Plasma Science and Innovation Center (PSI-Center) at Washington, Wisconsin, and Utah State

ARRA Supplement

Final Technical Report
3/1/2010-2/28/2011

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in collaboration with

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The U.S. Department of Energy
Office of Fusion Energy Sciences
Award No. DE-FC02-05ER54813

1. Executive Summary

The objective of the Plasma Science and Innovation Center (PSI-Center) is to develop and deploy computational models that simulate conditions in smaller, concept-exploration plasma experiments. The PSIC group at the University of Wisconsin-Madison, led by Prof. Carl Sovinec, uses and enhances the Non-Ideal Magnetohydrodynamics with Rotation, Open Discussion (NIMROD) code, https://nimrodteam.org, to simulate macroscopic plasma dynamics in a number of magnetic confinement configurations. These numerical simulations provide information on how magnetic fields and plasma flows evolve over all three spatial dimensions, which supplements the limited access of diagnostics in plasma experiments. The information gained from simulation helps explain how plasma evolves. It is also used to engineer more effective plasma confinement systems, reducing the need for building many experiments to cover the physical parameter space. The ultimate benefit is a more cost-effective approach to the development of fusion energy for peaceful power production.

The supplemental funds provided by the American Recovery and Reinvestment Act of 2009 were used to purchase computer components that were assembled into a 48-core system with 256 Gb of shared memory. The system was engineered and constructed by the group's system administrator at the time, Anthony Hammond. It was successfully used[1] by then graduate student, Dr. John O'Bryan, for computing magnetic relaxation dynamics that occur during experimental tests of non-inductive startup in the Pegasus Toroidal Experiment (pegasus.ep.wisc.edu). Dr. O'Bryan's simulations provided the first detailed explanation of how the driven helical filament of electrical current evolves into a toroidal tokamak-like plasma configuration.

2. Summary of Activities

In late 2009, when the supplement was proposed, the intent was to use the funds to purchase two eight-core workstations with 32 Gb of memory each. By the time that the award was received, it became evident that a much more powerful system could be constructed with the same funds, so we purchased four 12-core AMD Opteron Magny-Cours processors, 16 Kingston 16 Gb memory chips, a SuperMicro 1U rack server unit, and other components needed to construct a 48-core parallel server with a large amount of shared memory. Our system administrator was able to assemble the components and have the system operational soon after purchasing all components. Initially, cooling in the rack unit was a problem. One of the four processors was located downwind of the other three, and its measured temperature would exceed safe operating conditions when all four processors were in continuous use. This was remedied by finding a rack location below an open gap and by providing additional ventilation to the processors.

The simulations that were performed on the computer system made a major contribution to the Pegasus experimental program, and the results are still used today. They were presented at plasma science conferences and are published in the two journal articles cited in Section 3.

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[1]A number of these large-scale simulations were needed for the study, and O'Bryan also used resources at the National Energy Scientific Research Computing Center.

Over time, aspects of the system have deteriorated, and when it was last booted approximately two years prior to the preparation of this report, its capability for performing parallel computations had become significantly degraded. Being seven years old and not competitive with modern systems, its components no longer have appreciable value.

3. Products

Journal publications on simulation results computed with the 48-core system:

1. J. B. O'Bryan, C. R. Sovinec, and T. M Bird, "Simulation of Current-Filament Dynamics and Relaxation in the Pegasus Spherical Tokamak," Physics of Plasmas **19**, 080701 (2012).
2. J. B. O'Bryan and C. R. Sovinec, "Simulated flux-rope evolution during non-inductive startup in Pegasus," Plasma Physics and Controlled Fusion **56**, 064005 (2014).

Conference presentation on simulation results computed with the 48-core system:

1. J. B. O'Bryan and C. R. Sovinec, "Simulation of current-filament dynamics and relaxation in the Pegasus ST," presentation NP8.00069, Bull. Am. Phys. Soc. **57**, No. 12, 54th Annual Meeting of the APS Division of Plasma Physics, Oct. 29-Nov. 2, 2012, Providence, Rhode Island.
2. J. B. O'Bryan and C. R. Sovinec, "Simulation of current-filament dynamics and relaxation in the Pegasus ST," presented at the 2013 International Sherwood Theory Conference, April 15-17, 2013, Santa Fe, New Mexico.
3. J. B. O'Bryan and C. R. Sovinec, "Simulation of current-filament relaxation and dynamics in the Pegasus ST," presentation JO4.00003, Bull. Am. Phys. Soc. **58**, No. 16, 55th Annual Meeting of the APS Division of Plasma Physics, Nov. 11-15, 2013, Denver, Colorado.
4. John O'Bryan, "Simulation of flux-rope evolution and relaxation during non-inductive startup in the Pegasus ST," selected plenary talk at the 2014 International Sherwood Theory Conference, March 24-26, 2014, San Diego, California.

4. Computer Modeling

A description of the hardware purchased through this supplemental grant, and used for the simulations of non-inductive startup, is provided in Section 2. Detailed derivations and analysis of the model used for the simulations are published in the following peer-reviewed journal articles:

1. C. R. Sovinec, A. H. Glasser, T. A. Gianakon, D. C. Barnes, R. A. Nebel, S. E. Kruger, D. D. Schnack, S. J. Plimpton, A. Tarditi, M. Chu, and the NIMROD Team, "Nonlinear Magnetohydrodynamics Simulation using High-Order Finite Elements," Journal of Computational Physics **195**, 355 (2004).
2. C. R. Sovinec, J. R. King, and the NIMROD Team, "Analysis of a Mixed Semi-Implicit/Implicit Algorithm for Low-Frequency Two-Fluid Plasma Modeling," Journal of Computational Physics **229**, 5803 (2010).

Appendix

Because this supplemental grant was used for equipment purchase, receipts are included in the following pages.

REQ NUMBER: _____ AWARDED VENDOR NAME(S): New Egg AWARDED VENDOR NUMBER(S): 117514 FY 11

POSITIVE APPROVAL REQUIRED? YES ( ) NO ( ) DUE DATE: 1/18/11

SIMPLIFIED BID SUMMARY SHEET (see IPP #9)

INSTRUCTIONS: INDIVIDUALS OBTAINING BIDS SHOULD TELL THE VENDORS THEY ARE UNIVERSITY EMPLOYEES SEEKING COMPETITIVE BIDS. AN INSURANCE CERTIFICATE MAY BE REQUIRED (see IPP #12).

BID OBTAINED BY/DATE: kathy Wagner 1/18/11 ABSTRACT COMPLETED BY/DATE: WSm 1/18/11 AWARD APPROVED BY/DATE: WSm 1/11/11

MBE=MINORITY BUSINESS ENTERPRISE SW=SHELTERED WORK CENTER		MBE ( ) SW ( )			MBE ( ) SW ( )			MBE ( ) SW ( )			MINORITY VENDOR (√ if MBE provider not available)		
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TELEPHONE #		800-390-1119			866-352-1173			1-877-AS-3535					
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VENDOR CONTACT NAME		Website			website			website					
INITIAL CONTACT DATE/BID REC'D DATE		1/18/11			1/18/11			1/18/11					
DESCRIPTION	QTY	ALT (X)	UNIT PRICE	TOTAL PRICE	ALT (X)	UNIT PRICE	TOTAL PRICE	ALT (X)	UNIT PRICE	TOTAL PRICE	ALT (X)	UNIT PRICE	TOTAL PRICE
Rackmount Server System	1		$12,913.74	$12,913.74		$14,224.00	$14,224.00		$16,587.00	$16,587.00		$	$
			$	$		$	$		$	$		$	$
			$	$		$	$		$	$		$	$
FREIGHT F.O.B. (D)?			$ 46.91 S			$ S			$ S			$	
RECIPROCITY, MINORITY PREFERENCE CALCULATION (if applicable)			$			$			$			$	
BID TOTAL			$12,960.65			$ 14,224.00			$ 16,587.00			$	
*DELIVERY DATE													

ADDITIONAL COMMENTS OR JUSTIFICATION: Awarded to lowest cost Vendor

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Transaction Date	1/19/11
Estimated Delivery Date	1/21/11
Cardholder Name	Katherine Wegner
Cardholder Phone	3-6142
Name	Carl Sovinec
Email	sovinec@engr.wisc.edu
Phone	608-263-5525
FY	11
Fund	144
ProjGrant	PRJ38NE
Dept	198000
Program	4
Acct	4602
Amount	$12,966.53
Component Item	Yes
Cap Equip #	U0634194
PO/Req #	A821730
Vendor Name	Newegg
Manufacturer	Super Micro
Serial	S1F42GT10B0288
Model	818-14
Description	Server, memory, hard drives, cooler, processors - components for Fabrication "Custom Built Cluster Nodes"
Location	ERB (0762) Rm 1010A; ME (0407), Rm 4170
submit	SUBMIT

Original-recipient: rfc822;kjwegner@facstaff.wisc.edu
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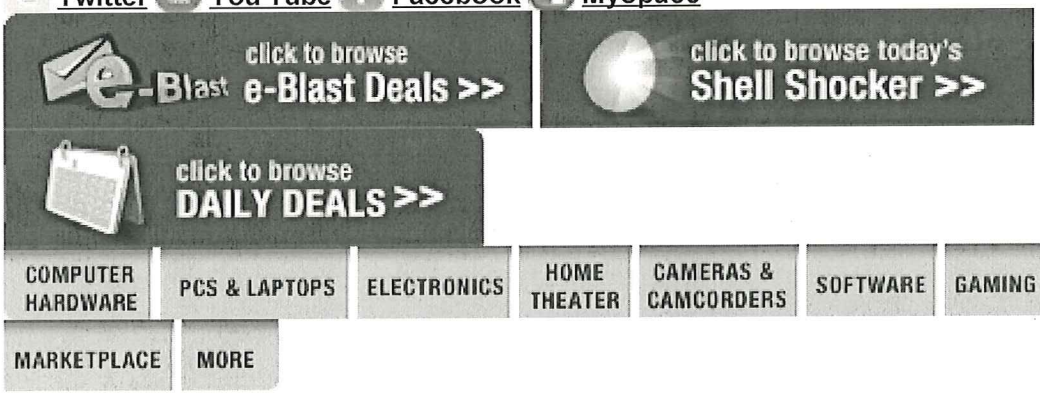

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Invoice Number:

69047191
Invoice Date:
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Item List:

ItemDescription		Quantity Unit Price Extended Price
19-105-267	CPU AMD|OPT X12 6168 1.9G G34 RT	4 $769.00 $3,076.00

Payment Summary:

Payment Term:
VISA
Subtotal:
$3076.00
Tax:
$0.00
Shipping and Handling:
$0.00
Total Amount:
$3076.00

UPS Ground
Tracking Your Order: 1Z1836920377012406

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Original-recipient: rfc822;kjwegner@facstaff.wisc.edu
Date: Thu, 20 Jan 2011 04:14:24 -0800
From: Newegg <info@newegg.com>
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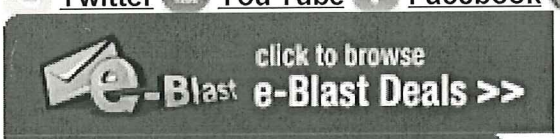

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608-263-8142

Invoice Number:

69037498
Invoice Date:
1/19/2011 3:22:19 PM

Item List:

Item	Description	Quantity Unit Price Extended Price
16-101-317	SERVER_BB SUPERMICRO|AS-1042G-TF R	1 $1,499.99 $1,499.99
20-139-271	MEM 8Gx2|KST KVR1333D3D4R9SK2/16G R	10 $499.99 $4,999.90
22-152-238	HD 1T|SAMSUNG HE103SJ 7K %	2 $99.99 $199.98
35-100-007	CPU THERMPASTE|AS5-3.5G %	1 $9.99 $9.99
35-106-158	CPU COOLER TT| CLS0015 RT	4 $31.99 $127.96

Original-recipient: rfc822;kjwegner@facstaff.wisc.edu
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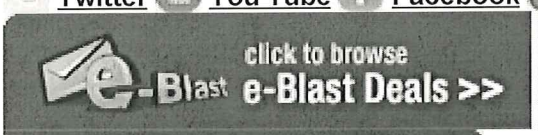

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Order Total: $3,008.48

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Madison, WI 53706-1609
608-263-8142

Invoice Number:

69064247
Invoice Date:
1/20/2011 10:52:45 AM

Item List:

ItemDescription		Quantity Unit Price Extended Price
20-139-271	MEM 8Gx2|KST KVR1333D3D4R9SK2/16G R	6 $499.99 $2,999.94

Payment Summary:

Payment Term:
VISA
Subtotal:
$2999.94
Tax:
$0.00
Shipping and Handling:
$8.54
Total Amount:
$3008.48

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Phone	3-5525
FY	11
Fund	144
ProjGrant	PRJ38NE
Dept	198000
Program	4
Acct	4602
Amount	$3,033.47
FYA	11
FundA	233
ProjGrantA	233J756
DeptA	198000
ProgramA	4
AcctA	4602
AmountA	$13.52
Component Item	Yes
Cap Equip #	U0634194
PO/Req #	A821730
Vendor Name	Amazon.com
Manufacturer	Samsung
Serial	n/a
Model	F4EG2-TB-SATA2
Description	Hard drives - components for Fabrication"Custom Built Cluster Nodes"
Location	ERB (0762) Rm 1010A; ME (0407), Rm 4170
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