U. S. DEPARTMENT OF ENERGY
WORK PROPOSAL

1. Work Proposal Number:	2. Revision Number:	3. Date Prepared:
FNAL09-23	0	June 9, 2009

4. Work Proposal Title:	5. Budget and Reporting Code
Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI)	KJ-0102-000

6. Work Proposal Term: Begin: September 1, 2009 End: August 31, 2012

7. Name (Last, First, MI) and Phone Number of the Headquarters Program Manager	8. Headquarters Organization
Dr. Teresa Beachley	Office of Science - SC
9. DOE Field Organization Work Proposal Reviewer:	**10. DOE Field Organization:**
	Fermi Site Office (FSO)
11. Contractor Work Proposal Manager:	**12. Contractor Name:**
Dr. Mine Altunay (630) 840-6490	Fermi National Accelerator Laboratory Pier J. Oddone, Director F. R. A. : Contract Number DE-AC02-07CH11359

13.

Preparing for and understanding Cybersecurity risk and threat is a crucial concern for the operation of wide-area distributed systems. Collaborations of up to thousands of users and hundreds of institutions mean that the behavior and spread of such risks and incidents span administrative boundaries and social networks of researchers. We propose to mathematically model, through agent based modeling and simulation methods, the risk and threat on multi-domain interconnected computers. We propose to compare the behaviors predicted by the models to measurements on the Open Science Grid. These measurements will be made as a result of stimulated incidents as well as actual security threats and incidents that occur over the distributed infrastructure.

14. Contractor Work Proposal Manager:	15. DOE Field Organization Official:
(Signature) Pier J. Oddone 6/9/09 (Date)	(Signature) (Date)

16. Detail Attachments (See Specific Attachments)

- [ ] a. Facility Requirements
- [ ] b. Publications
- [ ] c. Purpose (mandatory)
- [ ] d. Background
- [ ] e. Approach
- [ ] f. Technical Progress
- [ ] g. Future Accomplishments
- [ ] h. Relationship to Other Projects
- [ ] i. NEPA Requirements
- [ ] j. Milestones
- [ ] k. Deliverables
- [ ] l. Performance Measures/ Expectations
- [ ] m. ES&H Considerations
- [ ] n. Human/Animal Subjects
- [ ] o. Security Requirements
- [ ] p. Other (specify)

WORK PROPOSAL REQUIREMENTS FOR OPERATING/EQUIPMENT OBLIGATIONS AND COSTS

CONTRACTOR NAME	WORK PROPOSAL NO.	REV. NO.:	DATE PREPARED
Fermilab	FNAL09-23	0.0	09-Jun-09

	Prior Years	BY-1	Budget Year (BY)		BY+1	BY+2	Total to Complete
17. Staffing (staff years)			Request	Authorized			
a. Scientific							
b. Other Direct			0.7		0.7	0.7	0.7
c. Total Direct			0.7		0.7	0.7	0.7
18. Operating Expense							
a. Total Obligations			200.0		200.0	200.0	600.0
b. Total Costs			200.0		200.0	200.0	600.0
19. Equipment							
a. Equipment Obligations							
b. Equipment Costs							

20. Milestone Schedule Proposed Authorized

21. Reporting Requirements (Description)

The Project spokesperson will submit semiannual reports to the Department of Energy on the progress of the project.

U. S. DEPARTMENT OF ENERGY
WORK PROPOSAL

1. Work Proposal Number:	2. Revision Number:	3. Date Prepared:
27408		June 12, 2009

4. Work Proposal Title:	5. Budget and Reporting Code
LAB 09-23 Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI)	KJ-0102-000

6. Work Proposal Term: Begin: September 1, 2009 End: August 31, 2012

7. Name (Last, First, MI) and Phone Number of the Headquarters Program Manager	8. Headquarters Organization
Dr. Teresa Beachley	Office of Science - SC
9. DOE Field Organization Work Proposal Reviewer:	**10. DOE Field Organization:**
	Argonne Site Office (ASO)
11. Contractor Work Proposal Manager:	**12. Contractor Name:**
Dr. Dan Fraser (630) 854-8840	Argonne National Laboratory Charlie Catlett, CIS Director Contract Number DE-AC02-06CH11357

13.

Preparing for and understanding Cybersecurity risk and threat is a crucial concern for the operation of wide-area distributed systems. Collaborations of up to thousands of users and hundreds of institutions mean that the behavior and spread of such risks and incidents span administrative boundaries and social networks of researchers. We propose to mathematically model, through agent based modeling and simulation methods, the risk and threat on multi-domain interconnected computers. We propose to compare the behaviors predicted by the models to measurements on the Open Science Grid. These measurements will be made as a result of simulated incidents as well as actual security threats and incidents that occur over the distributed infrastructure.

14. Contractor Work Proposal Manager:	15. DOE Field Organization Official:
For (Signature) Charlie Catlett (Date) 6/11/2009	Not applicable (Signature) (Date)

16. Detail Attachments (See Specific Attachments)

- [ ] a. Facility Requirements
- [ ] b. Publications
- [ ] c. Purpose (mandatory)
- [ ] d. Background
- [ ] e. Approach
- [ ] f. Technical Progress
- [ ] g. Future Accomplishments
- [ ] h. Relationship to Other Projects
- [ ] i. NEPA Requirements
- [ ] j. Milestones
- [ ] k. Deliverables
- [ ] l. Performance Measures/ Expectations
- [ ] m. ES&H Considerations
- [ ] n. Human/Animal Subjects
- [ ] o. Security Requirements
- [ ] p. Other (specify)

WORK PROPOSAL REQUIREMENTS FOR OPERATING/EQUIPMENT OBLIGATIONS AND COSTS

CONTRACTOR NAME	WORK PROPOSAL NO.	REV. NO.:	DATE PREPARED
Argonne	27408	0.0	12-Jun-09

	Prior Years	BY-1	Budget Year (BY)		BY+1	BY+2	Total to Complete
17. Staffing (staff years)			Request	Authorized			
a. Scientific			1.3		1.2	1.2	3.7
b. Other Direct							
c. Total Direct			1.3		1.2	1.2	3.7
18. Operating Expense							
a. Total Obligations			200.0		200.0	200.0	600.0
b. Total Costs			200.0		200.0	200.0	600.0
19. Equipment							
a. Equipment Obligations							
b. Equipment Costs							

20. Milestone Schedule Proposed Authorized

Year 1

Extract static collaboration rules. Build a fundamental social network of agents in Repast.

Year 2

Validate one external mathematical model of threat and attack propagation against the agent-based model.

Year 3

Compare the performance and validation of the results of enhanced network-layer tools against that of native network-layer tools.

21. Reporting Requirements (Description)

The Project spokesperson will submit semiannual reports to the Department of Energy on the progress of the project.

Cover Page

Title of Proposed Project:

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI)

Office of Science Announcement Title/#:

LAB 09-23 Mathematics for Complex, Distributed, Interconnected Systems

Name of Lead Institution:

Fermi National Accelerator Laboratory (FNAL)

Principal Investigator(s):

Dr. Mine Altunay (Fermilab), Computer Science Researcher
P.O. Box 500, MS369
Batavia, Il 60510-5011
maltunay@fnal.gov
630-840-6490 (phone), 630-840-6345 (fax)

Dr. Dan Fraser (Argonne)

Official signing for Fermi National Accelerator Laboratory:

Piermaria J. Oddone, Laboratory Director
pjoddone@fnal.gov
630-840-3211 (phone), 630-840-2900 (fax)
Fermi National Accelerator Laboratory

Requested funding for Project; **ASCR** **KJ-0102**

	Fermilab	Argonne	Total
Year 1	$200,000	$200,000	$ 400,000
Year 2	$200,000	$200,000	$ 400,000
Year 3	$200,000	$200,000	$ 400,000
Total	$600,000	$600,000	$1,200,000

Duration of Entire Project Period:

09/01/2009 to 08/31/2012

Use of human subjects in proposed project: No
Use of vertebrate animals in proposed project: No

Signature of PI, Date of Signature:

Ruth Pordes for Mine Altunay ~~06/12/09~~ 6/9/2009

Signature of Official, Date of Signature:

6/9/09 06/9/09 ~~06/12/09~~

U. S. Department of Energy
Field Work Proposal
Cover Page

LAB 09-23 Mathematics for Complex, Distributed, Interconnected Systems

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI)

Preparing for and understanding Cybersecurity risk and threat is a crucial concern for the operation of wide-area distributed systems. Collaborations of up to thousands of users and hundreds of institutions mean that the behavior and spread of such risks and incidents span administrative boundaries and social networks of researchers. We propose to mathematically model, through agent based modeling and simulation methods, the risk and threat on multi-domain interconnected computers. We propose to compare the behaviors predicted by the models to measurements on the Open Science Grid. These measurements will be made as a result of stimulated incidents as well as actual security threats and incidents that occur over the distributed infrastructure.

Victoria White 6/8/2009

Victoria White (Date)

Fermilab CIO & Head, Computing Division

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C	Abstract (One page)	1	18
D	Narrative (Main technical portion of the proposal, including Background/introduction, proposed research and methods, timetable of activities, and responsibilities of key project personnel)	15	19
E	Literature Cited	2	34
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G	Description of Facilities and Resources	1	49
H	Other Support of Investigator(s)	4	50
I	Appendix 1		
J	Appendix 2		

Appendix Items:

Appendix 1:
Appendix 2:

*Proposers may select any numbering mechanism for the proposal. The entire proposal, however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

DOE F 4620.1
(04-93)
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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 1 Funding Proposal ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2009 thru 8/31/2010

ORGANIZATION: FERMILAB Computing Division

Budget Page No: 1

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Dr. Mine Altunay

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Dr. Mine Altunay — Computer Science Researcher	1.20			$12,025	
2. Dr.Wenji Wu — Computer Science Researcher	1.20			$10,470	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (2) TOTAL SENIOR PERSONNEL (1-6)	2.40			$22,496	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (1) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	6.03			$49,492	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$71,988	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) — Fringe +Vacation + Opto				$40,695	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$112,683	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL — 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
TOTAL TRAVEL					
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)				$112,683	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 10.5% on Travel expense and 16.03% on all other M&S expense; 77.49% on SWF					
TOTAL INDIRECT COSTS				$87,318	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$200,000	

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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 2 Funding Proposal ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2010 thru 8/31/2011

ORGANIZATION: FERMILAB Computing Division

Budget Page No: 2

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Dr. Mine Altunay

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)		DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Dr. Mine Altunay	Computer Science Researcher	1.20			$12,506	
2. Dr.Wenji Wu	Computer Science Researcher	0.91			$8,270	
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. (2) TOTAL SENIOR PERSONNEL (1-6)		2.11			$20,777	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( ) POST DOCTORAL ASSOCIATES						
2. (1) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)		6.00			$51,211	
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)					$71,988	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)	Fringe +Vacation + Opto				$40,695	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					$112,683	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL	1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
	2. FOREIGN					
TOTAL TRAVEL						
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( )	TOTAL COST					
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER						
TOTAL OTHER DIRECT COSTS						
H. TOTAL DIRECT COSTS (A THROUGH G)					$112,683	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 10.5% on Travel expense and 16.03% on all other M&S expense; 77.49% on SWF						
TOTAL INDIRECT COSTS					$87,318	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)					$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)					$200,000	

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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 3 Funding Proposal ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2011 thru 8/31/2012

ORGANIZATION: FERMILAB Computing Division

Budget Page No: 3

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Dr. Mine Altunay

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)		DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Dr. Mine Altunay	Computer Science Researcher	1.20			$13,007	
2. Dr.Wenji Wu	Computer Science Researcher	0.61			$5,721	
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. (2) TOTAL SENIOR PERSONNEL (1-6)		1.81			$18,728	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( ) POST DOCTORAL ASSOCIATES						
2. (1) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)		6.00			$53,260	
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)					$71,988	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)	Fringe +Vacation + Opto				$40,695	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					$112,682	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL	1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
	2. FOREIGN					
TOTAL TRAVEL						
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( )	TOTAL COST					
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER						
TOTAL OTHER DIRECT COSTS						
H. TOTAL DIRECT COSTS (A THROUGH G)					$112,682	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 10.5% on Travel expense and 16.03% on all other M&S expense; 77.49% on SWF						
TOTAL INDIRECT COSTS					$87,317	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)					$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)					$200,000	

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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

TOTAL of 3 Year Funding Proposa ASCR

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnecte
Systems (METI) LAB 09-23

9/1/2009 thru 8/31/2012

ORGANIZATION
FERMILAB Computing Division

Budget Page No: 4

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. Mine Altunay

Requested Duration: 36 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)		DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applpicant	Funds Granted by DOE
1. Dr. Mine Altunay	Computer Science Researcher	3.60			$37,538	
2. Dr.Wenji Wu	Computer Science Researcher	2.72			$24,462	
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. (2) TOTAL SENIOR PERSONNEL (1-6)		6.32			$62,000	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( ) POST DOCTORAL ASSOCIATES						
2. (1) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)		18.03			$153,963	
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)					$215,963	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)	Fringe +Vacation + Opto				$122,084	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					$338,047	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL	1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
	2. FOREIGN					
TOTAL TRAVEL						
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( )	TOTAL COST					
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER						
TOTAL OTHER DIRECT COSTS						
H. TOTAL DIRECT COSTS (A THROUGH G)					$338,047	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 10.5% on Travel expense and 16.03% on all other M&S expense; 77.49% on SWF						
TOTAL INDIRECT COSTS					$261,953	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)					$600,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)					$600,000	

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

BUDGET JUSTIFICATION

Fermi National Accelerator Laboratory

Fermilab will be providing approximately 0.7 FTE of effort towards the ASCR portion of the proposed project titled "Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23". The compensation is consistent with similar work both within and outside of Fermilab. Personnel Cost amounts in Years 2 and 3 are estimated based upon a uniform escalation of 4%

A. SENIOR PERSONNEL. Proposed compensation is consistent with that paid to other personnel engaged in similar work both within and outside Fermilab.

Dr. Mine Altunay is a Computer Science Researcher. Her role in the proposed project will be to lead the security research and validation activities. She will oversee the modeling and simulation effort, provide the linkage with the Open Science Grid to ensure measurement data is provided where needed, and design the security tests and probes.

Dr. Wenji Wu is a Computer Science Research. His role in the proposed project will be to work with the modeling and simulation effort to ensure appropriate awareness of networking connections and issues. He will provide information from the networking monitoring and logging and help with the comparison and validation of the security logs and information.

B. OTHER PERSONNEL

B2.

Computer Professional/ Science Researcher will be responsible for developing, implementing and running appropriate models of the open distributed system communities, sites and security risks, in collaboration with the framework provided by the professionals at Argonne. He will be responsible for taking the OSG logs and comparing the measured information to the predictions of the modeling for validation and feedback to tuning of the models for better match to what happens in reality. The Computing Professional will report to the project management.

C. FRINGE BENEFITS
Benefits are requested at the rate of 56.53% of professional salaries. This includes vacation accrual rate (11%), OPTO (6.25%), and Fringe Benefits rate (33.5%)

D. PERMANENT EQUIPMENT
None

E. TRAVEL AND SUBSISTENCE.

None

G. OTHER DIRECT COSTS
None

I. TOTAL INDIRECT COSTS
Fermilab's FY2009 provisional indirect cost rate is currently 77.49% (Salaries), 10.50% (Travel), and 16.03% (Other M&S) of MTDC, in accordance with Fermilab's contract with the Fermi Research Alliance, LLC (FRA) and the Department of Energy.

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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 1 Funding Proposal ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2009 thru 8/31/2010

ORGANIZATION
Argonne National Laboratory CIS (Computing and Information Systems) Division

Budget Page No: 1

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. Dan Fraser

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Dr. Dan Fraser	1.40			$15,507	
2. Charlie Catlett	0.70			$13,113	
3. Dr. Mike North	1.40			$18,936	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (3) TOTAL SENIOR PERSONNEL (1-6)	3.50			$47,556	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	11.70			$71,900	
2. ( ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$119,456	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) Fringe +Vacation + Opto				$22,838	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$142,294	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$2,000	
2. FOREIGN					
Covers domestic trips for collaboration and conference.					
TOTAL TRAVEL				$2,000	
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)				$144,294	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 38.6% on Salaries, Wages, Fringe Benefits and Travel					
TOTAL INDIRECT COSTS				$55,706	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$200,000	

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 2 Funding Proposal ASCR

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2010 thru 8/31/2011

ORGANIZATION
Argonne National Laboratory CIS (Computing and Information Systems) Division

Budget Page No: 2

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. Dan Fraser

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Dr. Dan Fraser	1.40			$16,097	
2. Charlie Catlett	0.70			$13,612	
3. Dr. Mike North	1.40			$19,689	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (3) TOTAL SENIOR PERSONNEL (1-6)	3.50			$49,398	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	11.00			$69,719	
2. ( ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$119,117	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) Fringe +Vacation + Opto				$23,176	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$142,293	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$2,001	
2. FOREIGN					
Covers domestic trips for collaboration and conference.					
TOTAL TRAVEL				$2,001	
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)				$144,294	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 38.6% on Salaries, Wages, Fringe Benefits and Travel					
TOTAL INDIRECT COSTS				$55,706	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$200,000	

DOE F 4620.1
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(See reverse for Instructions)

Year 3 Funding Proposal ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2011 thru 8/31/2012

ORGANIZATION
Argonne National Laboratory CIS (Computing and Information Systems) Division

Budget Page No: 3

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. Dan Fraser

Requested Duration: 12 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Dr. Dan Fraser	1.40			$16,661	
2. Charlie Catlett	0.70			$14,089	
3. Dr. Mike North	1.40			$20,365	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (3) TOTAL SENIOR PERSONNEL (1-6)	3.50			$51,115	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	10.30			$67,688	
2. ( ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$118,803	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) Fringe +Vacation + Opto				$23,491	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$142,294	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$2,001	
2. FOREIGN					
Covers domestic trips for collaboration and conference.					
TOTAL TRAVEL				$2,001	
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)				$144,295	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 38.6% on Salaries, Wages, Fringe Benefits and Travel					
TOTAL INDIRECT COSTS				$55,705	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$200,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$200,000	

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(04-93)
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U.S. Department of Energy

Budget Page

(See reverse for Instructions)

TOTAL of 3 Year Funding Proposa ASCR

OMB Control No. 1910-1400
OMB Burden Disclosure Statement on Reverse

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

9/1/2009 thru 8/31/2012

ORGANIZATION
Argonne National Laboratory CIS (Computing and Information Systems) Division

Budget Page No: 4

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. Dan Fraser

Requested Duration: 36 (Months)

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos. CAL	ACAD	SUMR	Funds Requested by Applicant	Funds Granted by DOE
1. Dr. Dan Fraser	4.20			$48,265	
2. Charlie Catlett	2.10			$40,814	
3. Dr. Mike North	4.20			$58,990	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (3) TOTAL SENIOR PERSONNEL (1-6)	10.50			$148,069	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES				$209,307	
2. ( ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				$357,376	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) Fringe +Vacation + Opto				$69,505	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$426,881	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				$6,002	
2. FOREIGN					
Covers domestic trips for collaboration and conference.					
TOTAL TRAVEL				$6,002	
F. TRAINEE/PARTICIPANT COSTS					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
TOTAL PARTICIPANTS ( ) TOTAL COST					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)				$432,883	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 38.6% on Salaries, Wages, Fringe Benefits and Travel					
TOTAL INDIRECT COSTS				$167,117	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$600,000	
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES					
L. TOTAL COST OF PROJECT (J+K)				$600,000	

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23

BUDGET JUSTIFICATION

Argonne National Laboratory

Argonne National Laboratory will be providing approximately 1.2 FTE's of effort yearly towards the ASCR portion of the proposed project titled "Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems (METI) LAB 09-23". The compensation is consistent with similar work both within and outside of Argonne National Laboratory. Personnel Cost amounts in Years 2 and 3 are estimated based upon a uniform escalation of 4%.

A. SENIOR PERSONNEL. Proposed compensation is consistent with that paid to other personnel engaged in similar work both within and outside Argonne National Laboratory.

Dr. Dan Fraser will lead the Agent Based Modeling and simulation activities and will be responsible for coordination between the two laboratories. He will guide the post-doctoral researcher who will provide effort to the senior personnel on this proposal and will provide the ANL link to the Open Science Grid.

Charlie Catlett is the CIO of Argonne National Laboratory and is the main author of the DOE Security Program document on which part of this call is based. His role will be to help guide the research to provide maximal benefit to the larger DOE security program.

Dr. Mike North is the expert on Agent Based Modeling who will be responsible for overseeing the simulation setup, testing, and interpretation of the results. He will provide best practices to the team and help guide policy making.

B. OTHER PERSONNEL

B2.

The Post Doctoral Researcher will be responsible for developing, implementing and running the simulation models in collaboration with the lead PI at Fermi National Laboratory. He will be responsible for receiving logs and security data from sources other than the OSG and for extending the models to incorporate this data. He will report to Project Management.

C. FRINGE BENEFITS
Benefits are requested at the rate of 33.8% of all regular salaries and 11% of all temporary salaries. This includes all fringe benefits (e.g. medical, dental, retirement, vacation).

D. PERMANENT EQUIPMENT
None

E. TRAVEL AND SUBSISTENCE.

Our travel budget of $2,000 per year covers domestic trips for collaboration and conference

G. OTHER DIRECT COSTS
None

I. TOTAL INDIRECT COSTS
Argonne National Laboratory's FY2009 provisional indirect cost rate for salaries and other direct cost is 24% (common support), 8% (LDRD), 2.7% (IGPP/IGPE) and 2.9% (G&A)., in accordance with Argonne National Laboratory's contract with the UChicago Argonne, LLC and the Department of Energy.

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems

Summary

A critical aspect of effective cyber security models is the characterization and simulation of emergent behavior of complex information systems as influenced by the combination of policies and protective measures, cyber security threats and incidents, and responses to incidents.[1] [2] We propose to simulate the risk and threat on multi-domain, interconnected information systems (including Grid- and Cloud-based systems) using an agent-based model that enables us to observe and characterize the behavior and resilience of the system as a function of policy, threats, protections, and responses. Understanding the response of today's complex systems - used by communities of up to thousands of users and including up to hundreds of institutions - to cyber security threats and attacks is crucial to enable their defense and operation. We will study the behavioral properties of such systems over time both through modeling and comparing the models with real scenarios before and during attacks.

One of the biggest challenges is the lack of clean, high volume '360 degree' data – simultaneous temporal information on attackers, security weaknesses, attack paths, and victims. Agent-based modeling can leverage the small available data sets to produce enough valid 360-degree data to build mathematically sophisticated cybersecurity models. The synthetic data sets can also be used to validate existing and future mathematical cybersecurity models including those from other teams selected by this call for proposals. We propose using such methods to observe the patterns and characterize the behavior over time of the systems under attack. The goal is to understand the policies, protections and responses that will be most effective at preventing the spread of the attack, the risk to and response of the individual components, and the relationships between them.

Based on the security properties, we will generate a mathematical model for predicting the spread of attacks. Our model will assign each component a likelihood of infection based on, and in reaction to, the properties of the response behavior. We will use these results and reactions to quantify the overall risk to the system in face of particular threats. We will develop and research methodologies for modifying usage patterns (agent behaviors) to minimize the spread and severity of attacks.

We will use as a first example the Open Science Grid, a stable, widely distributed operational infrastructure of more than sixty autonomous sites. We propose to extend the model by using data from other DOE computational centers such as data from the distributed intrusion detection system currently under development at Argonne National Laboratory and the cross-site information archived by the Fermilab security team. We will also extend the model to other scientific community based distributed systems, such as the global CMS LHC High Energy Physics experiment distributed computing facility and DOE BES user facilities – initially the ANL APS and ORNL SNS collaborative activities. A natural extension of this model is to leverage the experience of commercial cloud computing vendors and extend the security model into the cloud computing arena. We will actively explore this option. We will collaborate with, and supply the modeling and validation services to, other peer projects. Through comparing the predicted results to the spread of any actual incidents that occur we will build an important and significant body of research and community knowledge and understanding.

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[1] "A Scientific Research and Development Approach to Cyber Security," Charlie Catlett, Editor, A report presented to the Department of Energy Office of Science, December 2008.

[2] Some of the text used in this LAB 09-23 Program Announcement was excerpted from this document.

Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems

Agency Number: LAB 09-23
Institution: Fermi National Accelerator Laboratory (FNAL)
Principal Investigator: Mine Altunay, Fermi National Accelerator Laboratory
Co-Principal Investigators:
Charlie Catlett, Argonne National Laboratory
Dan Fraser, Argonne National Laboratory
Mike North, Argonne National Laboratory
Contributing Senior Personnel:
Wenji Wu, Fermi National Accelerator Laboratory

1 Introduction and Justification

A critical aspect of effective cyber security models is the characterization and simulation of emergent behavior of complex information systems as influenced by the combination of policies and protective measures, cyber security threats and incidents, and responses to incidents.[1] [2] We propose to simulate the risk and threat on multi-domain, interconnected information systems (including Grid- and Cloud-based systems). We propose to observe and characterize the behavior and resilience of the system as a function of policy, threats, protections, and responses. We will generate a mathematical model for risk and attack propagation by studying the observed behavior before and during attack scenarios.

One of the biggest challenges is the lack of clean, high volume '360 degree' data –simultaneous temporal information on attackers, security weaknesses, attack paths, and victims. Agent-based modeling offers a way to leverage the small available data sets to produce enough valid 360-degree data to build mathematically sophisticated cyber security models. The synthetic data sets can also be used to validate existing and future mathematical cyber security models including those from other teams selected by this call for proposals.

We will use agent-based modeling tools to simulate the system based on experience of modeling the social networks of community use over a diverse set of autonomous resources. Based on the security properties, we will generate a mathematical model for predicting attack-spread patterns over the complex distributed system. Our model will assign each component a likelihood of infection based on, and in reaction to, the properties of the behavior over time. We will use these results and reactions to quantify the overall risk to the system in face of particular threats. We will develop and research methodologies for modifying usage patterns (agent behaviors) to reach a desired behavior property to minimize the spread of the attacks . The initial studies done over the social networks and sensor networks are promising that the characteristics of the behavior over time can be used for thwarting or containing attacks [1][2]. We will also investigate the classes of cyber-attacks (e.g., ICMP-based distributed denial of service attack, or BGP-based routing attacks) with respect to the feasibility of modeling attack behaviors as well as the development of an attack library. We will compare the results to the spread of any actual incidents that occur and modify the models based on lessons learned.

[1] "A Scientific Research and Development Approach to Cyber Security," Charlie Catlett, Editor, A report presented to the Department of Energy Office of Science, December 2008.
[2] Some of the text used in this LAB 09-23 Program Announcement was excerpted from this document.

Grids are one of the prime examples of complex inter-connected systems. They include multiple autonomous components, each of which belongs to a different administrative domain, that constantly interact with one another and modify their interactions based on the immediate responses and past experiences. Each component implements different goals and policies, and they each have to interact and come to agreements with one another to reach their goals. People, software, services, computers, disks, are all components of the complex system. There is no centralized authority that organizes the interactions or makes decisions for its components. In practice, there is a limited situational awareness of normal behavior and it is a significant challenge to predict how security attacks and incidents propagate. A model that predicts the behavior and responses, as well as an ability to validate and adapt the model based on stimulated and real attacks, will give us a crucial ability to predict the risks from attacks as well as proactively respond to contain them. A natural extension of this model is to leverage the experience of commercial cloud computing vendors and extend the security model into the cloud computing arena. We will actively explore this option.

Understanding and simulating the responses to cyber security threat and attack will help us in number of ways. We will be able to analyze the characteristics of the behaviors over time, and can evaluate and model these characteristics to understand the security properties of the complex system. Qualitative risk and vulnerability assessment of a complex system of tens to hundreds of autonomous interconnected systems is very difficult. The aggregate effect of component-component interactions is different than that of a single interaction. Each interaction causes changes in the components that are not directly related; hence leading to an emergent behavior. Consider a user consuming all available CPU cycles of a compute node. Not only the compute node owner may change its job priority policy, but also other users seeing the congested resource will flock to use other nodes. Furthermore, interactions often have indirect non-obvious consequences. Consider a user uploading files into a storage node. The user becomes infected by a virus at home computer, and infects the storage element. As an indirect consequence other users which have used the same storage node for downloads are also infected, perhaps passing the virus to their friends as well.

The decentralized, autonomous nature of grid based distributed facilities does not lend itself for centralized risk assessment methodologies. No central authority has control over the system components to perform such assessment, but the component owners. Even if we had the ability to conduct such assessments, we would not be able to know whether the combined components result in new vulnerabilities [3][4]. Finally, the human factor and rapid change in interactions make it impossible to get a static model of the whole distributed infrastructure. Users develop social network, swap executables or data sets, and work around the rules to “get it done”. These interactions change the security properties of the system over time.

Validation of our observations and mathematical models is an important component of our program of work. We plan to generate mock-incident runs on the deployed infrastructures and systems to collect real data. For example, we will write mock-malicious code to measure the spread of the incident over time. We will compare the actual data against our predictions based on the mathematical model. We plan to extend our work and compare external mathematical capabilities (e.g. those that will be developed in response to this call.) with the mock-incident data we collect.

Methodologies for modifying agent interactions to obtain a desired behavior are included in our development plans. We will use simulations to understand how changing interaction patterns, such as removing an agent, or forbidding an interaction between two agents, will affect the

emergent behavior. The methodology we develop would be helpful in attack responses. We will explore goal-oriented agent simulation methods to reach a desired final system state. We can define several different goals such as minimizing number of infected agents or keeping highly productive agents un-infected while tolerating a higher number of infected agents.

Enhanced network-layer detection tools with interaction patterns learned from the middleware services layer is a useful extension to our work. Agent based models of the behavior of the interconnected systems can be used either stand-alone or in conjunction with existing network based intrusion detection techniques. Network-based intrusion detection tools suffer from large number of false positives, difficulties in detection of new attack patterns, and analysis of large number of network packets. The communities with whom we work typically transfer hundreds of terabytes of data over the distributed system per week. The volume of data is especially challenging for network-layer tools. The properties of emergent behavior in the agent-based models will reflect the actual interaction patterns between the system components (e.g. how users form a social network, how a single user interacts with other components, which applications are run on which computers on a daily basis). Feeding these properties into a network-layer tool can decrease the number of false positives and the amount of data that needs to be analyzed.

The agent based simulation approach benefits the mathematics in at least three important ways: First, the simulation generates data that can be used in guiding the construction of a mathematical model of the system. Second, the simulations can be used more generally to validate external mathematical capabilities (e.g. those that will be developed in response to this call.) Third, the simulation can be used to help coax policy-making capabilities from the mathematics.

1.1 Example Systems

As a first example, we will focus on simulating and creating a mathematical model and validating the predications using data from the Open Science Grid, a distributed infrastructure of more than sixty autonomous sites. We propose to extend the model by using data from other DOE computational centers such as data from the distributed intrusion detection system currently under development at Argonne National Laboratory. We will apply the model developed to other scientific community based distributed systems, such as the global CMS[5] high energy physics experiment distributed computing facility and the DOE BES user facilities – initially the ANL Advanced Photon Source (APS) and ORNL Spallation Neutron Source (SNS) collaborative activities. We will further apply and extend the model in collaboration with, and as a service to, other such projects.

The OSG is an ideal platform for this work as it is a stable, widely distributed operational infrastructure. OSG supports more than 300,000 jobs and data movement in the tens of terabytes a day. Data obtained from actual security threats and incidents are available on request. In addition, we also have the unique ability to generate mock-incidents for validating and testing propagation of threats across this internationally distributed infrastructure. We will use the threat propagation model in order to understand the policies, protections and responses that will be more effective at preventing the spread of attacks.

Further the cyber security and networking teams at ANL and Fermilab have much experience in recording and transforming disparate data sets into threat trending information and archiving the results. This is accomplished through many data collection efforts the use of recording and alerting mechanisms of connection attempts to unallocated network address space, network

[5] http://cms.web.cern.ch/cms/index.html

routing and connection records such as Netflow records and various network based sensors operating in passive mode detection. Efficient anomaly detection is required to ensure a low false positive rate while producing accurate threat assessments. This is accomplished through mathematical and statistical analysis of Netflow records and packet captures, with the collected datasets fed through both industries standard Intrusion Detection Systems and custom, locally developed, utilities. These datasets are also imperative for incident response usage.

2 Threat and Risk Modeling in Interconnected Complex Systems

Risk is often defined as a function of threat and vulnerability [7], that is a possibility that a threat will adversely impact a computer system by exploiting a vulnerability. The government's FIPS guideline employs financial variables to model threat and vulnerability. Average Loss Expectancy (ALE) is calculated by multiplying the financial impact I(Oi) of a harmful outcome (Oi) by the likelihood of the harmful outcome (Fi). Several methodologies have proposed for determining the financial impact and the likelihood of a threat [8] [9]. These methodologies rely on a combination of qualitative system analysis and probabilistic methods. Qualitative system analysis partitions the system into critical and non-critical parts, identifies vulnerabilities over the critical parts, and assigns values for the likelihood of a threat and its financial impact. Probabilistic methods are used to calculate the expected values for the risk.

For small-scale non-complex systems, such a qualitative approach would be meaningful. However, for large-scale complex interconnected systems this methodology becomes ineffective. First, the components (both computers and users) are drawn from different administrative domains, from many national laboratories and universities, and cross-domain accesses are the norm. No central authority has access to each of the components to perform an analysis. Also, the number of components makes such an analysis infeasible.

Second, such methodologies are best applied to static systems. The components of large scale distributed systems and as well as the large (DOE) networks are dynamic and constantly interact with one another. New components are added or subtracted routinely without any centralized intervention. Components are autonomous in their interaction decisions and have different, at times, conflicting goals. For example, a user's goal can be to access and consume the highest number of CPU cycles available, whereas a computer administrator's goal is to provide fair computing cycles to its authorized users. Moreover, each component is constantly introduced to new vulnerabilities and threats due to changing interactions. A computer is exposed to new threats by allowing access to new users or by running new applications. A user is exposed to new threats by sharing files with another user or downloading executables from a computer.

Third, the number of interactions between the components increases in a combinatorial fashion, and the nature of the interactions change over time. For example, users form trust relationships with one another and share access to the same resources. When resources get scarce users change their application submission mechanisms to ensure access to few available resources or they flock to certain computers that they believe to be highly available. For all these reasons, it is a challenge to capture a global risk model for the whole distributed facility by studying its components in isolation. Often, we do not know how the components would interact until they start the interaction.

In order to illustrate the interactions occurring in a multi-community distributed system and their security implications, consider Figure 1.

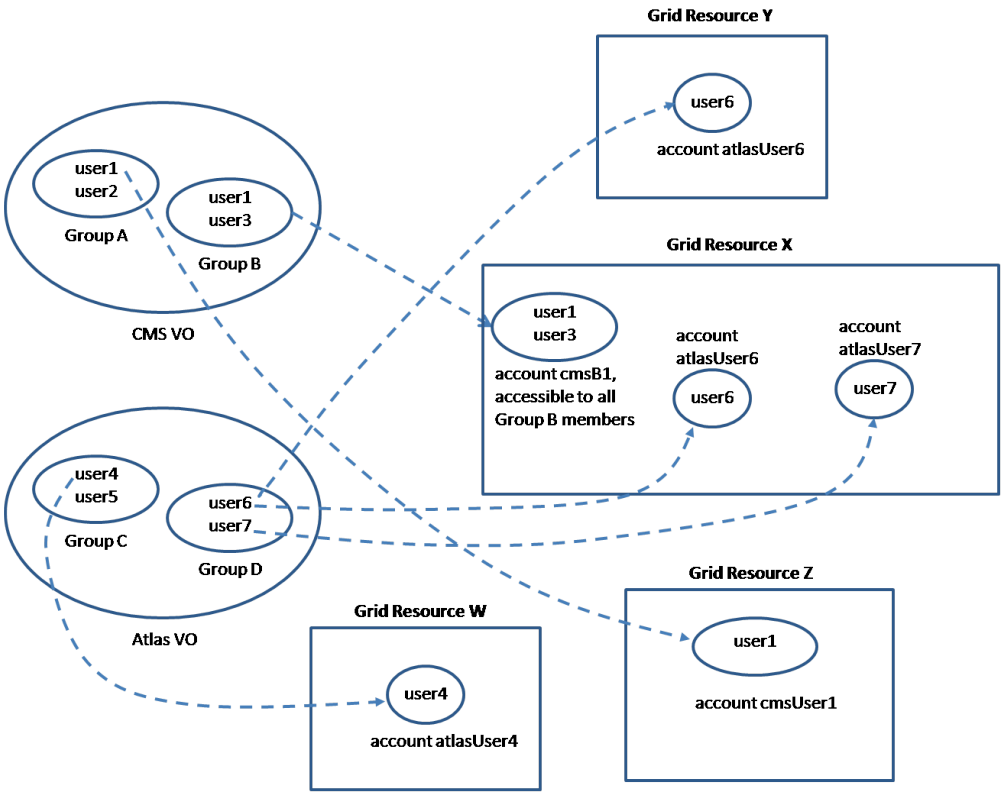

Figure 1. Interactions forming in the Multi-Community Distributed System.

Resources X, Y, Z, and W belong to different institutions. Users are mapped into accounts indicated by dashed arrows. User1 and user3 are mapped into the same account, whereas, user6 and user7 have individual accounts. User1 is a member of both group A and B. users that are in the same VO or the same group tend to collaborate very often. Resources X, Y, Z, and W all belong to different institutions, are governed by different policies and are seemingly isolated from one another. However by contributing to Atlas VO, resources Y, X and W have an implicit interaction with one another. Likewise, resources X and Z interact due to their joint contribution to CMS VO. These interactions become crucial during a security incident. Let's say there is a security incident at resource Z such that user1's account is compromised and his credentials are stolen. The user1's credentials would allow access to resource X as well. Thus, resource X is vulnerable against the attack. Let's assume the attacker accesses and compromises the account CMSB1 on resource X. It is a non-zero probability that the attacker can find and exploit a system level vulnerability on resource X and compromise other accounts on it. (In fact, past security attacks over such systems showed that once an attacker is inside a resource, his chances of gaining root privilege increases significantly). Let's assume the attacker compromises atlasUser6 account. Because user6 can access both resources Y and X, the attacker can use user6's credentials to access and compromise resource Y. Moreover, consider that once user6's and user7's credentials are stolen, the attacker can easily impersonate these users. The attacker can send infected emails that are signed by user6's proxies to infect user4 and user5. Of course, once users4 and 5 get infected, resource W can easily become compromised in a similar fashion. By taking advantage of interactions between different components, an attacker can quickly infect large number of components. The attacker does not have to know such interactions beforehand; he can learn them during the compromise. For example, log files on resource Z would reveal that user1 often makes an access request to resource X from Z.

The combined effects of the component interactions manifests itself as ever changing behavior across the system as a whole. Under a threat, understanding and modeling how the system responds and how the response evolves over time is crucial. It tells us not only the new vulnerabilities dynamically introduced to a component, but also how a threat is likely to spread. As a result, threat and risk models dynamically change because new vulnerabilities are introduced and non-malicious components can become malicious.

Although there are considerable studies on "emergent behavior", there are few studies analyzing the security properties. A recent paper by Gligor [10] is one of the first that analyzes the security characteristics of emergent properties through studies of ad-hoc sensor networks. He points out that the impact of the malicious behavior extends beyond the system components that it interacts directly with and that indirect (not directly connected) components can be affected by the change in behavior of affected components. He also notes that some resulting properties give desired security characteristics such as trust establishment among sensors, establishment of secure communication paths, and establishment of common access states in dynamic coalitions. He points out that observing such changes can help with detection of threats in ways that are not possible via network level intrusion detection tools. He also shows how emergent behavior is used for detecting node replication attacks in wireless sensor networks [11].

Dabrowski and Mills [12] studied the emergent properties of large scale, loosely coupled, distributed systems. They simulated users requesting resource reservation under normal conditions and under attack conditions. They injected service-provider spoofing attacks with 50% likelihood. They allowed users to react to the attackers and modify their interactions. They found that when users did not react to the attackers, their reservation protocol succeeded the most.

3 Agent Based Modeling

Agent based modeling (ABMS) is one of the most widely used modeling techniques for understanding emergent properties of complex adaptive systems (e.g. distributed interconnected systems including Supervisory Control and Data Acquisition (SCADA) systems) Furthermore these techniques have been used for over a decade to support policy and decision making [13]. Computational advances have made possible a growing number of agent-based applications in a variety of fields. Applications range from modeling agent behavior in the stock market and supply chains, to predicting the spread of epidemics and the threat of bio-warfare, from modeling consumer behavior to understanding the fall of ancient civilizations, to name a few. This is a natural technique to extend to threat analysis and mitigation on distributed computer networks.

The fundamental feature of an agent is the capability of the component to make independent decisions. This requires agents to be active rather than purely passive. Agents are diverse, heterogeneous, and dynamic in their attributes and behavioral rules. Behavioral rules vary in their sophistication, how much information is considered in the agent decisions (cognitive "load"), the agent's internal models of the external world including other agents, and the extent of memory of past events the agent retains and uses in its decisions. Agents also vary by their attributes and accumulated resources. ABMS's main roots are in modeling human social behavior and individual decision-making. With this, comes the need to represent social interaction, collaboration, group behavior, and the emergence of higher order social structure – all relevant concepts in the modeling of the social networks of complex, multi-community, interconnected systems we are dealing with.

3.1 Constructing Agent Based Models using Repast

The cyber security models we will use for the research will be implemented with the widely used Recursive Porous Agent Simulation Toolkit (Repast) Simphony toolkit [14]. Repast Simphony (Repast S) is a free and open source agent-based modeling toolkit that simplifies model creation and use. Repast S offers users a rich variety of features. The following are most important for our current program of work:

- A pure Java point-and-click model execution environment that includes built-in results logging and graphing tools as well as automated connections to a variety of optional external tools.
- An extremely flexible hierarchically nested definition of space including the ability to do point-and-click and modeling and visualization of:
    - 2D environments;
    - 3D environments;
    - Networks including full integration with the JUNG network modeling library as well as Microsoft Excel spreadsheets and UCINET DL file importing; and
    - Geographical spaces including 2D and 3D Geographical Information Systems (GIS) support;
- A range of data storage "freeze dryers" for model check pointing and restoration;
- A fully concurrent multithreaded discrete event scheduler;
- Libraries for genetic algorithms, neural networks, regression, random number generation, and specialized mathematics;
- An automated Monte Carlo simulation framework which supports multiple modes of model results optimization;
- Built-in tools for integrating external models;

Repast S introduces the following model creation process [15]:

- The modeler creates model pieces, as needed, in the form of generic Java objects, often using automated tools or scripting languages such as Groovy:
    - The model components can represent anything but are most commonly used to represent the agents in the model.
- The contents of the flowchart are automatically compiled to Groovy source code and then to Java bytecode.
- The modeler uses declarative configuration settings to pass the model pieces and legacy software connections to the Repast S runtime system.
- The modeler uses the Repast S runtime system to declaratively tell Repast S how to instantiate and connect model components.
- Repast S automatically manages the model pieces based on (1) interactive user input and (2) declarative or imperative requests from the components themselves.

Repast S has been optimized for performance. Examples of large models with fast execution times are included later in this section. Furthermore, due to the performance optimization, models developed using Repast S will have a manageable impact on the execution time of federated systems into which they are embedded.

The Repast S architecture can be embedded with larger federated systems of models. Repast S itself includes facilities for optimizing model parameters using a sequence of batch runs. OptTek Systems has also developed initial OptQuest Solver Engine harness to execute Repast S models. They are currently refining this harness. Repast S also includes advanced features to support and reduce the cost of model verification and validation [16]

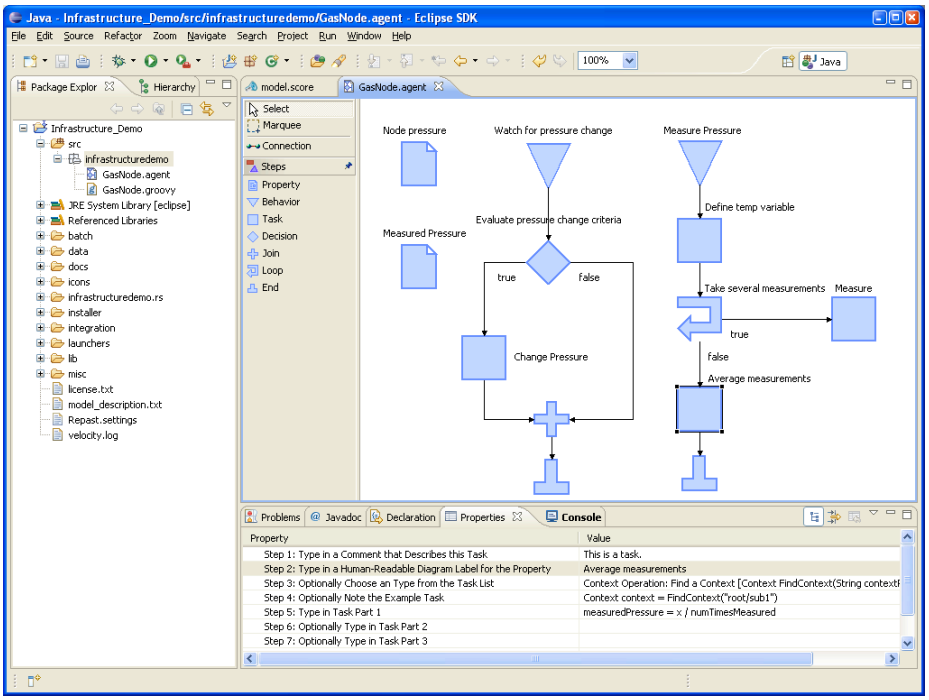

Figure 2: An Example Agent Flowchart

3.2 Recent Examples of Agent Based Models

Argonne has extensive, world recognized experience in applying Repast S agent-based modeling to solve practical problems. Repast has also been successfully used to develop agent-based models by a variety of other groups around the world [17]. Examples of Argonne's work include the development of the Procter & Gamble Virtual Category Laboratory (Virtual Lab), the Electricity Market Complex Adaptive Systems model (EMCAS), and the Department of Energy (DOE) hydrogen economy model to name a few.

The virtual lab is an innovative computational agent-based model of consumer markets that was developed for P&G. This capability represents a new milestone at the forefront of agent-based consumer market modeling technology in terms of its extraordinary detail, broad coverage, and the large number of agents considered. Some of these advances have resulted in a joint Argonne and P&G patent application titled "Methods of Creating and Using a Virtual Consumer Packaged Goods Marketplace" [18]. The capability was developed by Argonne, in conjunction with P&G, using the Repast agent-based modeling toolkit. Argonne and P&G successfully calibrated, verified, and validated the resulting model using several independent real world data sets for multiple consumer product categories with over sixty comparison tests per data set. The capability has been successfully applied by P&G to several challenging business problems where it has directly influenced managerial decision-making and produced substantial cost savings.

EMCAS [19] is an extensive Repast agent-based model of electric power markets with a focus on deregulated systems. Multiple and diverse market participants are each represented with their own unique set of business and bidding strategies, risk preferences, objectives, and decision rules. The success of an agent is a function not only of its own decisions and actions, but also of the decisions and actions of other market participants. EMCAS is now a commercial product used for and by many organizations around the world including the Illinois Commerce Commission, the

Energy Regulatory Office (DGGE) of Portugal, and the Croatian Power Company (HEP). Figure 3 shows a geographical model of Alaska networks.

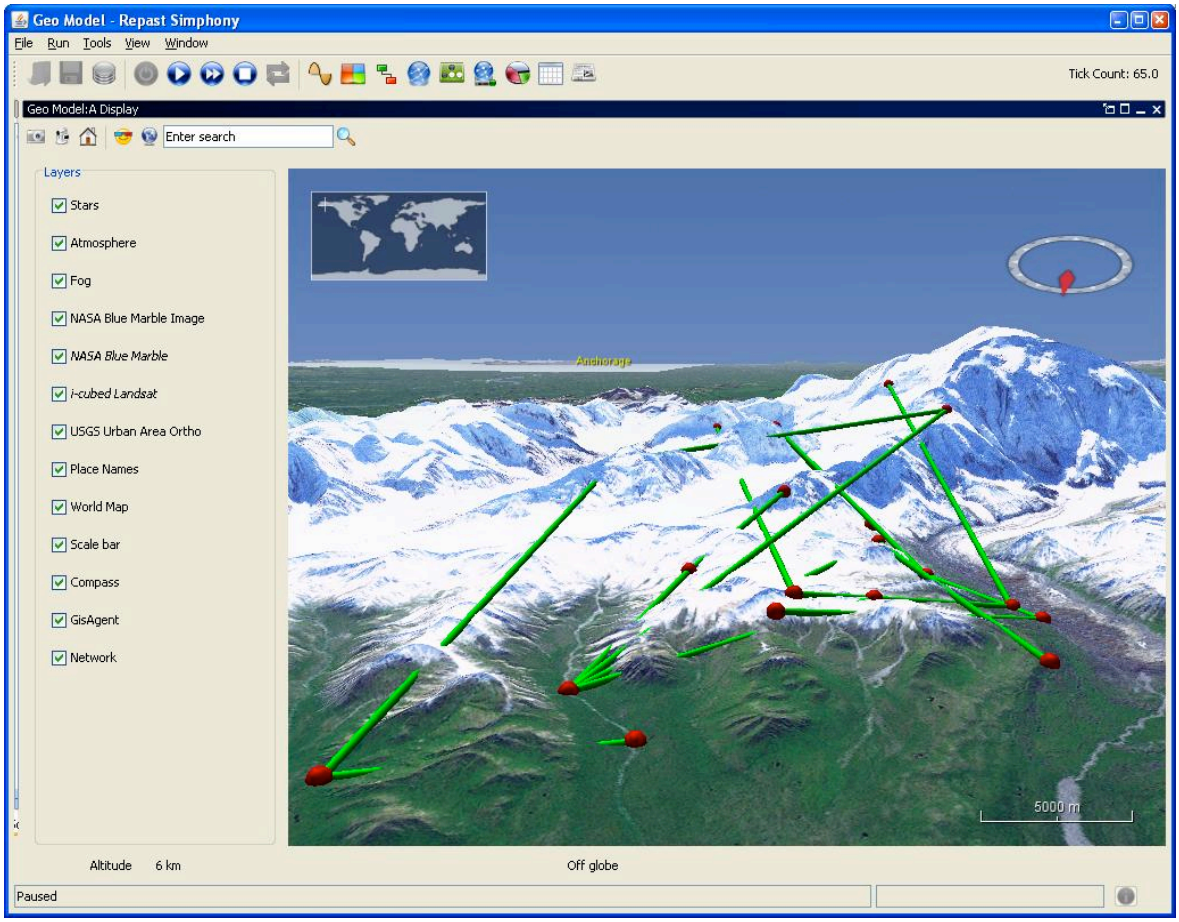

Figure 3: An Example Repast model showing a network integrated into a real map of Alaska (Anchorage is shown on the horizon)

The DOE hydrogen economy model [20] is a Repast S representation of the Los Angeles, California metropolitan area with 5,000 square miles of detailed GIS-sourced interstate highways and omnipresent local roads. The model has driver and investor agents. Driver agents use their cars to move between their demographically-assigned home neighborhoods and their jobs. Drivers have a variety of characteristics including income amounts, environmental concern levels, risk aversion, and car type preferences (e.g., wanting conventional fuel cars versus hydrogen cars). Investor agents build, own and operate hydrogen fuel stations based on the investor's estimates of the potential for profits at each available geolocated site.

4 Proposed Research: Modeling and Validation of Emergent Behaviors

We will use agent-based modeling to simulate large scale, wide area, distributed systems. Each system component will be modeled as an autonomous agent. We will include user agents and computer agents. Computer agents will be modeled after the resource types commonly used in such systems: compute and storage nodes. A compute element provides CPU cycles, while a storage element only provides storage space for data. Computing nodes exhibit different behaviors based on their roles in the system. We initially model two roles: gatekeepers and worker nodes. Gatekeepers act as the entry point to a cluster of worker nodes and enforce the security policies. Worker nodes are either compute or storage agents. We will initially limit our

model to these two roles. In the second and third year, we will introduce finer-grained resource roles including pilot and client nodes [21], VO portal nodes, etc. We model user agents as malicious and non-malicious agents. We will assume all users are non-malicious until a malicious agent compromises them. We assume that malicious agents are not members of the authorized communities and come from the outside. In other words, we will simplify our problem by ruling out the insider threat until an actual user becomes compromised. However, we will not have any restrictions on where and from where threats can come. We model that users and computers can arbitrarily get infected for any reasons and threats can be introduced via outside of the middleware and services that are part of the system. For example, a user's home laptop is compromised, or a gatekeeper is root compromised due to an institutional vulnerability, etc.

We propose to use a staged approach in two phases to allow for (Stage 1) proof-of-concept testing of the initial model configuration and model components before (Stage 2) expending effort on completing the entire software. The models will be developed using Argonne's widely used, free and open source Repast agent-based modeling toolkit (http://repast.sourceforge.net/). Our goals are to:

- Capture and analyze the properties of emergent behavior under threat and attack.
- Generate a mathematical risk model based on the observed emergent behavior.
- Validate our model against the real security data collected from deployed systems.
- Determine effective policies that can be used to a) prevent and b) minimize damage from attacks perpetrated on large scale, wide area distributed computing networks.
- Apply our models and measurements to existing systems: initially the OSG followed by the CMS experiment, DOE BES community and other research groups.
- Collaborate with other research teams participating in this call to assist in validating their mathematical models and exploring emergent behavior that can otherwise be hidden in pure mathematical models.
- Extend the simulations and capabilities so that they can be applied to more general distributed network Infrastructures such as the DOE National Laboratory Network.

4.1 Properties of Emergent Behavior

Our goal is to capture the emergent behavior properties and analyze their security characteristics. Although it is impossible to know beforehand what the emergent behavior will be like, we plan to generate a collaboration graph [24] [25] based on the emergent behavior. The edges of the graph will show the likelihood of interaction between the agents, while the vertices denote the agents. We will study the properties of the graph that are interesting in terms of security, such as the clustering coefficient, the existence of any dense sub-graphs and their connectivity with other sub-graphs i.e. "community structure", and the variation of the graph over time. There is recent work [26] studying the change in proximity graphs (representing people's geographical locations with Bluetooth enabled phones) over continuous time, as opposed to discrete-time analysis. Clauset finds out that the network snapshot value (periodicity of collecting network data) significantly bias the statistical properties of the resulting networks. In our work, we plan to compare emergent behavior at different time points to understand whether human periodicity affects the overall graph properties significantly. Moreover, because we use past behavior to predict the likelihood of future interactions, we apply statistical methods to the collected data and to the resulting collaboration graphs at different time points.

An important property of the emergent behavior is to tell us how likely an agent to be infected under an attack. One of our goals is to calculate a risk value (likelihood of infection) per agent given a set of infected agents at a specific time point. We will use the likelihood of interactions

(i.e. the edges of the collaboration graph) as the basis for calculating a risk value per node. Classical studies of epidemiology research do not focus on topology of the society, but on societal structures and biological characteristics of pathogens [27]. The recent studies [28][29][30], however, in epidemics network, studies biological infections based on a network topology. Given a human's susceptibility and recovery likelihood to an infection, these studies examines whether there exists an epidemic threshold, beyond which infection spreads and becomes persistent. The work found that small-world networks, which have a great clustering coefficient, represent the real-life networks better than regular networks. We will explore whether the observed emergent behavior in large-scale distributed systems is also a small-world network. Moreover, scale-free networks, with power-law degree distribution property, found to not have any epidemic threshold. Because degree distribution of nodes affects their connectivity with other nodes, e.g. power-law distribution results in a few nodes of very large degree, it can be an important factor to affect the attack spread.

Although we plan to compare our findings with that of epidemics studies, epidemics bring certain assumptions to the field that we cannot readily take in such as immunity gained after infection, given probabilities of individuals for being susceptible to a certain virus, and estimated recovery rates. Furthermore, the likelihood of interactions between agents is not studied very much in the epidemics yet. Yan et all [31] proposed to assign weights between nodes to denote familiarity between individuals, such as family members. Because we can keep track of past agent interactions, as opposed to purely social interactions with no written records, we can generate realistic likelihoods of interactions. Furthermore, we will calculate indirect interaction rates between third parties although these parties are seemingly unfamiliar. For example two user agents that belong to different communities may not be included in each other social networks, similar to members of two distant families. However, by observing their access patterns to a compute agent that serves both communities, we can detect the indirect interaction rates between two seemingly isolated agents.

To validate our findings, we will conduct live incident drills and collect real incident response data. The incident drill will imitate propagation of an attack without harming any of the actual users or computers. We will "mark" a set of system components with non-malicious test code that will signal its host's location periodically to a central location. Any component that is so marked will be assumed to be infected. In fact, similar security drills are done routinely over many infrastructures today to measure readiness of participants. We will compare the data collected from the system against our calculation of attack propagation. The discrepancies will show us any inefficiency in our work.

Another goal of our work will be to understand whether we can modify agent behaviors to achieve a desired behavior. Under an attack, the goal is to minimize the number of infected agents while keeping the rest of the agents continuing with their regular interactions. It is often desirable to restrict certain agent interactions, such as removing an agent from the node temporarily, or restricting certain interactions between two agents, to stop the spread. Often the goal is to keep certain agents that are important for high productivity uninfected. We will explore how changes in interaction rules will affect the observed emergent behavior. We will first test with the simulation technique, then generate a methodology and test it against the real incident data.

4.2 First Model: for the OSG

We will begin by extracting and defining interaction rules between the agents. First, we will make use of static collaboration rules. Each user community on the OSG uses a management tool, VO User Management Service (VOMS) [32]. VOMS is a user database that lists the user groups,

group hierarchy, and access rights given to each group. VOMS servers are publicly accessible. The members of the same VO tend to collaborate often. The likelihood of collaboration increases in smaller VO groups. We plan to set interaction rules between user agents based on their collaboration relationships. In other words, we will simulate the ***social networking*** between the users. Because we download data from all of the registered VOs, we can detect users with multiple VO and group memberships, and adjust the social network accordingly. Although membership in a community is dynamic, the structure of each is fairly stable; hence, we refer to them as static collaboration rules. In a similar fashion, we will extract data from gatekeeper nodes to determine which communities are allowed access. A gatekeeper has the knowledge of which groups are allowed access to which worker nodes. The existing mappings between user and computer agents will form a set of interaction rules.

Second, we make use of ***real data*** logged. The middleware comes equipped with logging and accounting capabilities. All of the resources send weekly accounting reports to the site, infrastructure and user management. An accounting record lists the users of a specific resource, users' group memberships, applications ran on the compute nodes, data accessed on storage nodes, the duration, and the outcome (complete, failure, etc). Currently accounting records are publicly available. As an initial test of our ideas, we analyzed accounting records and developed a simple operational mechanism [33]. Similar to a bank generated monthly credit-card statement, we generate activity reports per user collected across all system nodes over a week, and email those to each user's VO manager. The reports have proved to be very successful and help users to identify unrecognized suspicious activities and possible credential thefts. Although log files are kept locally on gatekeeper nodes, we have the technical means to retrieve service-level log files once a resource owner gives us permission. Because we are not interested in the system level logs and we can keep the collected files under restricted access, we do not expect much difficulty in obtaining the data.

The log files will give us more details on agent behavior, e.g. while running on a compute agent, which storage agent is accessed the most, if the user logged into another compute agent, which user usually runs which applications, etc. Accounting and log files enable us to learn the real behavior in two important ways. First, we see the actual rate of interactions between agents. Secondly, we can learn behaviors that are not covered by static collaboration rules either because they are not allowed or because they are beyond the scope. A large VO can have close to 3000 members; typically tens of uses are in the same VO-group and thus have the same access rights. However, all VO members are not actively using the system at all times. Even when given access to multiple nodes, users tend to use two or three nodes the most frequently. Compute agents tend to run a few applications over most of the time and they tend to exchange data with the same storage nodes. As a result, the actual interactions between the agents are more fine-grained than implied by the explicit collaboration rules. Furthermore, some interactions are not entirely captured by static rules. The VO structure gives us a starting point for modeling the social network. It is possible for users from different VOs or groups to collaborate frequently as well. We also expect some users will utilize resources in unintended ways, such as running personal applications, or have a community account across several colleagues, etc. The best way to supply our Agent-based simulation tool, Repast, with the actual log files is to install it on the OSG nodes and train it directly with the local logging and accounting data (see Section 3).

Initially, we implement our agents with simple goals: users greedily consume CPU cycles and storage space; compute and storage agents provide the highest productivity possible. A compute agent will not waste any CPU cycles by staying idle and a storage agent will utilize its memory to store highest number of data without loss. Gradually, we will introduce more complex goals. VOs can have agreements with resource owners such that they negotiate for scheduling priority,

certain number of cycles and storage space. These will be later introduced to computer agents' goals. Initially, all authorized user agents will treated equally by the storage and compute agents.

4.3 Subsequent Models

Subsequently we will model the global CMS experiment distributed system. This will require analysis of the interfaces between the national infrastructures that are part of the facilities, dealing with interactions across international boundaries, disparate policies and middleware etc. We will also take account of "unknowns" or incomplete knowledge of the system and validation information available. This work will start in the second year of the project. We also plan to outreach to the ANL APS and ORNL SNS support teams as they evolve their plans for collaboration and sharing of data and repositories across the DOE and University sites. Modeling the shared systems and analyzing the threat and incident propagations experienced will enable us to contribute to the body of knowledge for development and protection of these systems. We will work with more communities as the opportunity arrives.

4.4 Extending the distributed networks model

The model created in the manner described above is very powerful and can be extended in a variety of way. In years two and three, we will actively work on extensions that can aid in the creation of security policies. For example, we will run reverse simulations to identify the types of policies that can be used to create a desired final state. Additionally we will design malicious agents using data from existing attacks on both grid networks and DOE laboratory networks and characterize the emergent behavior of would-be attackers. We will investigate the classes of cyber-attacks (e.g., ICMP-based distributed denial of service attack, or BGP-based routing attacks) with respect to the feasibility of modeling attack behaviors as well as the development of an attack library. The purpose of the development of the attack library is to validate and demonstrate the effectiveness of security policies under a range of cyber-attacks. For the malicious agents, the design objectives are structured around a concept of an attacking agent that can incorporate different attack functionalities based on pluggable attack modules with configurable interfaces. An attacking agent is capable of generating the necessary types of cyber-attacks based on the configuration. Traffic patterns, together with the attack library, will be fed into our simulations, to aid in the creation of the security policies and anomaly-based intrusion detection rules. Also, we plan to find the "weakest-link" of a given system - which agents an attacker should target to achieve the largest amount of spread and disruption.

4.5 Improving Throughput of Agent Based Modeling by Running over the OSG

In order to run the tens of thousands of simulations needed to characterize the threat behaviors we will need more compute cycles than is available locally. We will there need to start to use other resources, most naturally from the Open Science Grid. To do this, Repast will need to be factored appropriately since the OSG model, unlike interactive simulations, assumes that each simulation can be run anywhere resources are available. Hence, data must be packaged with the executable to allow this level of resource independence. Once this is done however, other researchers using Repast will have a clear pattern to follow and will be able to use the OSG resources as well. Running Repast on the Open Science Grid can be achieved by setting up automatic driver software that (1) creates a setup of input parameter files to cover the range of runs to be completed; (2) uses Repast's installation file builder to bind each input parameter file and the master directories into a compressed installer; (3) distributing the installers over the grid; (4) invoking an installer on each target computer; (5) issuing a command line call to start a model run on each target computer; (6) copying the resulting output log files back to the central results repository; and (7) monitoring and restarting non-responsive jobs as needed.

4.6 Collaboration and Validation of New Mathematical Models

As described previously, one of the powerful capabilities of Agent Based Modeling is the ability to validate and justify mathematical models, including models that may be generated as part of this call for proposals. In years two and three, in addition to completing the validation of our security model, we will actively engage other teams that are creating other mathematical models of "complex, distributed, interconnected systems". We will actively explore this option. We are well positioned as part of broader groups to have access to these models and collaborate across the DOE complex.

Given the recent interest in cloud computing in DOE, our security model can be readily expanded to meet the unique security challenges that commercial cloud computing presents. Cloud computing providers are rapidly attempting to meet these challenges and have important experiences that can be leveraged for model building. The security team we have assembled is already engaged with a variety of commercial partners (e.g. Akamai and Apirio) that could eventually become collaborators on this project.

5 Organization and Deliverables

The ANL team will work on extending, adapting and running the agent based modeling code. The Fermilab team will work on the interpretation and validation of the models, risk calculation and analysis, stimulated scenarios and real threats and attacks. The teams will work together on modifying the models based on the observed behaviors.

Year 1:

- Extract static collaboration rules. Build a fundamental social network of agents in Repast.
- Extract log behavior data from OSG resources and train Repast with real system behaviors.
- Simulate and generate emergent behavior based on threat, social network connectivity and interactions. Analyze security properties of the emergent behavior.
- We will validate the risk model against one mock incident on a real grid infrastructure.
- Develop a quantitative risk model for attack propagation.

Year 2:

- Validate one external mathematical model of threat and attack propagation against the agent-based model. (E.g. social networks math model from MPS at ANL)
- Develop a methodology to modify agent behavior to obtain an expected and/or measured emergent behavioral property and minimize the spread of attacks.
- Develop and test the first mathematically based method for adapting the agent models and simulations based on the time-lines of observed behavior.
- Apply network attack library and measured traffic patterns to the model of the distributed system.
- Apply the model to another complex distributed system. Likely to be the global CMS experiment facility (in collaboration with the European infrastructure projects).

Year 3:

- Extend network-level tools with middleware/host-layer behavioral patterns to improve the performance and accuracy of the models.
- Compare the performance and validation of the results of enhanced network-layer tools against that of native network-layer tools.
- Apply the model to another complex distributed system.
- Development of network based attacking agent to validate and demonstrate the

effectiveness of security policies

- Iteratively further improve the mathematical models that enable the simulations to match the measured emergent behaviors.

Metrics:

We will define annual metrics based on our ability to understand and compare the simulations to the real data, to quantify risk and match that to the actual system responses.

6 Conclusion

We propose a program of work that will provide configurable, re-usable, mathematical models that are validated by experience in actual complex interconnected systems. We will apply the results of and adapt the models to a series of real world systems used by the DOE and other research communities. Our reusable agent-based modeling framework and our access to data from a spectrum of such systems gives us excellent opportunities to perform research on and also validate the assumptions used and policies in place. The collaboration between simulation, analysis and security teams gives us a good foundation to tune and adapt the models as well as the live policies and responses to give the most effective response to incidents and attacks.

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Zhou, Fu, Wang, "Epidemic Dynamics on complex networks" Physics and Society, Progress in Natural Science, 16(5): 452-457 (2006), http://arxiv.org/abs/physics/0508096v1
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[33] M. Altunay, "Achieving operational security with the help of grid users" Workshop on Monitoring, Logging and Accounting, 2009, Munich, Germany

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Education:
North Carolina State University, Raleigh, NC
Ph.D. in Computer Engineering, 08/2001-05/2007, GPA:3.82/4.00, Academic Advisor: Gregory T. Byrd

Bilkent University, Ankara, Turkey, (the highest ranked university in Turkey with 0.1 percent acceptance rate) B.S. in Electrical and Electronics Engineering, 09/1996-05/2001, GPA: 3.42/4.00

Dissertation:
Title: Collaboration Policies: Access Control Management in SOA-based Dynamic Collaborations

Service-oriented architectures change the computing paradigm by providing easily accessible services and by promoting collaborations among the provided services. The services can reach to a larger user pool, and they can easily be harnessed with other services to create more powerful services. Ideally, the end user expects to select from an existing service pool, mix-and-match services, and come up with original services that are tailored to his unique needs. This paradigm shift in computing, however, leads to the increased exposure of services. Access control becomes more complicated due to multiple autonomous security domains involved and the absence of pre-established trust among these domains. Our work, from a service owner's viewpoint, analyzes and identifies the security threats associated with joining a collaboration. We tackle these threats in two aspects: by providing a service owner with the necessary means to express and evaluate its trust requirements from a proposed collaboration (collaboration policies), and by creating an evaluation framework that incorporates these trust requirements. Our work aims to promote dynamic, on-demand collaborations among services by addressing the security issues.

Work Experience:

Open Science Grid (OSG, www.opensciencegrid.org) Security Officer, Fermi National Accelerator Laboratory, IL, US, 07/2007-present
· Head of OSG security, where 120+ sites and 30+ Virtual Organizations are member of. OSG is a $30M NSF and DOE-funded project for enabling distributed computing for various science experiments.
· Leads a small team of four people, interacts with partner grids, and projects, e.g. Globus project, TeraGrid, European Grids.

· Responsible for 1) operational security (incident response, vulnerability analysis, security monitoring, compatibility); 2) infrastructure and the software stack (includes 70+ software components such as Globus, Condor, MyProxy, etc, needed for distributed computing); 3) Policy work and interoperability (develop joint policies with International Grid Trust Federation and ensure European compatibility)
· Part of the DOE CyberSecurity R&D community; helps organizing meetings and providing feedback to the DOE.
· Responsible for OSG software stack (+70 components). This work includes software beyond the security. Co-leads the software tools group; determines which software gets into the stack, or how it is developed, integrated and put into production.

Student Fellow, IBM Tokyo Research Laboratory, Tokyo, JAPAN 06/2006-08/2006
· Worked on AJAX, Web 2.0, and Mashup technologies. Identified threats related to access control (auth/authz) in Web 2.0 and mashup applications. Created mashup applications using Yahoo! and Google APIs. The results from this work have been turned into a deliverable (See publications "AJAX Threat Analysis")
· Analyzed MySpace and Yamanner worms, and demonstrated a method for preventing them.
· Gave an IBM Professional Interest Community (PIC) Seminar on access management in dynamic SOAs (See Talks "Collaboration Policies: How to manage access in SOAs)

Summer Internship, IBM, HiPODS-BigSur Project, RTP, USA 06/2005-08/2005
· Created a Workflow Management Tool and remote user interface that enabled customers to deploy/manage/monitor their business processes on a remote WebSphere Server, which either contains the managed applications or is a target platform for future application deployment.
· Used WSAD 5.1 (WebSphere Application Development) APIs and JMX Application Management APIs

Extreme Blue Internship, IBM, North Carolina BioGrid Team,
RTP, USA, 06/2003-08/2003
· Extreme Blue is a prestigious internship program at IBM. In 2003, approximately 20 graduate students are admitted out of 1000+ applicants across North America.
· Created the first infrastructure, with a team of four people, which exposes standard bioinformatics applications and libraries to the remote grid processing power via web services
· Deployed the first bioinformatics application, BLAST, to run on North Carolina BioGrid (MCNC) with using Globus 2.0 as a computational grid and AVAKI as the data grid (this work has lead to an invention disclosure, see patents section)
· Designed, implemented and tested a security model which integrates secure web services with GSI model and MyProxy solution at NCBioGrid (this work has lead to an invention disclosure, see patents section)
· Extended standard BioPerl libraries, wrote a library for BLAST applications that dynamically submits BLAST jobs to the NC BioGrid (Implemented in SOAP::Lite)

Research Assistantship in Fungal Genomics Lab, NC State Univ, 01/2003-05/2003
· Installed Globus and Avaki grid middlewares, configured the home-grown cluster set to run

with these middlewares.
· Modified bioinformatics applications such as Nuclear Blast and DeCIFR (BioPipe) and configured them to run efficiently on the North Carolina BioGrid.
· Analyzed security requirements of several workflow engines (IBM BioWBI and Taverna) and enhanced current Globus Toolkit accordingly (see the publications section)
· Introduced trust and security requirements into the distributed resource selection problem (This work has resulted in an IEEE publication, see Publications below)

Teaching Assistantship in ECE Dept., NC State Univ. 09/2001-05/2007
· Taught laboratory sessions, graded papers, helped students to develop the analytical skills needed in various electrical & computer engineering classes

Undergraduate Internship, Univ. of Maryland Institute of Advanced Computer Studies, 06/2000-08/2000
· Development and implementation of parallel algorithms to well-known problems from FLASH and Olden Benchmarks in eXplicit-Multi-Threading model.
· Created a benchmark of parallel algorithms on eXplicit-Multi-Threading model and compared the performance with other models.

Nortel Networks University Case Competition, Fall 2000
· Selected to represent Bilkent University in a team of four people in the Nortel Business Case Competition in North America and Europe region.
· Helped preparing the business plan for a fictitious start-up company, which was assumed to sell networking services in Southeast region of US.

Patents Pending:
"A Method for Selective Security of Genomic Coding Regions" V. Batra, M. Altunay, C. Warade, D. Colonnese, L. K. Wilber, S. Vadlamudi. IBM Disclosure Number: CHA820030041, USA Patent Application Number: 20050234655

"A Method for Automatically Creating Workflow Using Web Service Signature Matching" V. Batra, M. Altunay, C. Warade, D. Colonnese, S. Vadlamudi. IBM Disclosure Number: CHA820030045, USA Patent Application Number: 20050234964

Publications:

M. Altunay, G. Byrd, D. Brown, R. Dean. "An Interaction Based Access Control Model (IBAC) for Collaborative Services" The International Symposium on Collaborative Technologies and Systems, Irvine, CA, pp: 547-554, 2008.

M. Altunay, I. Gaines, D. Petravick, I. Sifiligoi. "Virtual Organization Trustworthiness in the Grid World". International Conference on Computing in High Energy and Nuclear Physics 2007, Victoria BC Canada.
(http://indico.cern.ch/getFile.py/access?contribId=231&sessionId=21&resId=0&materialId=paper&confId=3580)

N. Seki, M. Altunay, S. Yoshihama, S. Makino, M. Kudo, N. Uramoto, "Threat Analysis for AJAX", IBM Internal Report. July, 2006. (in preparation to be submitted to IBM developerWorks)

M. Altunay, D.Brown, G.Byrd, R.Dean, "Collaboration Policies: Access Management in Heterogeneous Distributed Workflows", Journal of Software, 1(1):11-22, July 2006.

M. Altunay, D.Brown, G.Byrd, R.Dean, "Trust-Based Secure Workflow Path Construction", ACM Intl. Conf. on Service Oriented Computing ICSOC 2005, 2005, Amsterdam, The Netherlands (approximate acceptance rate 15%)

M. Altunay, D. Brown, G. Byrd, R. Dean, "Evaluation of Mutual Trust during Matchmaking", 6th IEEE Intl. Conf. On Peer-to-Peer Computing P2P 2005, Konstanz, Germany (approximate acceptance rate 18%)

M. Altunay, D. Colonnese, C. Warade, "High Throughput Web Services for Life Sciences", IEEE Intl. Conf. on Information Technology Coding and Computing (ITCC), NV, USA, 4/2005.

M. Altunay, D. Brown, G. Byrd "Encapsulation of Grid Information Services to Assess Secure Client Access" , GlobusWORLD, MA, USA, February 2005. (Poster Presentation)

M. Altunay, D. Colonnese, C. Warade, "Web services for Bioinformatics", IBM developerWorks, June 2004, http://www-106.ibm.com/developerworks/webservices/library/ws-bioinfo.html

V. Batra, M. Altunay, C. Warade, D. Colonnese, L. K. Wilber, S. Vadlamudi, "RSS Integration for OGSA for Federation of Sequence Data", Submitted to IBM Intellectual Archives, Disclosure Number: CHA820030042.

V. Batra, M. Altunay, C. Warade, D. Colonnese, L. K. Wilber, S. Vadlamudi, "A Method to Codify Amino Acid and Genomic Sequencing Representations", IBM Intellectual Archives, IBM Disclosure Numbers: CHA820030044, CHA820030043.

Invited Talks:

"Open Science Grid: Security", In regular meeting of the CIOS's of the Department of Energy National Laboratories (NLCIO). May, 5, 2008.

"Collaboration Policies: How to Manage Access in SOA", PIC Seminar, IBM Tokyo Research Laboratory, Tokyo, Japan, July 26, 2006.

"Grid Computing and Security Issues: Interoperability and Authorization Mapping", IBM Watson Research Center, Hawthorne, NY, September, 30, 2003.

"Security Aware Planning Tools for Grid-Based Workflows", Sun's COE Conference on Bridging the Gaps between Bioinformatics and Computer Science, Raleigh, USA, September,

22, 2005.

“Encapsulation of Grid Information Services to Assess Secure Client Access”, North Carolina Grid Working Group, Raleigh, NC, December 12, 2004.

Honors/Achievements:

· Full Scholarship from NC State University, as part of Graduate Student Support Plan during the entire graduate studies
· Dean's Honor List/Bilkent University, 8 semesters
· Full Scholarship from Bilkent University throughout the undergradute studies
· Ranked 122nd in the Turkish National University entrance exam (similar to US-SAT exams) out of 1.5 million applicants.

Wenji Wu

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Education

Ph.D., Dec. 2003, Computer Engineering, University of Arizona, Tucson, USA
Master, May 2001, Industrial Engineering, University of Arizona, Tucson, USA
Master, May 1997, System Engineering, Zhejiang University, Hang Zhou, China

Professional Appointments

June 2005 – Present, Network Researcher, Fermi National Accelerator Laboratory
September 2004 – June 2005, Research Assistant Professor, ECE dept., Univ. of Arizona, Tucson
September 2003 – September 2004, Research Engineer, ECE dept., Univ. of Arizona, Tucson

Publications Related to Proposed Project

Journals

[1] Wenji Wu, Phil Demar, Matt Crawford, "Sorting Reordered Packets with Interrupt Coalescing," To appear in Computer Networks (Elsevier), doi:10.1016/j.comnet.2009.05.012.
[2] Wenji Wu, Matt Crawford, "Interactivity vs. Fairness in Networked Linux Systems," Computer Networks (Elsevier), Volume 51, Issue 14, pp. 4050 – 4069, 2007.
[3] Wenji Wu, Matt Crawford, "Performance Analysis of Linux Networking – Packet Receiving," *Computer Communications* (Elsevier), Volume 30, Issue 5, pp. 1044 – 1057, 2007.
[4] Wenji Wu, Matt Crawford, "Potential Performance Bottleneck in Linux TCP," *International Journal of Communication Systems* (Wiley), Volume 20, Issue 11, pp. 1263 – 1283, 2007.
[5] Wenji Wu, Natalia Gaviria, Kevin M. McNeill, "Two-layer Hierarchical Wavelength Routing for Islands of Transparency Optical Networks," *Computer Communications* (Elsevier), Volume 29, Issue 15, pp. 2952-2963, 2006.
[6] Wenji Wu, Ralph Martinez, Peng Choop, "A Modeling Process and Analysis of GMPLS-based Optical Switching Routers," *Journal of Photonic Network Communications*, Volume 8, Issue 1, Jun 2004.

Conferences:

[1] Wenji Wu et al., 'End-to-End Network/Application Performance Troubleshooting Methodology," *Proceedings of Computing in High Energy Physics* (CHEP) 2007, Vitoria, Canada.
[2] Wenji Wu and Matt Crawford, "The Performance Analysis of Linux Networking–Packet Receiving," *Proceedings of Computing in High Energy Physics* (CHEP) 2006, Mumbai, India, 2006.
[3] Wenji Wu, Ralph Martinez, Peng choop, "Simulation-Based GMPLS Photonic Router using the OPNET MPLS Module," *OPNETWORKS2002*, Aug. 2002, Washington. (Best paper award)

[4] Wenji Wu, Ralph Martinez, Peng choop, "Constraint-based Routing for Islands of Transparency Optical Networks," *OPNETWORK2003*, Aug. 2003, Washington D.C, 2003

Grants

(1) Wenji Wu, Co-Principal Investigator, "Adaptive Voice Quality Enhancement Mechanisms for VoIP", NSF Connection One Grant ($84,000), July 2004.
(2) Wenji Wu, Co-Principal Investigator, "BAE Connection One Non-Core Research", supported by BAE SYSTEMS ($120,000), September 2004.

Professional Society

(1) IEEE Member
(2) IEEE Communications Society Member
(3) LHC Optical Networking Group

Reviewing

(1) DOE SBIR/STTR review panel, 2006
    - Reviewing proposal "Bandwidth Aware Network Interface Card"
(2) DOE SBIR/STTR review panel, 2009
    - Reviewing proposal "Wide Area QoS-per-Experiment through Intra-QoS Class Optimizing Boxes"

List of Collaborators and Co-editors

Dantong Yu, Ph.D., Brookhaven National Laboratory
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Professional Preparation

- Undergraduate: Utah State University, Mathematics, BS, 1981
- Graduate: Utah State University while in residence at the Los Alamos National Laboratory, Physics, Ph.D., 1986

Appointments:

1. 2007 – Present, Senior Fellow, Computational Institute, University of Chicago
2. 2009 – Present, Production Coordinator, Open Science Grid
3. 2007 – 2009, Director, Community Driven Improvement of Globus Software
4. 2006 – 2007, Technical Lead for the GridFTP Development Team.
5. 2006 – Present, Software Architect, Argonne National Laboratory, Argonne, IL
6. 2004 – 2006, Distinguished Engineer, Paremus Ltd, London, New York, Chicago
7. 1999 – 2004, Principal System Engineer, Sun Microsystems, Santa Clara, CA
8. 1995 – 1999, Principal Scientist, NEC, Houston, TX
9. 1992 – 1995, Scientist, Thinking Machines Corporation, Boston, MA
10. 1988 – 1992, Program Director, General Atomics/US Air Force, Albuquerque, NM
11. 1986 – 1988, Staff Scientist, Los Alamos National Laboratory, Los Alamos, NM

Selected Publications:

- H. Trease, D. Fraser, Robert Farber, Steve Elbert, "Using Transaction Based Parallel Computing to Solve Image Processing and Computational Physics Problems", Cloud Computing Conference Poster, CCA-08 (Cloud Computing and Its Applications), Chicago, IL, 2008.
- D. Fraser, F. DeCarlo, I. Foster, M. Papka, "Real Time Analysis of Advanced Photon Source Data," annual progress report submitted to ANL, August 2008.
- D. Fraser, S. Marru, S. Martin, N. Wilkins-Diehr, I. Foster, S. Perera, et al, "Engaging with the LEAD Science Gateway Project: Lessons Learned in Successfully Deploying Complex Systems on the TeraGrid," TeraGrid '08, May 2008.
- D. Fraser, J. Bresnahan, R. Kettimuthu, N. LeRoy, M. Link, M. Livny, "The Managed Object Placement Service", presented at the annual Condor Week meeting April 30, 2007.
- I. Foster et al, "Center for Enabling Distributed Petascale Science", annual progress report to the US, Department of Energy, Nov 2007.
- I. Foster, D. Fraser, C. Kesselman, L. Liming et al, "Community Driven Improvement of Globus Software 2008," annual progress report to the National Science Foundation, Dec 2008.
- D. Williams, et. al, "The Earth System Grid Center for Enabling Technologies: Scaling the Earth System Grid to Petascale Data", semi-annual progress report to

the US, Department of Energy, May 2007.

- D. Fraser, *Redefining Enterprise Grid*, Paremus Technical White Paper, 2006.
- R. Maldonado, D. Fraser, et al., *Sun Grid Reference Architecture*, Sun Blueprint, 2004.
- H. Schwartz, M. Ahronovitz, J. Coomer, C. Chaubal, D. Fraser, J. Fowler, D. Gardiner, W. Gentzsch, F. Hatay, B. Hammond, R. Rafinski, S. Unger, *Web Services for High Performance Technical Computing*, Sun Microsystems Technical Report, 2003.

Collaborators and Other Affiliations

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Kate Ericson, SDSC
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Raj Kettimuthu, ANL/UC
Ian Foster, Argonne National Laboratory/University of Chicago, IL
Dennis Gannon, Indiana University, Bloomington, IA
Carl Kesselman, University of Southern California ISI, Los Angeles, CA
Stuart Martin, ANL/UC
B. Tieman, Advanced Photon Source, Argonne National Laboratory

Michael John North, MBA, Ph.D.

Education

Ph.D. Computer Science, Illinois Institute of Technology, Chicago, IL 2005
MBA Keller Graduate School of Management, Oakbrook Terrace, IL 1996
MS Computer Systems Engineering, Illinois Institute of Technology, Chicago, 1995
MS Computer Science, Governors State University, University Park, IL 1994
BS Computer Science, Magna Cum Laude, North Central College, Naperville, IL 1992
BA Mathematics, Magna Cum Laude, North Central College, Naperville, IL 1992
AES High Honors, College of DuPage, Glen Ellyn, IL 1999
AGS High Honors, College of DuPage, Glen Ellyn, IL 1992
AS High Honors, College of DuPage, Glen Ellyn, IL 1991
AA High Honors, College of DuPage, Glen Ellyn, IL 1991

Present Positions

Deputy Director of the Center for Complex Adaptive Agent Systems Simulation
Decision and Information Sciences Division (DIS)
Argonne National Laboratory

Senior Fellow
Computation Institute
University of Chicago and Argonne National Laboratory

Selected Publications

- North, M.N., and C.M., Macal, *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation*, Oxford University Press, New York, NY USA (March 2007).
- North, M.J., N.T. Collier, and R.J. Vos, "Experiences Creating Three Implementations of the Repast Agent Modeling Toolkit," *ACM Transactions on Modeling and Computer Simulation*, Vol. 16, Issue 1, pp. 1-25, ACM, New York, New York USA (January 2006).
- Brown, D.G., R. Riolo, D.T. Robinson, M.J. North, and W. Rand, "Spatial Process and Data Models: Toward Integration of Agent-Based Models and GIS," *Journal of Geographical Systems*, Vol. 7, No. 1, pp. 25-47, Springer, Heidelberg, FRG (October 2005).
- Macal, C.M., and M.J. North, "Validation of an Agent-based Model of Deregulated Electric Power Markets," *Proceedings of the 2005 North American Association for Computational Social and Organizational Science (NAACSOS) Conference*, NAACSOS, Notre Dame, IN USA (June 2005).
- Howe, T.R., N.T. Collier, M.J. North, M.T. Parker, and J.R. Vos, "Containing Agents: Contexts, Projections, and Agents," *Proceedings of the Agent 2006 Conference on Social Agents: Results and Prospects*, Argonne, Argonne, IL USA (September 2006).
- North, M.J., T.R. Howe, N.T. Collier, and J.R. Vos, "A Declarative Model Assembly Infrastructure for Verification and Validation," in S. Takahashi, D.L. Sallach and J.

Rouchier, eds., *Advancing Social Simulation: The First World Congress*, Springer, Heidelberg, FRG (2007).

- North, M.J., P. Sydelko, J.R. Vos, T.R. Howe, and N.T. Collier, "Legacy Model Integration with Repast Simphony," *Proceedings of the Agent 2006 Conference on Social Agents: Results and Prospects*, Argonne, Argonne, IL USA (September 2006).
- Macal, C.M. and M.J. North, "Tutorial on Agent-Based Modeling and Simulation," *Proceedings of the 2005 Winter Simulation Conference*, M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds., IEEE, Piscataway, NJ USA (December 2005).
- Emonet, T., C.M. Macal, M.J. North, C.E. Wickersham, and P. Cluzel, "AgentCell: A Digital Single-Cell Assay for Bacterial Chemotaxis," *Bioinformatics*, Vol. 21, No. 11, pp. 2714-2721, Oxford University Press, Oxford, UK (March 17, 2005).

Selected Activities

Dr. North has contributed to wide range of multidisciplinary modeling and simulation research projects. These projects include the following:

- Repast is a leading free and open source large-scale agent-based modeling and simulation library that is available for download http://repast.sourceforge.net/. Repast has been used in a wide variety of applications that ranges from to social systems, to biological systems, to economic modeling. Repast is maintained by the nonprofit volunteer Repast Organization for Architecture and Design (ROAD). Dr. North has been involved with the Repast project since its inception in 2000. Since 2005 Dr. North has been the coordinator of the ROAD Board as well as the lead architect and manager for the Repast project.
- The Electricity Market Complex Adaptive Systems model (EMCAS) model is an agent-based electric power market model. EMCAS has been commercially licensed to many organizations throughout the world. Dr. North was the lead EMCAS software engineer from the start of the project in 2000 until 2002. Since then, Dr. North has contributed to EMCAS as an agent-based modeling consultant.
- The NSF MADCABS project is a collaborative effort between the Illinois Institute of Technology (IIT) Chemical Engineering and Computer Science Departments and Argonne. Argonne is funded through a subcontract to award #0325378. MADCABS seeks to apply complex adaptive systems tools such as agent-based modeling to the problem of real-time supervision of diverse networks. Dr. North has contributed to the MADCABS as an agent-based modeling consultant since its inception in 2003.
- The University of Chicago AgentCell modeling project applied the Repast toolkit to the study of bacterial chemotaxic signal transduction including the integration of the widely used StochSim stochastic chemical model. AgentCell is now a free and open source project available for download from http://www.agentcell.org/. Dr. North has contributed to AgentCell project design and development since its inception in 2002.

Selected Professional Organizations

- Senior Member, Association for Computing Machinery (ACM)
- Senior Member, Institute of Electrical and Electronics Engineers (IEEE)

Charlie Catlett (http://en.wikipedia.org/wiki/Charlie_Catlett) is Chief Information Officer at Argonne National Laboratory, director of the Computing and Information Systems Division, and a Senior Fellow in the Computation Institute, a joint institute of Argonne National Laboratory [1] and The University of Chicago. From 2004-2007 he was Director of the TeraGrid Project. [2]

Prior to joining Argonne in 2000, Catlett was Chief Technology Officer at the National Center for Supercomputing Applications (NCSA). He was part of the original team that established NCSA in 1985 and his early work there included participation on the team that deployed and managed the NSFNet. In the early 1990's Catlett participated in the DARPA/NSF Gigabit Testbeds Initiative, coordinated by the Corporation for National Research Initiatives.

Catlett was the founding chair of the Global Grid Forum (GGF, now Open Grid Forum) from 1999 through 2004. [1] During this same period he designed and deployed one of the first regional optical networks dedicated to academic and research use - I-WIRE, funded by the State of Illinois.

He has been involved in Grid (distributed) computing since the early 1990s, when he co-authored (with Larry Smarr) a seminal paper "Metacomputing" in the Communications of the ACM, which outlined many of the high-level goals of what is today called Grid computing. [3]

Selected publications:

- "A Scientific Research and Development Approach to Cyber Security," Charlie Catlett, Editor, A report presented to the Department of Energy Office of Science, December 2008.
- "TeraGrid: Analysis of Organization, System Architecture, and Middleware Enabling New Types of Applications," Charlie Catlett et al., HPC and Grids in Action, ed. Lucio Grandinetti, IOS Press Advances in Parallel Computing series, Amsterdam, 2008.
- "Metacomputing", Communications of the ACM, Charlie Catlett, Larry Smarr. vol. 35, no. 6, June 1992.
- "Creating and Operating National-Scale Cyberinfrastructure Services", CTWatch Quarterly, Charlie Catlett, Pete Beckman, Dane Skow, and Ian Foster,vol. 2, no. 2, May 2006.
- Witness Testimony, U.S. House Committee on Energy and Commerce, May 2004.
- "Global Grid Forum Documents and Recommendations: Process and Requirements (GFD.1)", Global Grid Forum Document Series, June 2001.
- "Standards for Grid Computing: Global Grid Forum", Journal of Grid Computing, Vol. 1, May 2003.
- "Testbeds: From Research to Infrastructure", Charlie Catlett and John Toole, in "The Grid: Blueprint for a New Computing Infrastructure," Ian Foster and Carl Kesselman, ed., Morgan Kaufmann, August 1998.

- "Distributed Data and Immersive Collaboration", Communications of the ACM, Dan Reed, Charlie Catlett, and Roscoe Giles, vol. 40, no. 11, November 1997.
- "From the I-WAY to the National Technology Grid", Communications of the ACM, Rick Stevens, Charlie Catlett, Paul Woodward, and Tom DeFanti, November 1997.
- "In Search of Gigabit Applications", IEEE Communications Magazine, April 1992, Winner, IEEE Communications Society Fred W. Ellersick best paper award 1992[4]
- "Balancing Resources", IEEE Spectrum Magazine, September 1992.
- "Internet Evolution and Future Directions", in Internet System Handbook, Dan Lynch and Marshall T. Rose, ed. Addison-Wesley, 1992.

References:

1. "Peer-to-peer potential rediscovered". CNN. 2001-08-03. http://archives.cnn.com/2001/TECH/internet/08/03/p2p.potential.idg/
2. "National Supercomputer Grid Set For $148M Expansion". Information Week. 2005-08-18. http://www.informationweek.com/news/management/showArticle.jhtml?articleID=169400332
3. Laforenza, Domenico (2004). Recent Advances in Parallel Virtual Machine and Message Passing Interface. Springer. p. 11. ISBN 3540231633. http://books.google.co.uk/books?id=fojc1rKPRCAC&pg=PA11&dq=%22Charlie+Catlett%22&num=100&sig=24XMkAxLE0DqG2UYldALexwo5cI
4. "Witness Testimony". United States House Committee on Energy and Commerce. http://energycommerce.house.gov/reparchives/108/Hearings/05062004hearing1264/Catlett1972.htm

Recent Collaborators:

```
* Tim Cockerill (NCSA)
* Ian Foster (UC/ANL)
* Kelly Gaither (TACC)
* John Gerber (UC/ANL)
* Dave Hart (SDSC)
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* Daniel S. Katz (LONI/LSU)
* Scott Lathrop (UC/ANL)
* Elizabeth Leake (UC/ANL)
* Lee Liming (UC/ANL)
* Amit Majumdar (SDSC)
* J.P. Navarro (UC/ANL)
* Tony Rimovsky (NCSA)
* Sergiu Sanielevici (PSC)
* Rick Stevens (UC/ANL)
* Nancy Wilkins-Diehr (SDSC)
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Description of Facilities and Resources
The researchers and students involved in the proposed project have access to excellent computational facilities:

Fermi National Accelerator Laboratory. The computing facilities at Fermi National Accelerator Laboratory include mass storage systems (Enstore), distributed managed disk cache systems (dCache), a few major parallel computing systems, and wide are networking to support Tevatron Run II experiments, the theoretical physical research of Lattice QCD, and Large Hadron Collider (LHC) experiments with large US collaborations for ATLAS and CMS. Enstore is the mass storage system and provides distributed access to data on tape to both local and remote users. It totally has 90,000 tape slots, with a potential capacity of 40 petabytes. Currently it has 12 petabytes of data stored, with a daily transferring rate to/from tape up to 100 terabytes per day. The dCache system is a distributed managed disk cache system, a collaboration between DESY in Germany and Fermilab. It has around 3 petabytes of disk. The storage arrays are made by Nexsan and Promise. There are 12 head, administrative and monitoring nodes, and 138 data mover nodes. Each data mover node is configured with bonded GE. The dCache system typically moves data at 3-5 GBytes/sec, and have peak performances in the 15-20 GByte/sec. The laboratory current major parallel computing systems: (1) FermiGrid, a petaflops-scale Linux cluster, which has 3,200 computer nodes, with a total of 18,000 batch slots (CPUs). Typically, each node has 4 or 8 cores with a 2.4-3.0 GHz Intel Core 2 duo/quad processors, and 16GB memory. Totally, there is 88 TB of cluster-wide BlueArc storage. (2) QCD Cluster, a 127-node cluster with single 2.8 GHz Pentium 4 professors and a Myrinet fabric. The Pentium processors have an 800 MHz front side bus. (3) PION Cluster, a 518-node cluster with single 3.2 Hz Pentium 640 processors and an Infiniband fabric. The Pentium processors have an 800 MHz front side bus. (4) KAON Cluster, a 600-node cluster with dual dual-core Opteron 270 (2.0GHz) processors and a double-data-rate Infiniband fabric. For wide area networking, Fermilab uses both ESNET and Starlight and is heavily involved in the management and use of the dedicated LHCnet between CERN and the US. In aggregate, Fermilab has over 80Gbps capacities for offsite data movement to provide support of both production use and research efforts.

Fermilab
Current and Pending Support

Mine Altunay
Support Status: Proposed
Project Title: Modeling and Validation of Emergent Behavior under Threat on Multi-Domain Interconnected Systems
Funding Source: DOE
Total Award Amount: 200K to Fermilab
Dates of Award: 8/1/09-6/30/12
Person-months Per Year: 1.2 months

(I am not a PI or senior personnel on the below award)
Support Status: Current
Project Title: Sustaining and Extending the Open Science Grid: Science Innovation on Petascale Nationwide Facility
Funding Source: DOE & NSF
Total Award Amount: $5,979,000 at Fermilab
Dates of Award: 10/01/06- 9/31/11
Person-months Per Year: 9.0

Wenji Wu

Support Status: Pending
Project Title: Network Weather and Performance Service E-Center Nationwide Facility
Funding Source: DOE
Total Award Amount: $1050K at Fermilab
Dates of Award: 8/01/2009- 8/31/2012
Person-months Per Year: 3.0

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Dr. Dan Fraser

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Open Science Grid

Source of Support: NSF, DOE Office of Science

Total Award Amount: $30M Total Award Period Covered: 2006 - 2011

Location of Project: Multiple locations. Fraser funding through Univ. of Chicago

Person-Months Per Year Committed to the Project. Cal: 9.0 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

STCI: Adopt a Tightly Coupled Commodity Cluster Program

Source of Support: DOE Office of Science

Total Award Amount: $3.6M Total Award Period Covered: 2009 - 2011

Location of Project: Multiple locations, Fraser funding through Univ of Chicago

Person-Months Per Year Committed to the Project. Cal: 4 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Petascale X-Ray Microscope

Source of Support: NSF

Total Award Amount: $2.5M Total Award Period Covered: 2009 - 2011

Location of Project: Unive. of Chicago, Oper. of Argonne National Laboratory

Person-Months Per Year Committed to the Project. Cal: 2.5 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Power Caching Energy Systems

Source of Support: Argonne National Laboratory LDRD

Total Award Amount: $550K Total Award Period Covered: 2009 - 2010

Location of Project: Argonne National Laboratory

Person-Months Per Year Committed to the Project. Cal: 2 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

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Current and Pending Support

Investigator: Michael J. North

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

ITR: Agent-Based Systems for Monitoring, Analysis, Diagnosis, and Control

Source of Support: National Science Foundation Information Technology Research 2003

Total Award Amount: $2,851,158 Total Award Period Covered: 08/15/2003 – 08/14/2008 (w/1 year extension)

Location of Project: Illinois Institute of Technology and Argonne National Laboratory

Person-Months Per Year Committed to the Project. Cal: 0.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: AOC: Changing climate, innovative technology, and adaptive decision-making: implications for land use and land tenure in agricultural production systems

Source of Support: NSF Human and Social Dynamics 2007

Total Award Amount: $ Total Award Period Covered: 09/01/07 – 08/31/10

Location of Project: Argonne National Laboratory

Person-Months Per Year Committed to the Project. Cal: 0.5 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: An Agent-based Model of the U.S. Buildings Sector

Source of Support: Department of Energy

Total Award Amount: $1,500,000 Total Award Period Covered: 9/31/2009 – 12/31/2010

Location of Project: Argonne National Laboratory

Person-Months Per Year Committed to the Project. 4.0 Cal: 4.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Hierarchical Representation and Simulation of Modular Cellular Systems

Source of Support: National Science Foundation

Total Award Amount: $199,578 Total Award Period Covered: 9/1/2008 – 8/31/2011

Location of Project:

Person-Months Per Year Committed to the Project. 0.0 Cal: 0.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Various Proprietary and Official Use Only Projects

Source of Support: Various

Total Award Amount: $ Total Award Period Covered:

Location of Project: Argonne National Laboratory

Person-Months Per Year Committed to the Project. 6.0 Cal: 6.0 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Charlie Catlett

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Argonne National Laboratory CIO

Source of Support: Argonne National Laboratory Operations
Total Award Amount: $n/a Total Award Period Covered: n/a
Location of Project: Argonne National Laboratory
Person-Months Per Year Committed to the Project. Cal: 12.0 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: 1 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

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