GRANTS.GOV

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:** Econ. Based Data Center Liquid Cooling

Mandatory Documents

Move Form to Complete

Move Form to Delete

Mandatory Documents for Submission

Other Attachments Form
Application for Federal Assistance (SF-424)
Project/Performance Site Location(s)

Optional Documents

Disclosure of Lobbying Activities (SF-LLL)

Move Form to Submission List

Move Form to Delete

Optional Documents for Submission

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:	* 2. Type of Application:	* If Revision, select appropriate letter(s):
☐ Preapplication	☒ New	
☒ Application	☐ Continuation	* Other (Specify):
☐ Changed/Corrected Application	☐ Revision	

* 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: IBM TJ Watson Research Center

* b. Employer/Taxpayer Identification Number (EIN/TIN): EX 4
* c. Organizational DUNS: 084006741

d. Address:

* Street1:	1101 Kitchawan Road
Street2:	
* City:	Yorktown Heights
County:	
* State:	NY: New York
Province:	
* Country:	USA: UNITED STATES
* Zip / Postal Code:	10598

e. Organizational Unit:

Department Name:
Division Name:

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

Prefix:	Mr.
* First Name:	Carl
Middle Name:	E.
* Last Name:	Taylor
Suffix:	

Title: Sr. Gov't Contracts & Negotiation Manager

Organizational Affiliation:

* Telephone Number: 713-797-4625
Fax Number: 845-491-5599

* Email: cetaylor@us.ibm.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:

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 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.):

N/A

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

Economizer Based Data Center Liquid Cooling with Advanced Metal Interfaces

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: NY-019

* b. Program/Project: NY-019

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

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 12/01/2009

* b. End Date: 11/30/2011

18. Estimated Funding ($):

* a. Federal	2,347,801.07
* b. Applicant	EX 4
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	2,934,751.34

*** 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: Carl

Middle Name: E.

* Last Name: Taylor

Suffix:

* Title: Sr. Gov't Contracts & Negotiation Manager

* Telephone Number: 713-797-4625

Fax Number: 845-491-5599

* Email: cetaylor@us.ibm.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: IBM TJ Watson Research Center

DUNS Number: 0840067410000

* Street1: 1101 Kitchawan Road

Street2:

* City: Yorktown Heights County:

* State: NY: New York

Province:

* Country: USA: UNITED STATES

* ZIP / Postal Code: 10598-0000 * Project/ Performance Site Congressional District: NY-019

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: IBM Corporation

DUNS Number: 0840067410000

* Street1: 2455 South Road

Street2:

* City: Poughkeepsie County:

* State: NY: New York

Province:

* Country: USA: UNITED STATES

* ZIP / Postal Code: 12601-5400 * Project/ Performance Site Congressional District: NY-019

Project/Performance Site Location 2

☐ 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: IBM Corporation

DUNS Number: 0840067410000

* Street1: 3039 E CORNWALLIS RD

Street2:

* City: Research Triangle Park County:

* State: NC: North Carolina

Province:

* Country: USA: UNITED STATES

* ZIP / Postal Code: 27709-2195 * Project/ Performance Site Congressional District: NY-019

IBM Cost Proposal Supplement Prepared February 19, 2010

IBM Proposal in response to DE-FOA-0000107

Cost Proposal	
(1) BAA Number	DE-FOA-0000107
(2) Technical area	Category II
(3) Lead Organization Submitting Proposal	IBM Thomas J. Watson Research Center
(4) Type of Business, Selected Among the Following Categories: "Large Business", "Small Disadvantaged Business", "Other Small Business", "HBCU", "MI", "Other Educational", or "Other Nonprofit"	Large business
(5) Contractor's Reference Number (if any)	NA
(6) Other Team Members (if applicable) and Type of Business for Each	NA
(7) Proposal Title	DELC -*Economizer Based Data Center Liquid Cooling with Advanced Metal Interfaces*
(8) Technical Point of Contact to Include: Title, First Name, Last Name, Street Address, City, State, Zip Code, Telephone, Fax (if available), Electronic Mail (if available)	Timothy Chainer, Ph.D. IBM T. J. Watson Research Center 1101 Kitchawan Road Yorktown Heights, NY 10598 Phone: (914) 945-2641 Email: tchainer@us.ibm.com
(9) Administrative Point of Contact to Include: Title, First Name, Last Name, Street Address, City, State, Zip Code, Telephone, Fax (if available), Electronic Mail (if available)	Carl E. (Ed) Taylor Sr. Contracts & Negotiation Manager IBM T. J. Watson Research Center 1101 Kitchawan Road Yorktown Heights, NY 10598 Phone: 713-797-4625 Email: cetaylor@us.ibm.com
(10) Award instrument requested: contract, grant, cooperative agreement, other transaction or other type of procurement contract (specify)	Cost Reimbursement – Cost Share
(11) Place(s) and period(s) of performance	IBM: Yorktown Heights, NY IBM: Poughkeepsie, NY IBM: Raleigh, NC Period 1: 12/1/2009 – 11/30/2010 Period 2: 12/1/2010 – 11/30/2011
(12) Total proposed cost separated by basic award and option(s) (if any)	Total Cost: $2,934,751. Government Share: $2,347,801 Period 1 Total: $1,915,532. Period 1 Govt Share: $1,532,425. Period 2 Total: $1,019,219. Period 2 Govt Share: $815,375.

IBM Cost Proposal Supplement Prepared February 19, 2010

Cost Proposal	
(13) Name, address, and telephone number of the proposer's cognizant Defense Contract Management Agency (DCMA) administration office (if known)	Mr. Marvin Liebman, ACO DCMA, New York Ft. Wadsworth, Building 120 207 New York Avenue, Staten Island, NY 10305
(14) Name, address, and telephone number of the proposer's cognizant Defense Contract Audit Agency (DCAA) audit office (if known)	Tom Caruso Supervisory Auditor DCAA Greater Connecticut Branch Office 12 Cambridge Drive Trumbull, CT 06611 Phone: 914-945-3412 Email: tom.caruso@dcaa.mil
(15) Date proposal was prepared	July 20, 2009
(16) DUNS number	084006741
(17) TIN number	130871985
(18) Cage Code	2G381
(19) Subcontractor Information	NA
(20) Proposal validity period [minimum of 90 days]	October 20, 2009

This proposal includes data that shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed - in whole or in part - for any purpose other than to evaluate this proposal. If, however, a contract is awarded to this proposer 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.

Table of Contents

B: Detailed Estimated Cost Breakdown

(1) Total Cost by Major Cost Items

IBM is proposing a 24 month period of performance starting December 1, 2009 for a total cost of $2,934,751. The Government Share is $2,347,801 and the IBM Share is $586,950. The Cost Summary broken down by major cost item for each period is illustrated below.

SUPPORT	PERIOD 1	PERIOD 2	TOTAL
Total Contract Expense	REDACTED EXEMPTION 4		
Research Share			
Government Share	$1,532,425	$815,375	$2,347,801
Government Share %	80.00%	80.00%	

EXPENSE	PERIOD 1	PERIOD 2	TOTAL
REDACTED EXEMPTION 4	REDACTED EXEMPTION 4		
TOTAL ESTIMATED COST			

Periods of Performance were assumed to be:
Period 1: 12/1/2009 – 11/30/2010
Period 2: 12/1/2010 – 11/30/2011

REDACTED
EXEMPTION 4

a. Direct Labor Costs

REDACTED
EXEMPTION 4

LABOR (Hours to be Spent on Contract)		
NAME	Period 1	Period 2

REDACTED
EXEMPTION 4

b. Other Direct Costs

In the DOE Budget Justification, there are two categories – equipment and supplies. Both are defined per 10 CFR 600 as:

"Equipment" means tangible nonexpendable personal property including exempt property charged directly to the award having a useful life of more than one year and an acquisition cost of $5000 or more per unit.

"Supplies" means tangible, expendable personal property that is charged directly to the award and that has a useful life of less than one year or an acquisition cost of less than $5,000 per unit.

The IBM Research accounting uses the following definitions from FAR Part 45.101:

"Equipment" means a tangible asset that is functionally complete for its intended purpose, durable, nonexpendable, and needed for the performance of a contract. Equipment is not intended for sale. and does not ordinarily lose its identity or become a component part of another article when put into use.

"Material" means property that may be consumed or expended during the performance of a contract, component parts of a higher assembly, or items that lose their individual identity through incorporation into an end-item. Material does not include equipment. special tooling, and special test equipment.

Per the FAR Part 45.101 Definitions, the items listed below are Materials. Also provided is both a justification and description to better explain how the item is being utilized. For the proposal preparation, these Materials were placed on the "Supplies" tab of the PMC123.1 Spreadsheet to denote the "expendable" nature of these purchases.

Item	Qt	Cost	Total Cost	Task
REDACTED EXEMPTION 4			REDACTED EXEMPTION 4	

Item	Justification	Description

REDACTED
EXEMPTION 4

CSS: The acronym stands for Central Scientific Services which is best thought of as model shop charges. They would apply to a range of services having to do with electrical fabrication, mechanical engineering, etc. The rates vary by function and are offered to whichever sites or external customers as may require them.

CSS CHARGES A. Model Shop	09 Rate	Period 1	Period 2

Travel: These are the project related costs. The air fare where applicable is obtained from American Express which holds the IBM Corporate contract and is responsible to get us the lowest possible fare. Per Diem costs associated with travel are in compliance with the Federal Travel Regulations for domestic and the Joint Travel Regulations published by the U. S Dept. of State for overseas travel. Per Diem includes taxi fares, parking, tips, etc. Car rental, when used, is based on IBM Corporate agreement with Hertz Corp. Car Rental includes $113 for round trip to the airport. Travel destinations and expenses are estimates based on current information at the time of pricing.

Estimated travel is based on the following cost assumptions for each year of this project.

Period 1 TRAVEL	# OF PEOPLE	# OF DAYS	AIR FARE	HOTEL & MEALS	PER DIEM MISC	AUTO RENTAL	OTHER	TOTAL	# OF TRIPS	TOTAL COST

REDACTED
EXEMPTION 4

Period 2 TRAVEL	# OF PEOPLE	# OF DAYS	AIR FARE	HOTEL & MEALS	PER DIEM MISC	AUTO RENTAL	OTHER	TOTAL	# OF TRIPS	TOTAL COST

REDACTED
EXEMPTION 4

Charges from other divisions: There are times when the Research Division needs to employ other IBM Divisions to assist in completing the objectives of the proposal. In those cases the divisions participate and their person year rate is used to compute charges.

IBM Server and Technology Group (STG) is a commercial division of IBM.

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

c. Indirect Charges

The indirect costs are defined below with the rates provided in Appendix B.

REDACTED
EXEMPTION 4

C: Cost by Task

(1) Direct Labor Costs by Task

sss

Appendix A - IBM 2009 Provisional Rate Letter

Appendix B - IBM Cost Calculations by Phase/Year

Economizer Based Data Center Liquid Cooling with Advanced Metal Interfaces

1) Project Overview

The objective of this project is to reduce the cooling energy to 5% of total data center energy which addresses the second area of interest, Information and Communication Technologies R&D for Energy Efficiency. The proposal will focus on the development of two complimentary novel technologies that can radically reduce the energy consumption of data centers by using direct cooling from the outside ambient environment and eliminate refrigeration equipment with a projected US energy savings of 140 Trillion BTU's by 2020.

Firstly, a server compatible Liquid Metal Thermal Interface (LMTI) [1] will be developed to improve the thermal conduction path of the hot server components to the data center ambient cooling. This liquid metal thermal interface has a thermal conductivity an order of magnitude better than state of the art materials. When integrated directly between a bare die and a water cooled heat sink this technology will achieve a significant improvement in thermal conduction and enable the computer devices to operate in a much higher ambient temperature environment.

Secondly, a dual enclosure air/liquid cooling system will be developed to allow direct cooling from the outside ambient environment. This Dual Enclosure Liquid Cooling (DELC) system uses recirculated air and water which are cooled only by heat exchange with the outside ambient air. The DELC will also comprise sensors and servo control algorithms which can adjust the cooling component operating parameters based upon the server rack heat load and the outdoor air temperature to minimize the cooling component energy usage.

The integration of LMTI and DELC will eliminate the data center refrigeration chiller plant as well as several other cooling components, thus allowing for as much as 85% reduction in the cooling energy cost. The water, cooled only by heat exchange with the outside ambient environment, will enter the DELC at a temperature above the outdoor air temperature and will warm up by extracting heat from the higher temperature server components. In cases when the DELC outlet water temperature exceeds 40C, this provides an opportunity to recover the waste heat from the servers in the form of hot water that could be utilized for low grade commercial or residential heating [2].

To maximize the energy impact, this proposal will focus on the largest segment of the server market which is the Volume server as shown in Figure 1 . The processor power for Volume servers are currently in the range of 60-130 watts and have been increasing. The solutions to be demonstrated in this proposal are extendible to much higher power processors > 200W and can be applied to today's Mid-range and High-end servers, allowing extendibility to future server requirements.

Thus far, water cooling has been based on chilled water and has been limited to High-End systems due to cost of infrastructure, implementation and energy required to provide refrigeration chilled water. The DELC and LMTI technologies will advance the state of the art of water cooling by enabling the use of ambient cooled water to provide a cost effective solution for commercial Volume, Mid-range and High-End systems where the largest segment will use processor power of 90 watts or greater and node power of 200 watts or above.

2) Technical Background

2.1 Data Center Energy Consumption Trends

A recent study from the Lawrence Berkeley National Laboratory [3] has reported that in 2005, server driven power usage amounted to 1.2% and 0.8% of the total US and Worldwide energy consumption respectively. Figure 1 illustrates these trends reported in the Koomey report [4]. This study also reports a doubling of the server related electricity consumption between 2000 and 2005 and a 76% increase in server related power usage between 2005 and 2010. Thus, understanding and improving the energy efficiency of data center systems is important from a cost and sustainability perspective.

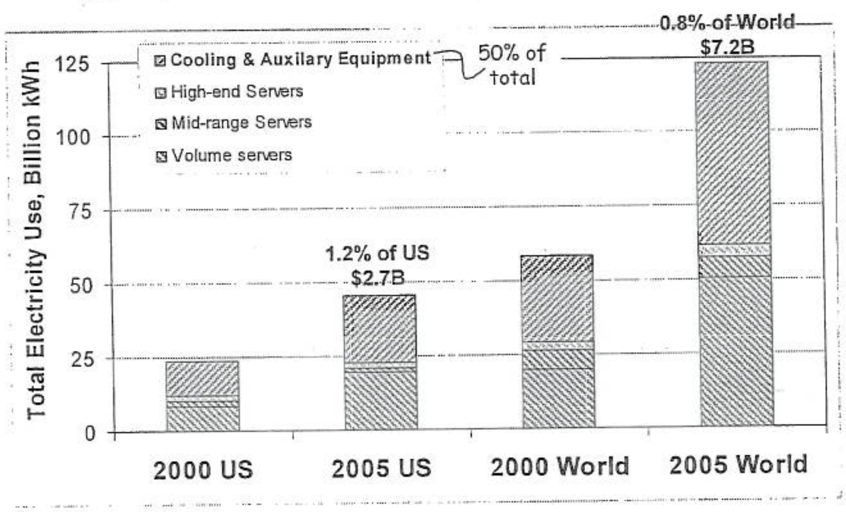
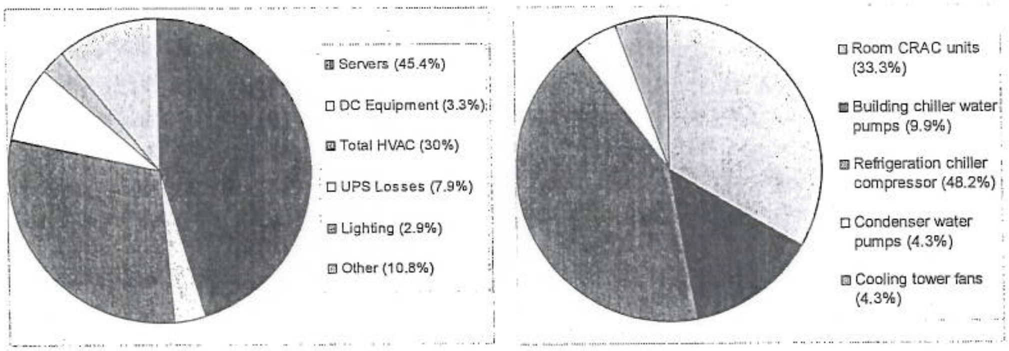


Figure 1 US/Global trends - Energy use by Servers, Cooling, & Auxiliary Equipment [1]

2.2 Data Center Energy Consumption Breakdown

Figures 2(a) displays the energy consumption breakdown for a typical data center, and Figure 2(b) presents a detailed break up of the cooling energy components. In a typical data center, electrical energy is drawn from the main grid to power an Uninterruptible Power Supply (UPS) system, which then provides power to the IT equipment. Electrical power from the main grid is also used to supply power to offices, as well as to power the cooling infrastructure, i.e. for the room air-conditioning units (CRAC), building chilled water pumps, and the refrigeration plant. The IT equipment usually consumes about 45-55% of the total electricity, and total cooling energy consumption is roughly 30-40% of the total energy use. The cooling infrastructure is made up of three elements, the refrigeration chiller plant (including the cooling tower fans and condenser water pumps, in the case of water-cooled condensers), the building chilled water pumps, and the data center floor air-conditioning units (CRACs).



Typical total data center energy breakdown — Typical data center cooling energy breakdown

Figure 2 Data Center Energy Consumption (2a) Overall break up of energy use components, (2b) Detailed break up of the cooling energy components

2.3 Traditional Data Center Cooling Loop Design

The cooling energy flow for a data center facility is shown in Figure 3. Sub-ambient refrigerated water leaving the refrigeration chiller plant is circulated through the CRAC units, using building chilled water pumps. This water carries heat away from the raised floor room and rejects the heat into the refrigeration chiller plant evaporator heat exchanger. The refrigeration chiller plant operates on a vapor compression cycle and consumes compression work via a compressor. The refrigerant loop rejects the heat into a condenser water loop via the refrigeration chiller condenser heat exchanger. A condenser pump circulates water between the refrigeration chiller plant and the evaporative cooling tower. The evaporative cooling tower uses forced air movement and water evaporation to extract heat from the condenser water loop and transfer it into the outside ambient environment.

In this "standard" facility cooling design, the primary energy consumption components include [5]:

- Server fans
- Computer Room Air Conditioning (CRAC) blowers
- Building Chilled Water (BCW) pumps
- Refrigeration chiller compressors
- Condenser water pumps
- Cooling tower blowers

Several factors, which contribute to the inefficiency of current data center cooling designs and excessive energy consumption, include:

- Large thermal resistance between computer chips and the coolant that removes the heat
- Use of sub-ambient temperature air and water which require energy intensive chillers
- Inefficiency of using air as a cooling medium
- Low thermal conductivity and heat capacity, leading to large temperature drops
- Leakage of air from the under floor plenum to undesirable areas
  - Pressure drop of the under floor plenum.
  - Use of several daisy chained loops adding inefficiencies in each heat-exchanger
  - Inability to efficiently exploit "free cooling" from the environment

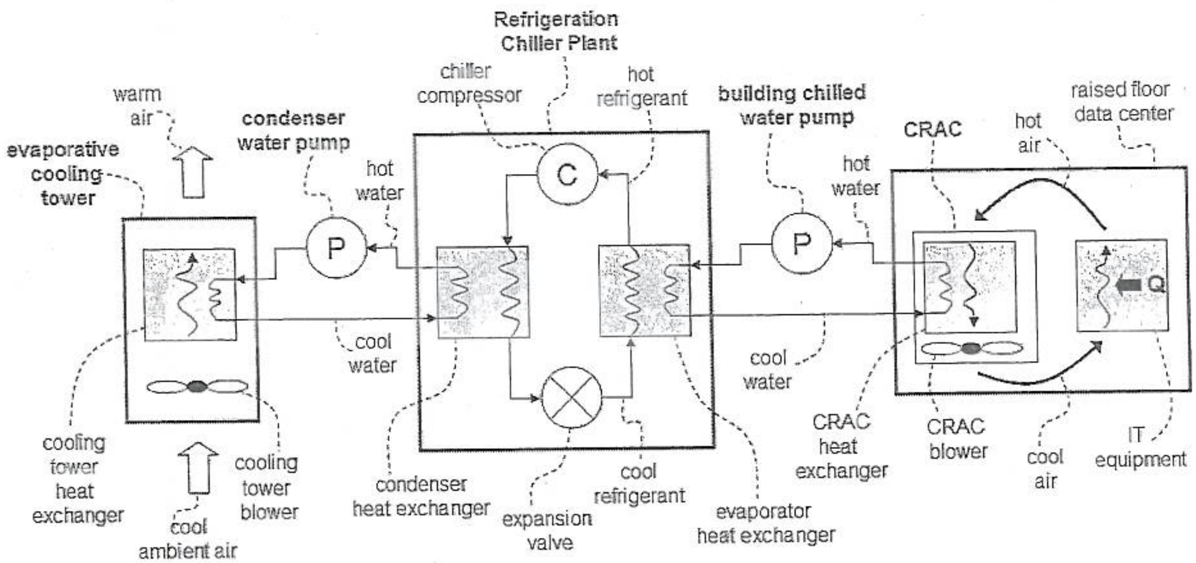


Figure 3 Schematic of Typical Data Center Facility Cooling Infrastructure

2.4 Chip Package Stack

A chip package stack for a computer is shown in Figure 4. The semiconductor die or "chip" is soldered to a chip carrier made of organic or ceramic material which provides electrical power, ground and signal paths to subsystems within a computer system. To remove the heat generated by the chip it is conducted to a heat spreader Lid and a heat sink which transfers the heat to the ambient air in the data center. To facilitate the transmission of the heat from chip to Lid and then Lid to heat sink, a thermal interface material is used which thermally joins the components to provide a conduction path. The thermal interface from the chip to Lid is commonly referred to as TIM1 and from Lid to heat sink as TIM2.

In most applications the TIM material used is a thermal grease or adhesive with moderate thermal conductivity which completely fills the gap between the surfaces between which heat must be transferred, even when these surfaces are rough or do not fit perfectly. Since TIMs have significantly lower bulk thermal conductivity than silicon or high-conductivity metals such as copper or aluminum, the TIM layer must be as thin as possible consistent with filling the gap and providing necessary compliance as the surfaces deform under thermomechanical stress. Typical TIMs are greases or adhesives heavily loaded with conductive fillers.

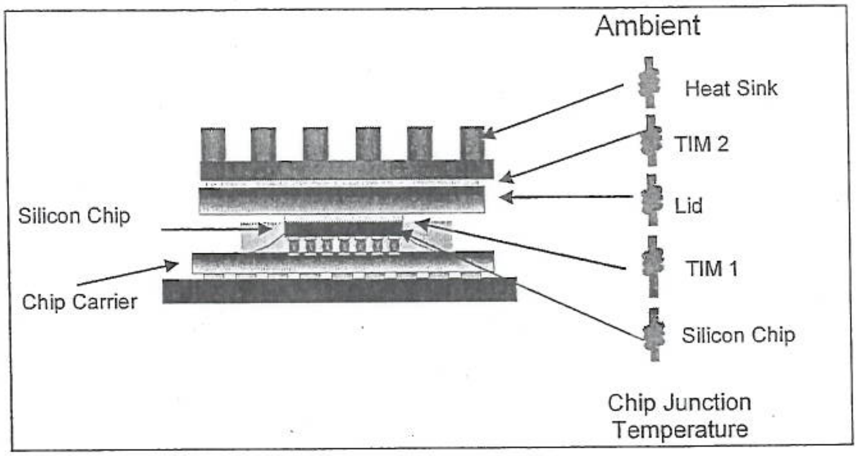


Figure 4 Chip Package Stack

2.5 Lidded Solder Metal Thermal Interface

The use of Indium alloy solder thermal interfaces [6] between the die and Lid (TIM1) are deployed commercially. However solder thermal interfaces require elevated processing temperature which is not compatible with direct heat sink or direct cold plate attachment and therefore requires a heat spreader Lid and a TIM2 to attach to a heat sink or cold plate.

The minimum bondline or thickness of solder thermal interfaces is limited by the Coefficient of Thermal Expansion (CTE) mismatch between Silicon (4ppm /C) and a typical copper Lid (17ppm/C) which produces mechanical stress in the solder thermal interface between the die and the copper lid. As a result, in current applications relatively thick indium metal of 250-300um um bondlines have been used with a resulting unit thermal resistance of between 6~10 mm^2 C/W. The thermal resistance achieved by solder metal interfaces is not significantly lower than TIM1 polymer adhesives which are able to achieve much thinner bondlines and unit thermal resistances of 10-13 mm^2 C/W.

3) Technical Merit

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

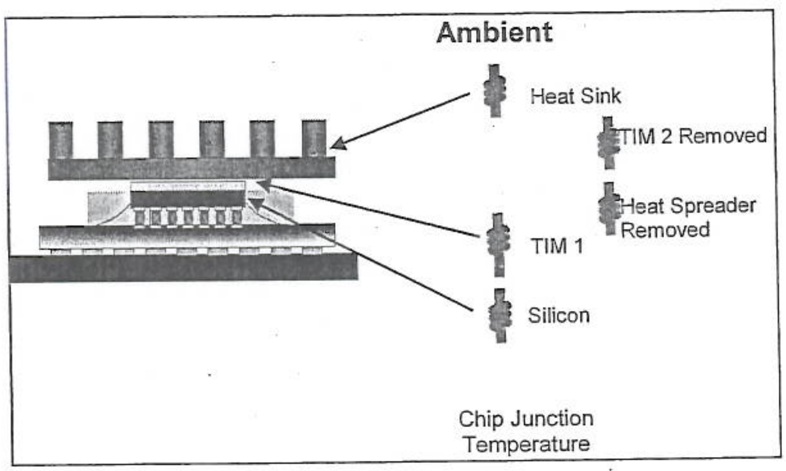


Figure 8 Removal of Lid and TIM2 to achieve Direct Heat Sink Attachment to Bare Die

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

REDACTED
EXEMPTION 4

4) Potential Benefits

A case study of the energy savings from deploying these new technologies will be described. Figure 12 shows a 1 MW server heat load cooled first using the traditional cooling scheme of Figure 3 and secondly with the newly proposed DELC and LMTI configuration cooling solution shown in Figure 5. The new proposed system only has three of the six cooling components that are found in typical layouts. The total facility power consumption for this 1 MW IT load was 1.7 MW for the typical configuration and 1.2 MW for the proposed design, thus showing a 29% reduction in total annual energy use. An assumption of 25°C ambient air was used to conduct this study and the inlet air or water temperature to the server components was assumed to be as high as 45°C. The current proposal will evaluate a range of operating conditions (e.g. temperature and flow rate of the air and water coolant) and different geometries.

A plot of the Power Usage Effectiveness (PUE) versus the temperature difference between the ambient air and the coolant (air or water) at the server cooling devices for the new proposed cooling technology is shown in Figure 13. PUE is defined as the total data center load divided by the IT load and is a popular method of gauging data center cooling efficiency.

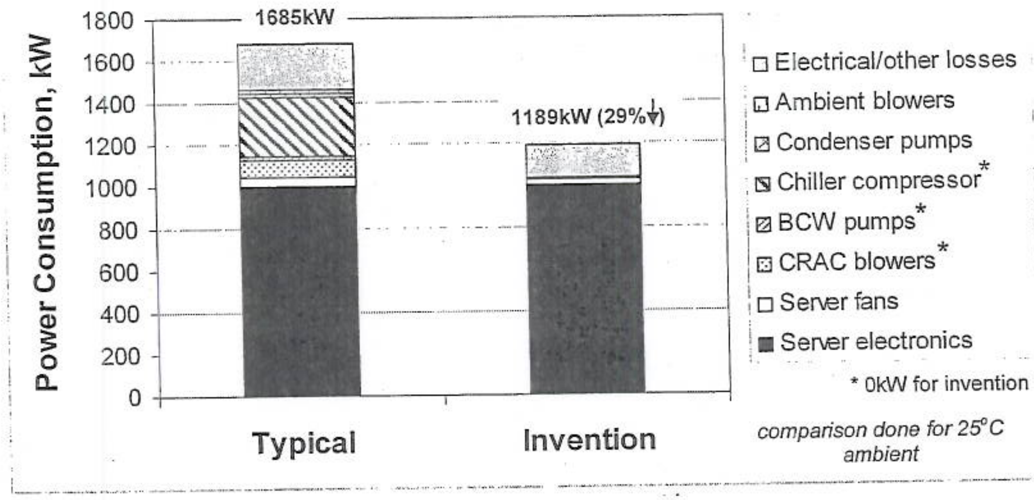


Figure 12 Data Center Power Consumption Comparison via a 1000kW IT Load Case Study

The closer the PUE value is to 1, the more power efficient the design. Typical numbers reported in the industry and literature, as well as the average value from the data collected by Tschudi et al. [3] in their 2006 study are also shown in Figure 13. The X axis in Figure 13 is the important temperature difference that drives the heat transfer between the server electronics and the ambient air. The smaller the available temperature difference between coolant and ambient, the more energy is needed to carry out the heat exchange.

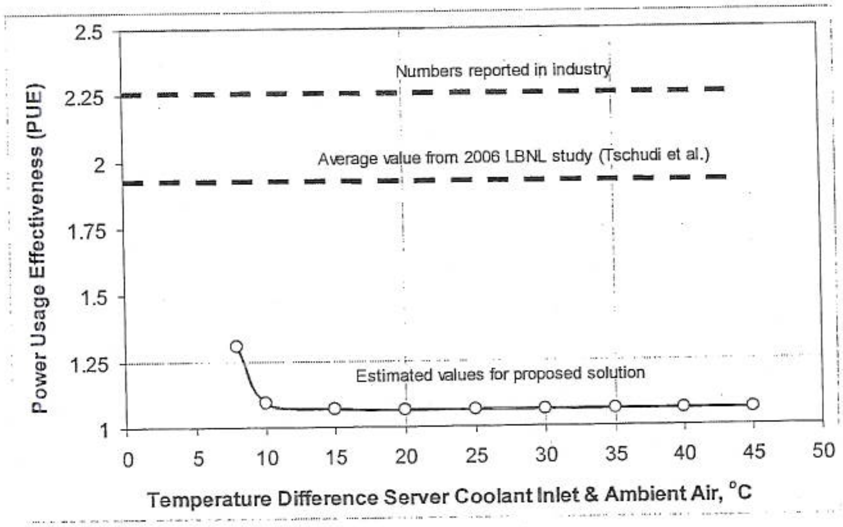


Figure 13 PUE vs (Liquid Coolant – Outside Air Temperature) of Proposed System and Typical Values and Impact of Outside Air Temperature

It is interesting to note that for the case study considered, the PUE is relatively insensitive to this temperature difference until this difference becomes very small (5-8°C) in which the heat extraction enclosure required a disproportionate amount of air to be pumped through it, thus steeply raising the blower motor power consumed for heat rejection to the ambient. To achieve an acceptable temperature difference of 10°C or greater, the goal will be to design a system which can be operated with coolant temperatures up to 45°C to accommodate 35° C outside ambient air temperatures. It is one of the goals of this study to investigate the feasibility of server thermal management with such relatively high coolant temperatures. While the high air temperature at the server inlet might result in high temperatures of devices such as DIMM memory cards, the CPU module temperatures are expected to be well within typical specifications as a result of the thermally efficient water cooled cold plates and LMTI. Alternatively, if needed, liquid cooling can also be applied to the DIMM and other components which is part of the risk management plan for this proposal.

The case study presented in the preceding section only captures energy savings for a single 1.7 MW data center. The 2006 EPA [5] document reported that 2006 US IT data center energy use was 61 Billion kWh and that was projected to be 124 Billion kWh by year 2011.

REDACTED
EXEMPTION 4

Migration of Volume servers from air to water cooling

A potential benefit of DELC and LMTI is to accelerate the migration of Volume servers which are presently air cooled to more energy efficient water cooling. Thus far, only chilled water cooling has been applied to High-End or Supercomputers servers due to the high cost of components and infrastructure.

The DELC / LMTI technology can drive the adoption of water cooling by enabling the following cost reductions:

- Elimination of the refrigeration plant and CRAC units, and associated maintenance costs;
- Substantial reduction in data center energy costs
- Large volume scaling of liquid cooling technology components

REDACTED
EXEMPTION 4

A letter of support for the DELC/LMTI technology from the Vice President and leading product technologist from IBM's volume server product development group in STG can be found in the appendix of this proposal.

Energy Reuse

The use of outside ambient air temperature "warm" water cooling enabled by the liquid metal interface technology and the Dual Enclosure Liquid Cooling systems, respectively, can result in the generation of hot water that exits the server rack. If the data center water exit temperature is at a sufficiently high temperature, all of the electrical energy that is being consumed by the servers for computational work can be recovered in the form of "useful" higher grade waste heat [2]. The available waste heat is relatively higher grade and more useful than the water exiting conventional data center facilities due to the higher exit water temperature that may allow for its use for heating applications. This recovered waste energy can then be used for heating of buildings within the data center or in the neighboring campus setting. Data centers are often located in a campus setting, thus lending themselves to such waste heat reuse concepts. Thus, this reuse of energy that was originally utilized by the servers can serve to offset energy that may have otherwise been consumed for heating purposes. While the waste heat from data centers discussed herein is not intended for residential purposes, it is illustrative to note that an average house in the north east region of the US will require about 30kW of furnace heating in winter, which would be roughly two servers, based on the configurations considered in this study. Assuming that this technology is installed on 3M servers in the US (roughly 25% of the US installed servers), which would translate to about 71,400 racks with 42 servers each, one could heat about 35,700 homes.

Job Creation

IBM recognizes that the receipt of this grant to conduct research for the study and commercialization of energy efficiency technologies will have measurable and lasting short- and long-term impact directly on our company and indirectly on the communities where we work and operate.

We use the historical information from the Bureaus of Economic Analysis and Labor Statistics to predict the direct and indirect impact on the economy. Specifically, using BEA Regional Input-Output Multipliers (RIMS II data), we have attempted to estimate how much this one-time increase and the sustained commercialization of the technology will impact how goods and services are supplied within each region and how the spending of earnings by labor within the region will change. The short-term impact represents a two year view of the increase due to stimulus, affecting IBM's employment and earnings, as well as the employment and earnings of business in the region. The long-term impact represents the sustained effects on the local economy due to the commercialization of the technology. In each case, we assume that Grant Award amount equals the RIMS II "Final Demand Change" for purposes of our calculations, and we apply the Output, Employment, and Earning Multipliers accordingly.

For the proposed energy saving technologies, in the short-term (next 24 months), the direct effect will be the hiring of a new Post-Doctoral student, continued employment and partial funding of 10 researchers and engineers by IBM Research for the project. The indirect effect on the local economy of awarding the grant to IBM will be an increase of 17 jobs in the first year, 9 jobs in the second year, with an overall financial contribution to GDP of $8.1M, and with $2.4M in additional earnings realized by IBM employees and other local workers. [BEA RIMs (Type II) Table 3.5; Table 54151A – Computer Facilities Mgmt]

In the long term, new job opportunities will be created as the advanced DELC and LMTI energy efficient technologies proposed are adopted for servers for both Mid-tier and Enterprise Class Data Centers. The 2013 ICD Market Analysis for Volume Server shipments is 3 M in the US and 8.8 M Worldwide. In the case of fully populated racks of 42 servers, this would project Worldwide shipments of approximately 209,000 fully populated racks.

Assembly: The total cost of ownership of servers will drive adoption of new energy efficient cooling technology. Using 2013 volumes and assuming a 25% market penetration of Worldwide new server shipments would result in approximately 52,000 racks per year shipped with DELC and LMTI technology. The DELC technology requires manual assembly of cooling components at the rack level which we estimate at 40 hours per rack which would require 1040 assembly jobs for a 50 week work year. The maximum number of assembly jobs for 50% market penetration would be 2080. These jobs are sustainable as the server volume shipments are renewed every year.

Manufacturing: The DELC components include a side car heat exchanger which has a construction similar to an automobile radiator, but with much larger area. IT heat exchangers have been manufactured by automotive parts suppliers, for example by Delphi. The DELC technology would provide new volumes for the automobile parts suppliers to address the IT equipment sector of 50,0000 to 100,000 heat exchangers for 25% and 50% market penetration respectively. This could provide new market opportunities for these suppliers in a growing IT market segment which could offset declining automobile sales.

The DELC and LMTI technology deploy two cold plates for each Volume Server, which would require 4.4 Million and 8.8 Million units for 25% and 50% market penetration respectively. The number of new manufacturing jobs for cold plate is dependent upon the level of manufacturing automation.

Engineering: As the DELC and LMTI technology will require mechanical designs of heat exchangers, liquid cold plates, metal alloys and gaskets , this technology would require engineering and manufacturing processing job creation including:

- Mechanical Engineering for heat exchanger and cold plate mechanical designs
- Process and Chemical engineering for cold plate fabrication
- Material science for metal alloys and gaskets

REDACTED
EXEMPTION 4

5) Commercialization and Market Acceptance

5.1 IBM Commitment to Energy Saving Technology

IBM's approach to the energy and environmental challenges are twofold: we are working to make our existing products and processes more efficient for both the environment and for business, while also developing new innovations that can accelerate the adoption of products and services that have lesser environmental impact. Today's energy- and climate-related issues are at the top of our strategic agenda. We recognize that information technology plays an extremely important role in helping solve the myriad of ecological challenges faced by the global society—such as conserving our scarce resources even as global demand skyrockets, reducing pollution, minimizing the environmental impact of our activities, and enabling safe and renewable alternative sources of energy.

IBM research, technology and our ability to solve complex business challenges are helping clients achieve their energy- and environment-related goals. As a globally integrated enterprise, IBM is ushering in a new era of business responsibility, based on environmentally sound stewardship in both mature and fast-growing markets. With decades of leadership in environmental stewardship; unmatched talent in IT and business innovation; and unparalleled global reach, IBM is unique in its ability to foster a sustainable future for our clients, for IBM itself and society as a whole.

5.2 DELC / LMTI Commercialization Plan

IBM plans to commercialize this technology for broad market adoption. The first step is to work with a commercialization partner to prototype this IBM technology and measure the resultant prototype against its goals for energy efficiency, product cost targets, and manufacturability. This industry partner will be selected on the basis of their strengths in manufacturing mechanical systems, and in marketing and selling cooling technologies within the United States.

Once prototypes have been built, evaluated, and determined to meet product goals, a license grant would be extended to the commercialization partner to allow the partner to make, sell, and distribute products based on the IBM technology.

IBM may offer product as part of the IBM offerings portfolio. IBM has products and solutions on the market today, targeted at data center efficiency. Solution examples include the IBM Scalable Modular Datacenter ™ and the IBM Portable Modular Datacenter ™, which are solutions from IBM's Global Technology Services organization, and offer leading edge IT and cooling technologies to datacenters. Product examples include the Cool Blue™ portfolio, which are a set of products from IBM's Systems and Technology Group, and include rack level cooling via the IBM Rear Door Heat Exchanger, and power usage monitoring and management via the IBM Active Energy Manager software. The DELC / LMTI technology could be an addition to either IBM's solutions portfolio through IBM's Global Technology Services offerings, and/or a standalone product offered through IBM's Systems and Technology Group.

IBM's commercialization partner would offer product as part of a solution that they market and sell, that is not restricted to IBM or any other company's offerings. IBM or our commercialization partner may also offer product as an OEM solution, to other companies with interest in marketing and selling products or solutions into the data communications facilities cooling market.

IBM and the commercialization partner would work together on go-to-market deliverables, to ensure that total cost of ownership (TCO) tools are developed and available for potential customers to use for evaluation, to incorporate the technology into IBM's datacenter modeling tools, and to prepare technical specifications and marketing collateral that both IBM and the commercialization partner can utilize. IBM and IBM's commercialization partner may also participate together, and independently, in industry conferences, trade shows, and industry testing, such as Silicon Valley Lab Group technology evaluations.

5.3 IBM's Integrated Product Development (IPD) Process

IBM will adapt its Integrated Product Development (IPD) Process shown in Figure 15 to the DOE Stage-Gate Innovation Management Process to commercialize the technology resulting from this work. The IBM IPD Process is used by IBM to develop commercial hardware, software, services, and solutions and to manage these from concept to end of life. It is very extensive, and only key points can be highlighted within the space constraints of this document. With an emphasis on early and continuing decision making about the business value proposition, commercialization is guided by a set of structured Decision Checkpoints (DCPs) for Concept, Plan, Availability (at end of Develop & Qualify Phase) and End of Life.

REDACTED
EXEMPTION 4

The IPD is segmented into five phases, each of which has a set of specific entry and exit criteria similar to the DOE Stage-Gate Process. The IPD phases are:

- Develop Requirements and Concepts
- Develop Definition and Project Plan
- Develop & Qualify
- Ramp-up and Launch
- Manage Life Cycle

The purpose of the 'Develop Requirements and Concepts' phase is to test the offering concept and initial project plan for business value. The cross-functional PDT looks at the business value proposition from all angles and recommends proceeding, or not, to the Integrated Portfolio Management Team (IPMT). A Concept Design Checkpoint (CDCP) must be passed to advance to the Plan phase.

The purpose of the 'Develop Definition and Project Plan' (Plan) phase is to develop a cross functional business plan for review and approval by the IPMT. The Project Development Team (PDT) uses extended team members, with specific functional expertise, to create a full business plan that looks at all parts of the cross-functional involvement for the offering. The key decision at the end of the phase is whether to commit significant development resources to the project, along with some resources in all the other functions. A Plan Design Checkpoint (PDCP) must be passed to advance to the Develop & Qualify phase.

The purpose in the 'Develop & Qualify' phase is to prove that the technology and the surrounding cross-functional items in the approved plan can meet the key market requirements included in the new offering request charter. The phase includes initial functional verification and risk assessments across all functions, system testing and integration, and any special testing for external certification. Customer testing may include an Early Ship Program. Significant development resources and some other functional extended teams are used. An Availability Design Checkpoint (ADCP) must be passed to advance to the Ramp-up and Launch phase.