseline data center. The new data center will have an efficiency of 85.6% which is a 21.6% efficiency improvement over the baseline.

Criterion 2: Potential Benefits

a. Estimated Energy Savings

Calculations indicate electrical energy savings of approximately 1.28 billion kWh by year 2015 as determined by the ICT Benefits worksheet (see ***Figure 10***). This is a reasonable assumption based on the commercialization of the technology in 2012. In addition to the energy savings, the technology has the potential to significantly reduce the creation of Greenhouse Gases. By 2015, the technology would displace 214 metric tons of CO2 (see ***Figure 10***).

b. Economic Benefits and Initial Cost Advantages

Traditional data centers have 18-20% electrical distribution losses due to UPS equipment, distribution transformers, and low efficiency power supplies. Additional energy is also used by the cooling equipment to extract the generated heat from the facility. Continuing technological advances on power delivery equipment and mechanical/cooling infrastructure promise to significantly reduce power distribution losses with a gross reduction in daily power and cooling costs.

The proposed research and development goes a step further, innovating on power conversion methodologies by looking to integrate functions and circuits that have traditionally been part of different products, and thereby reducing parts count, overall product cost, power conversion stages as well as bringing the cooling elements as close to the source as possible eliminating waste cooling. This in turn increases energy efficiency and results on direct operating cost savings, and given the U.S. dependency on fossil fuels for electric power generation, results on a reduction of Greenhouse Gas emissions. In addition

to direct cost savings, electrical energy savings release stranded infrastructure thus alleviating the country's need for immediate additional power generation, transmission and distribution infrastructure

c. ICT Benefits Spreadsheets

Figures 7 through 10 are screen shots of the four tabs in DOE's ICT Benefits Spreadsheet, which is required for use as part of the energy savings calculations.

	A	B
1	Project Name:	
4	Preparer: Name and Organization	REDACTED EXEMPTION 5
11		
12	Technology Description Please provide a concise description (more than one-half page is unnecessary) of the new technology you are proposing, addressing: - Its function, and benefits to the industrial user of the technology - The state-of-the art technology it replaces - The target of the technology and potential limitations to its applications and barriers - Plant modifications necessary to incorporate the new technology - Competing technologies - The definition of one technology unit-year	
13–27	REDACTED EXEMPTION 4	REDACTED EXEMPTION 5

Figure 7. ICT Benefits Spreadsheet: Description Worksheet

	A	B	C	D
1	**Unit Inputs**			
2		0		
3				
4	**Per Unit Impacts per year**			
5		New Technology	Current Technology	Net Impact
6				
7				
8	*Energy Use*	REDACTED EXEMPTION 4		
9	Electricity (billion kWh)			5.20E-04
10	Natural Gas (trillion Btu)			0.00E+00
11	Petroleum - Residual Fuel (million barrels)		REDACTED EXEMPTION 4	0.00E+00
12	Petroleum - Distillate Fuel (million barrels)			0.00E+00
13	Petroleum - Liquefied Petroleum Gas (million barrels)			0.00E+00
14	Coal (million short tons)			0.00E+00
15	Feedstock (trillion Btu, please specify)	REDACTED EXEMPTION 5	REDACTED EXEMPTION 5	0.00E+00
16	Biomass (trillion Btu, please specify)			0.00E+00
17	Waste (trillion Btu, please specify)			0.00E+00
18	Other (please specify. trillion Btu)			0.00E+00
19				
49		Comments	REDACTED EXEMPTION 4	
50–53			REDACTED EXEMPTION 5	

Figure 8. ICT Benefits Spreadsheet: Unit Inputs Worksheet

Market Inputs

Total Market	x	Ultimate Potential Market Share	x	Market Penetration
# of installed units [US market]		Ultimate Potential Accessible Market (%)		
year for data above		Likely Technology [Market] Share (%)		
annual market growth rate [%]				
3.3%				
Comments		Comments		Comments

	(10+ years)	(4-8 Years)		(2-3 Years)		
Case	Initial R&D Completed	Initial System Prototype	Refined Prototype	Commercial Prototype	Commercial Introduction	Technology Class	Years to Saturation
With ITP							10

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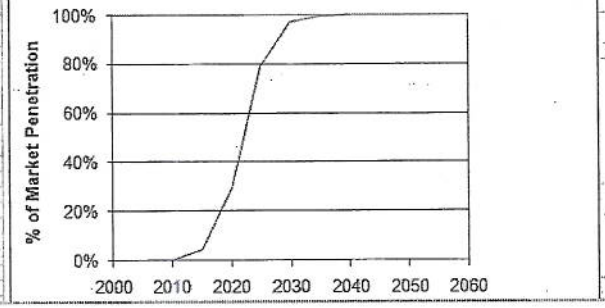

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	A	B	G	L	Q	V	AA	AF
1	Impacts: New Technology vs Current Technology							
2	0							
3	**Impact By Year**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
4	Cumulative Units installed	0	2,463	19,275	60,959	88,266	106,558	125,708
5	Annual New Units Installed	0	902	5,850	8,105	4,160	3,591	4,040
7	Annual Installations Total	0	902	5,850	8,105	4,160	3,591	4,040
8	Market penetration	0%	4%	29%	79%	97%	100%	100%
9								
10	ANNUAL SAVINGS							
11	*Energy Metrics*							
12	Total primary energy displaced (trillion Btu)	0.00	10.59	79.09	250.13	362.17	437.22	515.80
13	Direct electricity displaced (billion kWh)	0.00	1.28	10.02	31.70	45.90	55.41	65.37
14	Direct natural gas displaced (bcf)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Direct petroleum displaced (million barrels)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	Direct coal displaced (million short tons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Feedstock energy displaced (trillion BTU)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	Biomass energy displaced (trillion BTU)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Waste energy displaced (trillion BTU)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Other energy displaced (trillion Btu)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21								
22	*Financial Metrics*							
23	Energy-cost savings ($MM/yr)	0.00	76.46	591.58	1914.63	2793.98	3373.00	3979.15
24								
25	*Environmental Metrics*							
26	CO Displaced (Metric tonnes)	0.00	213.72	1647.39	5210.15	7544.03	9107.45	10744.13
27	Carbon Dioxide emissions displaced (MM TCE)	0.00	0.21	1.54	4.86	7.04	8.50	10.03
28	Other greenhouse emissions displaced (MM TC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	SO2 displaced (Metric tonnes)	0.00	2999.62	20744.35	65607.58	94996.44	114683.37	135292.90
30	NOx displaced (Metric tonnes)	0.00	1888.36	13619.97	43075.51	62371.14	75296.86	88828.31
31	Particulates displaced (Metric tonnes)	0.00	64.12	441.58	1396.58	2022.18	2441.26	2879.97
32	VOCs displaced (Metric tonnes)	0.00	22.96	177.43	561.16	812.53	980.92	1157.20
33	Hydrocarbons displaced (Metric tonnes)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	Solid Waste (Metric tonnes)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	Other environmental benefits (Metric tonnes)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36								

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The average data center in the United States operates with a PUE of 2.04 (Sullivan, 2009)[1]. For the average data center, an IT load of 100KW would require an additional 100KW of infrastructure load for power distribution and cooling.

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* Silicon Valley Leadership Group, LBNL

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Table 1. Energy breakdown of the typical facility for 100KW of IT load

IT Load	Electrical Losses	Chilled Water	Fans	Lighting	Infrastructure Load	Total Data Center Load	PUE
100 KW	22 KW	54 KW	16 KW	8 KW	100 KW	200 kW	2

This research and development effort is aimed at reducing the energy needed to support the IT load by increasing the efficiency of the power distribution and cooling systems. Using a chilled water-based, closed-loop cooling system reduces the energy needed by the fans and chilled water system by 75% compared to traditional data center designs. The ability to directly match the cooling requirements to the IT load allows the temperature of the server inlet supply to be raised to the higher limit of the manufacturer's specification .The higher server inlet temperature enables the use of air side economizers - further reducing the energy needed by the cooling systems.

The lack of recirculation in the air supply (typical of hot aisle/cold aisle data centers) will result in additional savings of 4%. Closed-loop cooling also allows the support of high heat densities in the rack, saving on the needed data center's floor space and supporting infrastructure. In this example, the floor space reduction will reduce the lighting requirements by 40%. The combination of increased cooling efficiency and power distribution results in a data center PUE of 1.25 (see ***Table 2***). Addressing the cooling aspects of the 100KW IT load will result in a 60% increase in overall energy efficiency. This would reduce the carbon footprint of the data center by 456 metric tons per year (see ***Table 3***).

Summary for a 100KW IT LOAD (see *Tables 2 and 3*)

Table 2. Energy Breakdown for a Data Center with a PUE of 1.25.

IT Load	Electrical Losses	Chilled Water	Fans	Lighting	Infrastructure Load	Total Data Center Load	PUE
100 KW	5.5 KW	13.5 KW	4 KW	2 KW	25 KW	125 kW	1.25

Table 3. Yearly Energy Saving: Comparison of Data Centers with PUEs of 2 vs. 1.25

	PUE = 2	PUE = 1.25
Total Data Center Load	200 KW	120 KW
Yearly Energy Usage	1,752,000 KW	1,095,000 KW
Yearly Cost	$175,200	$109,500
Carbon Footprint	1,056 Tons	600 Ton

d. For Demonstration Projects: Ability to Improve Existing DCiE and Energy Performance

Not Applicable.

e. Potential to Reduce Greenhouse Gas Emissions

Yearly Energy Saving: Please see ***Table 3*** (above).

Criterion 3: Commercialization and Market Acceptance

a. Commercialization Strategy for Proposed Technology

HP and Eaton have proven track records of transitioning intellectual property developed in our R&D labs into successful products that address critical market requirements. Both HP and Eaton have well

structured Product Development Processes with clearly defined steps to move IP from the concept stage to successful product introductions. However, due to the current economic environment, it is difficult to gain adequate funding to fully research and develop these types of new and innovative solutions when in contention for funding for more mainstream solutions this is also limited.

HP and Eaton are committed participants in the data center infrastructure market place having introduced innovative technologies such as the HP Performance Optimized Data Center and the HP Modular Cooling System.

The HP and Eaton teams complement each other to bring innovation and technology to the market. In the data center space, HP's leadership position in the server marketplace and the organizational support of EYP Mission Critical Facilities present data center and IT managers with the ideal vehicle to promote advanced solutions that can revolutionize the industry. Eaton's position as electrical component and system manufacturer and a market leader on power quality, provides complementary sales and marketing channels, including electrical distributors and manufacturer representatives, particularly for components not traditionally sold by IT resellers.

b. Viability of Proposed Technology to Meet Target Market Needs

With the demand for compute power ever growing, business will continue to face the challenge of scaling their data centers to meet the demand for power and cooling. In the past, the only way to increase the capacity of a data center was through expensive retrofits or building of a new data center. Both of these alternatives are costly and can require multiple years to bring online. The technology in this proposal allows the release of stranded data power in an existing facility without the need of Capital Expenditure (CAPEX) to build a new facility. The modular design of the solution provides gradual expansion of the infrastructure to better match requirements. The solution optimizes the operation of the data center for better power density and more efficient energy use. By providing close-couple cooling combined with a highly efficient power distribution system, the solution has an operational PUE of 1.25.

At the same time, the viability of alternative energy sources is becoming more evident. Cost-effective commercially available solutions that interface renewable energy sources with traditional data center power infrastructure will be a key market need that needs to be satisfied.

c. Evidence of Corporate Commitment

HP and Eaton are committed to providing the most energy efficient solutions in the industry. This is evidenced by HP's introduction of the most energy efficient IT solutions with the recent G6 platforms and energy efficient management solutions in our Thermal logic applications such as Dynamic power capping. HP has also launched new datacenter level solutions like the HP Modular Cooling System, and Dynamic Smart Cooling. In addition, HP Labs has a long history of innovation and research in datacenter power and cooling efficiencies.

Eaton is similarly committed to provide power protection for data center markets in the most efficient way. The 9395 UPS product line, being introduced in several power ratings, brings high-efficiency transformer-less solutions to medium and large data centers. More recently, Eaton introduced the Energy Saver System, an even higher efficiency multi-mode version of the 9395 and the 9390 product families, achieving efficiencies of over 99%. Committed to reducing the losses in the entire power delivery chain in all segments, Eaton's Electrical Sector is also working in other areas, for example high-efficiency distribution transformers, building management systems aimed to reduce overall energy consumption, and solar inverters sold in the market under OEM agreements.

d. Impact on Manufacturing Supply Chain (Reference: V.A.3.ii)

HP and Eaton will leverage the existing supply chains for this product development effort.

Criterion 4: Technical Approach/Project Management Plan

a. Validity and Completeness of Proposed Technical Approach

HP and Eaton intend to use the requested funding to dramatically accelerate R&D and market introduction of the end-to-end power and cooling solution proposed.

The proposed solution consists primarily of:

- Mechanical enclosure system utilizing closed loop cooling via air and removing the heat via a high efficiency water heat exchangers. The enclosure can house up to eight IT racks that are pre configured and rolled into the system. Power and cooling requirements for each IT rack can vary but not exceed the total maximum system power level of 100KW.
- Expanded water based cooling solution capable of cooling up to 100KW of heat load and based on the HP developed MCS technology.
- New SW management and control systems to manage the above.
- New HVAC input and HVDC output power system converter based on Eaton's cylcoconverter technology.
- DC power distribution system to provide point to point power to the IT loads.

b. Project Management Plan

HP will use its existing program development processes to manage this program as this process already incorporates a co-development process for third parties (such as Eaton) as well as program milestones that map well with DOE's Stage-Gate Innovation Management Guidelines version 1.3..

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Figure 12. HP's Product Development Cycle

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HP will assign a Program Manager that will have overall responsibility for development effort and that will have oversight for all sub programs as well as any third parties. Primary development will consist of using resources from HP's current Rack and Power development organization as well as Eaton. Further, as part of this program, HP will leverage resources from multiple HP internal teams as needed for research and development assistance,

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The project management plan will consist of two phases lasting approximately one year each.

Phase I will be focused on researching and developing critical technology elements including a reconfigurable power and cooling architecture, control algorithms and hardware risk mitigations.

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Phase II will focus on actual product solutions as the R&D effort matures that are tied to the agreed to milestones and gates per the DOE submittal process.

Phase I Detail: Critical Technology Elements Development: 12 months

Power: The power phase element of this program will be a one year effort. The work will be focused on researching and developing critical technology elements including a reconfigurable power architecture, control algorithms, and hardware risk mitigations.

1.
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3.

Mechanicals/Cooling: In parallel with the power phase, the cooling phase is comprised of completing testing and validation for cooling of a 4, 6, and 8 rack enclosure up to 100KW given multiple rack power loads and configurations. Inclusive in this phase is:

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3.

Phase II Detail: Full Energy Efficient Prototype Development and Testing:

Phase II will focus on actual product solutions as the R&D effort matures that are tied to the agreed to milestones and gates per the DOE submittal process.

Power:

1. Power converter prototype/stage development for HW and SW
2. Demonstrated energy efficiency gains in a typical data center application.

Mechanicals/Cooling:

1. Cooling system prototype system
2. 100KW enclosure system to house the power, cooing, and rack IT elements.
3. Validation/testing of dynamic load cooling system

Overall System Testing: Testing of the entire system will be performed with both real and simulated loads to determine the overall functionality and energy optimization.

c. Work and Budget Distribution

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Criterion 5: Qualifications and Resources

a. Evidence of Capability/Experience

1. Research

HP is a diversified IT manufacturer with 2008 sales exceeding $100 billion. Under HP Technology System Group (TSG) we plan to bring to this program a multitude of disciplines and teams, including HP Labs and EYP Mission Critical Facilities. We will also bring a strong Rack and Power infrastructure team that has over 15 years experience in providing leading edge rack infrastructure solutions to support the data center. Combined this is over 300 engineers and researchers.

HP has a proven track record of innovation and support in this space as is evidenced by ongoing innovative power saving IT hardware and software with products such as HP Blade systems and the recently launched G6 servers that also incorporate power management elements such as HP Insight Power Manager and Thermal Logic. In infrastructure, HP has a long history in innovation including high volume commercialization of industry standard racks, line interactive UPS systems, power distribution and energy efficient modular cooling systems such as the HP MCS which was the first product commercially introduced to cool up to 35KW of IT load utilizing a closed loop cooling architecture. This architecture was further used in HP's first generation POD solution. HP will use design, development, and manufacturing locations across the US to support this effort. The primary design location will be Houston, Texas.

HP also has an extensive and dedicated Marketing and sales team focused on rack based power and cooling infrastructure that will be used to bring this solution to market. The development team will also use expertise as needed from other organizations within HP such as EYP, EDS, and HP Labs. Key major contributors for this specific program are listed in the resume section but include:

Eaton Corporation is a diversified industrial manufacturer with 2008 sales exceeding $15 billion. As a global leader in electrical systems and components for power quality, distribution, and control, the Eaton Electrical Sector had sales in excess of $6.9 billion in 2008. With over 55,000 employees worldwide, Eaton sells products to customers in more than 125 countries. The Eaton groups supporting this program include:

Eaton Power Quality Division (PQD) – Eaton Power is a leading global provider of comprehensive power quality and backup power management solutions, consistently delivering the high 9s of availability demanded by today's digital economy under the Powerware brand. Powerware solutions provide a broad range of power quality products and services including Uninterruptible Power Systems (UPSs), DC Power Systems, Management software and comprehensive services. Current Eaton UPS products have achieved a high level of power rating, power density, and cost effectiveness.

The Eaton Innovation Center – The Innovation Center is Eaton's central research and development organization. A broad spectrum of scientists, engineers, and support staff focus on the creation of growth and value through innovation and technology development. Technology Thrusts include: Power Conversion and Power Quality, Wireless Communications, Arc Science for Electrical Power Protection and Control, Prognostics for Wellness, and Sensor/Transducer/Actuator design.

2. Manufacturing

On the manufacturing side, both HP and Eaton have factories in both the US and global locations, to manufacture components and systems in a cost effective manner, providing customers with commercially viable solutions.

3. Bringing Technology to End User through Sales/Marketing

The HP and Eaton teams complement each other to bring innovation and technology to the market. In the data center space, HP's leadership position in the server marketplace (~35% market share) and the organizational support of EYP Mission Critical Facilities present data center and IT managers with the ideal vehicle to promote advanced solutions that can revolutionize the industry. Eaton's position as electrical component and system manufacturer and a market leader on power quality, provides complementary sales and marketing channels, including electrical distributors and manufacturer representatives, particularly for components not traditionally sold by IT resellers. As such, both companies will leverage their extensive experience and expertise is sales and marketing to bring this solution to market.

b. Evidence of Organizational Experience in Similar Projects

HP has a dedicated team of engineers, program managers, marketers, and technicians focused solely on the data center infrastructure space. HP has multiple examples of innovation in this space including work performed internally and with partners for commercial products available from HP today for UPS, PDU, racks, SW management, and cooling over the past 15 years. HP has also created new innovated products directly related to data center efficiency such as HP's Dynamic Smart Cooling and Modular Cooling rack systems. Further between HPs various development organizations and HP Labs, HP has over 1000 patents in power and cooling technologies. In addition to product expertise, HP has a very successful customer engagement and services team for data centers this includes consulting with EYP Mission Critical Services, and EDS that will be engaged as needed to meet development guidelines and milestones.

Eaton has over 150 patents in the area of power conversion alone and has a long history of innovation in the power quality market. Eaton developed the first commercial UPS combining battery chargers and inverters in 1968, the first UPS over 100KVA for a computer room in 1986, and the first high-frequency transformer-less UPS in 1989. More recent product innovations include high-efficiency multi-mode UPS starting at 10KW and available up to multi-MW power range.

Eaton's Power Quality Division and the Innovation Center have teams of experienced engineers and researchers focused on satisfying customer needs and overcoming technical challenges, and have been involved with advanced power electronics R&D projects of similar nature.

c. Level of Experience and Availability of Key Personnel

A dedicated team from HP comprised of engineers, program managers, marketers and technicians will be assigned to work this program. This team averages over 15 plus years of experience in innovation, research, and development in the datacenter infrastructure space. In addition, HP will leverage expertise and knowledge from HP Labs, EYP, and EDS an needed to help resolve issues and problems that arise during the research and development phase of the program. A list of these individuals is available in the resume summary file.

Similarly Eaton has a dedicated team that will be assigned to this program, including researchers, engineers, and technicians. The principal investigator on the Eaton team has over 40 years of experience in the field, and this project will be his primary responsibility.

d. Adequacy of Facilities/Equipment for Proposed Project

HP has a dedicated lab for research and development of rack power and cooling infrastructure located in Houston, TX. Additionally, HP will be utilizing HP resources and facilities as needed from other HP US facilities such as Palo Alto, Cupertino, and Dallas.

Eaton will use facilities and equipment in its Power Quality labs in Raleigh, NC and the Innovation Center in Milwaukee, WI.

3. American Recovery and Reinvestment Act (ARRA) Information

Calculations shown in the proposal indicate a significant electrical energy savings for the US data centers with the deployment of new high-efficiency technologies. Furthermore, the mass deployment of these technologies in mid-size data centers has the potential to preserve if not create hundreds of new jobs in the US, from manufacturing, installation, consulting services, and the retrofitting of existing data center with the proposed technology.

As the global economy is going through the effects of a recession, its full impact yet unknown, we expect that in the short term, we will at least be able to preserve research, development and engineering jobs in the U.S., and more importantly, accelerate the funding and focus in areas that are vital to reduce the country's dependence on fossil fuels.

Depending on final costs, retrofitting older installations with higher efficiency solutions can show a fairly quick return on investment. In the short to medium term, this can result in many data center retrofit jobs.

Longer term, the results of this R&D effort and subsequent commercialization will maintain a competitive data center industry in the U.S., with all the jobs that it entails

4. Letters of Commitment from Third Parties

HP has attached to this file Eaton's letter of commitment (as requested).

REFERENCES

[1] Sullivan, A., 2009, "Data Center Efficiency with ENERGY STAR", presentation at 7x24 Exchange, Spring 2009, Florida.

[2] Scheihing, P., 2008, US DOE EERE.

EATON
Powering Business Worldwide

Power Quality Operations
3301 Spring Forest
Raleigh, NC 27616
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July 21, 2009

Ms. Anne Elkins
U.S. Department of Energy
Golden Field Office
1617 Cole Blvd.
Golden, CO 80401

Subj: Commitment for Eaton Corporation proposal under Solicitation # DE-FOA-0000107

Dear Ms. Elkins:

Eaton Corporation is pleased to partner with Hewlett-Packard on a proposal for financial assistance responding to the subject line solicitation. Hewlett-Packard's project is "Adaptive Environmentally Contained Power and Cooling IT Infrastructure for the Data Center".

Eaton is committed to energy efficiency in its products and processes and views the Energy Efficient Information and Communication Technology Program as a critical step toward reducing energy consumption and carbon footprint in information and communication industries.

Eaton is committed to, upon notification of award, a budget of EX 4 and an in-kind cost share of EX 4 over the two-year period of performance.

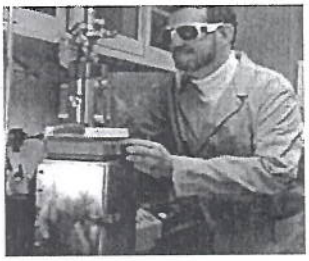
Eaton is eager to move forward with the Hewlett-Packard Team and the Department of Energy on a successful Energy Efficient Information and Communication Technology project.

Sincerely,

Miguel Chavez
Director of Engineering
Critical Power Solutions
Eaton Corporation

Hewlett-Packard's Proposal to the U.S. Department of Energy, Golden Field Office for the Recovery Act: Energy Efficient Information and Communication Technology Funding Opportunity





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Non Disclosure - FAR 52.215-1, Restriction on Disclosure and Use of Data (Oct 1997)

This proposal or quotation includes data that shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed - in whole or part - for any purpose other than to evaluate this proposal. If, however, a contract is awarded to this offeror as a result of - or in connection with - the submission of this data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the resulting contract. This restriction does not limit the Government's right to use information contained in this data if it is obtained from another source without restriction. The data subject to this restriction are contained in all sheets.

Overview

This file contains resumes of the key personnel from HP and Eaton, who will be contributing in a substantive, measurable way to the execution of the project.

MULTIPLE PRINCIPAL INVESTIGATORS

The following individuals who will act as Principal Investigators (PI) for each company:

- Ron Mann, PI/Contact PI for HP
- Miguel Chavez, Co-PI for Eaton

COORDINATION AND MANAGEMENT PLAN

Multiple PIs at Multiple Institutions – Subcontract Model

Ron Mann, PI at HP will be responsible for the oversight and coordination of project management for this program. Miguel Chavez, Co-PI at Eaton will be responsible for their portion of the program. Each PI will be responsible for his own fiscal and research administration. The PIs will communicate weekly, either by phone, e-mail, or in person, to discuss experimental design, data analysis, and all administrative responsibilities. All PIs will share their respective research results with other PIs, key personnel, and consultants. They will work together to discuss any changes in the direction of the research projects and the reprogramming of funds, if necessary. A publication policy will be established based on the relative scientific contributions of the PIs and key personnel. Ron Mann will also serve as contact PI and be responsible for submission of progress reports to DOE and all communication.

Intellectual Property

The Technology Transfer Offices at HP and Eaton will be responsible for preparing and negotiating an agreement for the conduct of the research, including any intellectual property. An Intellectual Property Committee composed of representatives from each institution that is part of the grant award, will be formed to work together to ensure the intellectually property developed by the PIs is protected according to the policies established in the agreement.

Conflict Resolution

If a potential conflict develops, the PIs shall meet and attempt to resolve the dispute. If they fail to resolve the dispute, the disagreement shall be referred to an arbitration committee consisting of one impartial senior executive from each PI's company and a third impartial senior executive mutually agreed upon by both PIs. No members of the arbitration committee will be directly involved in the research grant or disagreement.

Change in PI Location

If a PI moves to a new company, or in the event that a PI cannot carry out his duties, a new PI will be recruited as a replacement at one of the participating companies.

Budget

Budgets shall be set up for HP as Prime, and for Eaton as sub-contractor.

Resumes

Ronald M. Mann (PI)

RONALD M. MANN, HEWLETT PACKARD COMPANY

EDUCATION AND TRAINING

- University of Houston, M.S.I.E., Engineering Management, 1993.
- Mississippi State University, B.S.I.E., 1986.

PROFESSIONAL EXPERIENCE

Industry Standard Servers, Hewlett Packard | **1997 - Present**

Director, Engineering Rack and Power Systems

Lead engineering development for HP rack infrastructure products supporting HP enterprise servers, storage, and blade systems. Products include uninterruptible power systems, rack power distribution and cooling, rack cabinets, associated rack accessories, digital and analog KVM switches, console products, software management applications, and rack configuration/integration for all HP server and storage platforms. Work closely with a diverse set of HP suppliers in multiple industries for development and co-development of hardware and software products.

Compaq Computer Corporation | **1994 - 1997**

Manager, Engineering Problem Resolution, ISS

Established a sustaining support organization within the Storage and Options Division to resolve design-related issues for released server option products. Options included SCSI hard drives, DAT and DLT tape drives, SCSI SMART controllers, DLT tape libraries, external storage enclosures, memory, and UPS products. Required operating in a team environment with Marketing, WW Geographies, Product Engineering, Operations, Service, and Design to insure timely resolution of issues.

Compaq Computer Corporation | **1993 - 1994**

Systems Options Program Coordinator

Responsible for program coordination of new system option projects, such as SCSI hard drives, tape drives, CD ROMs, and server option cards. Duties included project cost forecasting, project scheduling, cost analysis, new component procurement, and facilitating project meetings.

Compaq Computer Corporation | **1991 - 1993**

Project Manager

Responsible for the introduction of new printed circuit assemblies into production with concentration in the areas of product definition, process development, and design for manufacture. Was the primary interface between design, worldwide manufacturing, and test engineering.

PUBLICATIONS

- Designing a Fault Tolerant Power System, Storage Management Solutions Vol. 5, Issue 2.
- Powering Today's Data Centers, Electrical Contract & Engineering News, March 2003.

PATENTS

- US20090021907A1 Modular High-Density Computer Systems

Resume of Tahir Cader

TAHIR CADER, HEWLETT-PACKARD COMPANY

EDUCATION AND TRAINING

- University of Kentucky, Lexington, KY, Ph.D. in Mechanical Engineering, 1994.
  - Research Emphasis: Experimental and numerical investigation of turbulent two-phase flows in turbomachinery.
- University of Kentucky, Lexington, KY, M.S. in Mechanical Engineering, 1987.
  - Research Emphasis: Numerical investigation of turbulent two-phase flows in slurry pipelines.
- University of Kentucky, Lexington, KY, B.S. in Mechanical Engineering, 1983.

PROFESSIONAL EXPERIENCE

Hewlett Packard, Liberty Lake, WA | **2008 - Present**

Power and Cooling Strategist

Work with multiple business units, as well as HP Labs, to deliver the best end-to-end power and cooling solutions for HP's HPC, Web 2.0, and Cloud Computing customers. Focus is on delivering the most energy efficient and cost-effective solutions. Leading the authorship of a book entitled "Real-Time Energy Consumption Measurements in Data Centers." Book is a joint effort between ASHRAE TC9.9 and The Green Grid.

SprayCool, Inc., Liberty Lake, WA | **2000 – 2008**

Technical Director, Product Group Director

Directed the group that delivered SprayCool's first device-level, liquid-cooling solution for server racks deployed in data centers. Directed the development of multiple liquid-cooling technologies for commercial and military products. Received 17 US and international patents for liquid-cooling innovations.

Energy International, Inc., Bellevue, WA | **1994 – 2000**

Program Manager, Research Engineer

Served as Principal Investigator for a major investigation into the development of a new coolant for use to improve heat transfer in utility transformers. Led multiple energy efficiency studies for utilities.

PUBLICATIONS

- Sisk, D., Hatley, D., Marquez, A., Cader, T., Schmidt, R., 2008, "Real-Time Data Center Energy Efficiency at Pacific Northwest National Laboratory", appears in the proceedings of the ASHRAE Winter 2008 annual meeting.
- Sorell, V., Cader, T., Westra, L., and Marquez, A., 2008, "Liquid-Cooling in Data Centers", appears in the proceedings of the ASHRAE Winter 2008 annual meeting.
- Cader, T., Westra, L., McAllister, H., Regimbal, K., and Marquez, A., 2007, "Performance of a Rack of Liquid-Cooled Servers", ASHRAE Transactions, Vol. 113, Part 1.
- Cader, T., Westra, L., Regimbal, K., and Mooney, R., 2006, "Airflow Management in a Liquid-Cooled Data Center", ASHRAE Transactions, Vol. 112, No. 2, pp. 220 - 230.
- Cader, T., Westra, L., J., and Eden, R. C., 2004, "Spray Cooling Thermal Management for Increased Device Reliability", IEEE Transactions on Device and Materials Reliability, Vol. 4, No. 4, pp. 605 – 613.
- Cader, T., Westra, L., and Marquez, A., 2007, "Technologies for the Energy-Efficient Data Center", proceedings of ASME InterPACK2007, Vancouver (BC).

Ronald M. Mann (PI)

RONALD M. MANN, HEWLETT PACKARD COMPANY

- Johnston, A., Stone, D., Cader, T., and Locklear, D., 2007, "SprayCool Compact Server for military shipboard environments", proceedings of Thermes 2007, Albuquerque (NM).
- Cader, T., Tolman, B., Kabrell, C., and Olsen, D., 2006, "Dense Spray Cooled DC-DC Converter", proceedings of Itherm2006, San Diego (CA).
- Cader, T., Tolman, B., Kabrell, C. A. I., Krishnan, S., 2005, "SprayCool Thermal Management for Dense Stacked Memory", Proceedings of IMECE: IMECE 2005, Orlando (FL).
- Goruganthu, R. R., Bethke, D., McBride, S., Crawford, T., Frank, J., Cotton, D., and Cader, T., 2004, "Spray Cooling for Time Resolved Emission Measurements of ICs", 2004 International Symposium on Test and Failure Analysis.

PATENTS

- US patent number 6,857,283 B2, "Semiconductor Burn-In Thermal Management System"
- US patent number 6,889,509, "Coolant Recovery System"
- US patent number 6,889,515, "Spray Cooling System"
- US patent number 6,836,131 B2, "Spray Cooling and Transparent Cooling Plate Thermal Management System"
- US patent number 6,958,911, "Low Momentum Loss Fluid Manifold System"
- US patent number 6,996,996 B1, "Sealed Spray Cooling System"
- Taiwanese patent allowed, 2006, "Spray Cooling Thermal Management System and Method for Semiconductor Probing, Diagnostics, and Failure Analysis"
- US patent number 7,308,801, "Method of Operating a Spray Unit"
- US patent number 7,102,374, ""Spray Cooling Thermal Management System and Method for Semiconductor Probing, Diagnostics, and Failure Analysis"
- US patent number 7,086,455, "Spray Cooling System"

Darrel Gaston

DARREL GASTON, HEWLETT-PACKARD COMPANY

EDUCATION AND TRAINING

- Texas A&M University, College Station, TX, B.S. in Electrical Engineering, 1983.

PROFESSIONAL EXPERIENCE

Rack and Power Group, Hewlett-Packard, Houston, TX	**2004 - Present**

Senior Engineering Manager

In charge of mechanical and electrical engineers and technicians in support of the program management team for the Enterprise Rack and Power group. New product development of uninterruptible power sources (UPS), power distribution units (PDU), and keyboard, video and mouse (KVM) products from concept phase to announce. Grew the KVM business year over year by 17% (CAGR). Developed a family of intelligent power distribution units that allowed out of band communications with Integrated Lights Out (iLO) by way of the server power supply.

Rack and Power Group, Hewlett-Packard, Houston, TX	**1997 - 2004**

Senior Engineering Program Manager

Designed UPS and PDU for industry standard servers (ISS) to enhance the HP enterprise solution set. Delivered two generations of PDU's and boosted sales by an average of 15% annually and increased the attach rate of UPS's to ISS servers by 11%.

Portable Development, Compaq Computer Corp, Houston, TX	**1987 - 1997**

Engineering Program Manager

Program manager with responsibility to introduce all options for the Portable Computing Division including electrical and mechanical design engineering resources. Ensured that all 31 option products were available at the same time as two new notebook platforms. Directed a product development team for notebook computer refreshes, including display technology improvements and processor speed bumps. Developed first monochrome thin film transistor (TFT) panel in a Compaq notebook computer and received the 1992 MVP award from PC Computing. Oversaw the development of the display subsystem for the first color TFT notebook computer. Improved overall first pass factory yields by 37% while reducing run-in from 96 to 8 hours based on statistical methods.

Small Business Computers, Texas Instruments, Austin, TX	**1976 - 1987**

Engineering Project Manager

Performed product engineering support function of PC and small business computer manufacturing. Led the Portable Quality Improvement Team and reduced factory audit failures by 18%.

PUBLICATIONS

- Investigation of nickel-nickel contacts in portable computer battery pack applications; Proceedings of the Fortieth IEEE Holm Conference on Electrical Contacts 17-19 October 1994, Pages: 155 – 160.
- Selected as a presenter for the 2009 HP Tech Con forum with a technical paper entitled 'Power Topology Discovery'; this abstract was one of 130 selected from 1300 submissions across HP.

Darrel Gaston

DARREL GASTON, HEWLETT-PACKARD COMPANY

PATENTS

- Applications submitted to USPO: 20080272655: Uninterruptible Power Supply With Remote Capabilities; 200800654 / 200800656: A method to discover datacenter power network topology by correlation of ROMBURN events.

Alan Epperson

ALAN EPPERSON, HEWLETT-PACKARD

EDUCATION AND TRAINING

- University of Houston, Clear Lake, Master of Business Administration, 1993.
- University of Houston, University Park, B.S. in Electrical Engineering, 1984.

PROFESSIONAL EXPERIENCE

Rack and Power Group, Hewlett-Packard, Houston, TX | **2000 - Present**

Engineering Program Manager

Responsible for the definition, design, development, manufacture, and customer satisfaction of IT infrastructure products, leading a cross-functional team of engineers, technicians, and suppliers. Manage programs using suppliers and internal groups to develop power and infrastructure products. Develop Plan of Record to marketing requirements, detailed product specifications, and all necessary project documentation. Manage cost and schedule to the product plan. Responsible for cost and status reporting to management, and for leading cost reduction efforts. Ensure product compliance to quality and functional requirements. Support customer issues and provide training. Manage personnel, conduct performance appraisals, and determine raises, promotions, and awards.

Muniz Engineering, NASA-JSC, Houston, TX | **1997 - 2000**

Systems Engineer

Lead Systems Engineer responsible for the overall electrical design and systems integration of Space Shuttle Payloads. Responsible for defining the experiment electrical and avionics requirements. Designed and developed data acquisition and control system. Developed LabVIEW software for payload display and control. Designed power distribution circuitry.

Lockheed Martin, NASA-JSC, Houston, TX | **1995 - 1997**

Engineering Supervisor

Supervisor of a diverse group of engineers and scientists in the management, design, development, and operations of various Space Shuttle Payloads. Responsible for maintaining core competency skills in matrix organization. Staffed projects and interviewed/hired new personnel. Conducted performance appraisals and determined raises and promotions. Handled all administrative matters and implemented company policies and procedures. Ensured projects and labs conducted in a safe manner and in accordance with ISO 9001 certification.

Lockheed Martin, NASA-JSC, Houston, TX | **1990 - 1995**

Engineering Project Manager

Responsible for the "cradle-to-grave" hardware design, development, manufacture, test, and certification of Space Shuttle Payloads, employing up to 20 engineers and technicians. Assembled, managed, and provided leadership of project team in matrix organization. Developed program requirements, work statements, and all necessary project documentation. Performed cost estimating, scheduling, and resource management. Responsible for cost and status reporting to management and customer. Responsible for ensuring the quality and safety of the hardware and its compatibility with the orbiter. Conducted environmental testing (EMI, vibration, thermal-vacuum, static loads, fundamental frequency) to verify hardware survivability through launch and space environments. Integrated payloads to the orbiter.

Alan Epperson

ALAN EPPERSON, HEWLETT-PACKARD

Lockheed Martin, NASA-JSC, Houston, TX	**1988 - 1990**

Electrical Integration Engineer

Lead Engineer responsible for the electrical integration of various Space Shuttle Payloads, which required in-depth knowledge of the orbiter electrical/avionics accommodations and the experiment developer's requirements. Responsible for defining the experiment/orbiter power and avionics interfaces. Designed electrical integration hardware. Reviewed/critiqued experimenter's electrical designs with respect to NASA requirements. Educated the community on orbiter electrical systems and NASA payload development process. Proposal evaluation team member who assessed the integration needs of flight experiment proposals. Supported NASA safety analysis and all program documentation.

Lockheed Martin, NASA-JSC, Houston, TX	**1985 - 1988**

Electrical Integration Engineer

Electrical engineer responsible for digital/analog design and development of test support equipment. Designed and developed a microprocessor-based electronics tester to quickly test and troubleshoot flight boards. The tester simulated interface signals, exercised the board's electronics, and displayed the system results on a menu-driven, portable computer. Designed and developed a data acquisition system for NASA's Manned Maneuvering Unit. The design included analog and digital electronics to collect, condition, format, and store system parameters. Supported sustaining effort by testing, troubleshooting, and modifying flight hardware. Designed and developed various electrical test support equipment.

PUBLICATIONS

None

PATENTS

None

Mark Spence

MARK SPENCE , HEWLETT-PACKARD COMPANY

EDUCATION AND TRAINING

- Our Lady of the Lake University, MBA, 1999.
- Achieved Master Novell Certified Network Engineer Certificate, 1993.
- Achieved Novell Certified Network Engineer Certificate, 1990.
- Saginaw Valley State University, continuing management education, 1989.
- Delta College continued post-baccalaureate work in CIS and Programming Logic, 1986.
- Ferris State University, B.S. in Management, 1985.
- Oakland University studies in management/computer science, 1983.
- Oakland Community College, completed prerequisite courses, 1980.

PROFESSIONAL EXPERIENCE

Compaq / Hewlett-Packard, Houston, TX	**1993 - Present**

Research and Development Engineering Manager

Manage research and development teams in the areas of power and cooling products. Products include Modular cooling systems, Uninterruptable Power Systems, Power Distribution Systems, Control systems for power, and cooling systems.

PUBLICATIONS

None

PATENTS

None

John Grisham

JOHN GRISHAM , HEWLETT PACKARD COMPANY

EDUCATION AND TRAINING

- San Jose State University, CA, B.S. in Business Administration, 1980.

PROFESSIONAL EXPERIENCE

Hewlett-Packard, Cupertino, CA	**2008 - Present**
Strategic Planning and Partnerships	
Maintained EIS technology roadmap. Worked with divisional partners to define product requirements for infrastructure products and ensured that roadmaps were synchronized to deliver successful server launches.	
Hewlett-Packard, Cupertino, CA	**2007 - 2008**
Customer Engagement Manager	
Manage Dynamic Smart Cooling customer deployments. Coordinating delivery of solution elements with third-party partners, HP Services, and customer's infrastructure team for successful DSC implementations.	
Hewlett-Packard, Cupertino, CA	**2004 - 2007**
Advanced Technology Manger	
Managed Advanced Technology Team within EIS which was charted to investigate new data center infrastructure technologies. Investigations resulted in three new product development programs which increased HP's recognition as a leading data center solution provider.	
Company, City, State	**2000 - 2004**
Business Development Manager	
Led tiger teams focused on resolving data center infrastructure escalations. Investigations resulted in new ESS strategy approved by Rack Council and ESS Marketing.	

PUBLICATIONS

None

PATENTS

None