The Virtual Grid Application Development Software (VGrADS) Project

Overview

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VGrADS Director
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http://vgrads.rice.edu/

VGrADS
Virtual Grid Application Development Software Project

The VGrADS Team

- **VGrADS is an NSF-funded Information Technology Research project**

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Dan Reed

RICE

Keith Cooper
Ken Kennedy
Charles Koelbel
Richard Tapia
Linda Torczon

Jack Dongarra

Carl Kesselman

Fran Berman
Andrew Chien
Henri Casanova

Rich Wolski

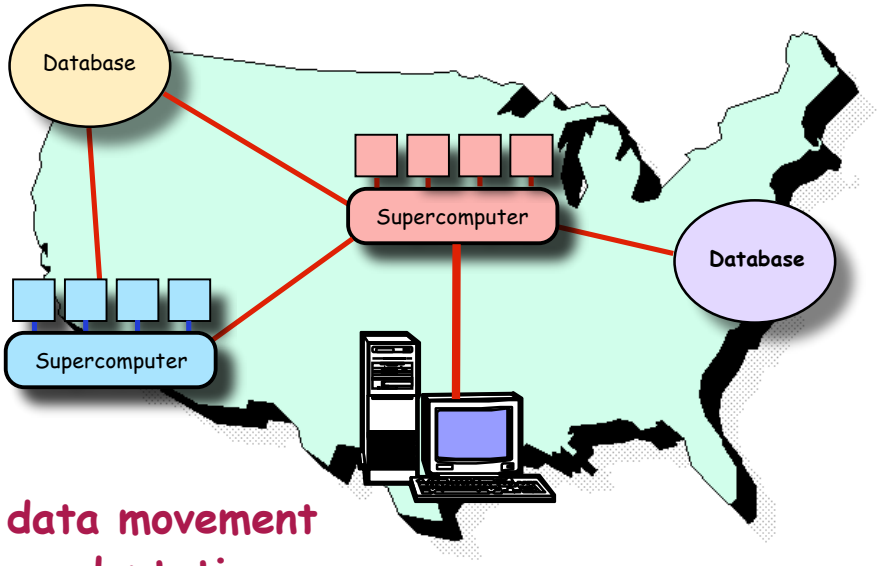
Lennart Johnsson

- **Plus many graduate students, postdocs, and technical staff!**

VGrADS
Virtual Grid Application Development Software Project

Vision: Global Distributed Problem Solving

- Where We Want To Be
  - Transparent Grid computing
    - Submit job
    - Find & schedule resources
    - Execute efficiently
- Where We Are
  - Low-level hand programming
  - Programmer must manage:
    - Heterogeneous resources
    - Scheduling of computation and data movement
    - Fault tolerance and performance adaptation



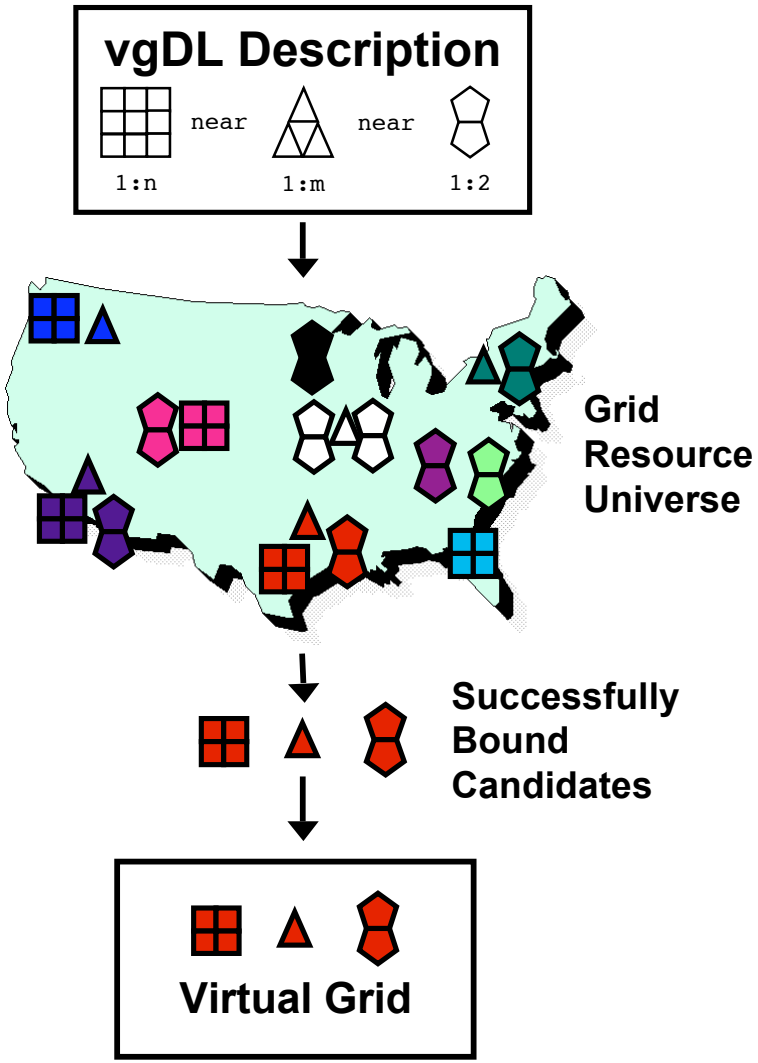
- What Do We Propose as A Solution?
  - Separate application development from resource management
    - Through an abstraction called the Virtual Grid
  - Provide tools to bridge the gap between conventional and Grid computation
    - Scheduling, resource management, distributed launch, simple programming models, fault tolerance, grid economies

VGrADS Big Ideas

- Virtualization of Resources
  - Application specifies required resources in Virtual Grid Definition language (vgDL)
    - Give me a loose bag of 1000 processors, with 1 Gb memory per processor, with the fastest possible processors
    - Give me a tight bag of as many Opterons as possible
  - Virtual Grid Execution System (vgES) produces specific virtual grid matching specification
  - Avoids need for scheduling against the entire space of global resources
- Generic In-Advance Scheduling of Application Workflows
  - Application includes performance models for all workflow nodes
    - Performance models automatically constructed
  - Software schedules applications onto virtual Grid, minimizing total makespan
    - Including both computation and data movement times

Virtual Grids (VGs)

- A Virtual Grid (VG) takes
  - Shared heterogeneous resources
  - Scalable information service
- and provides
  - An hierarchy of application-defined aggregations (e.g. ClusterOf) with constraints (e.g. processor type) and rankings
- Virtual Grid Execution System (vgES) implements VG
  - VG Definition Language (vgDL)
  - VG Find And Bind (vgFAB)
  - VG Monitor (vgMON)
  - VG Application Launch (VgLAUNCH+DVCW)
  - VG Resource Info (vgAgent)



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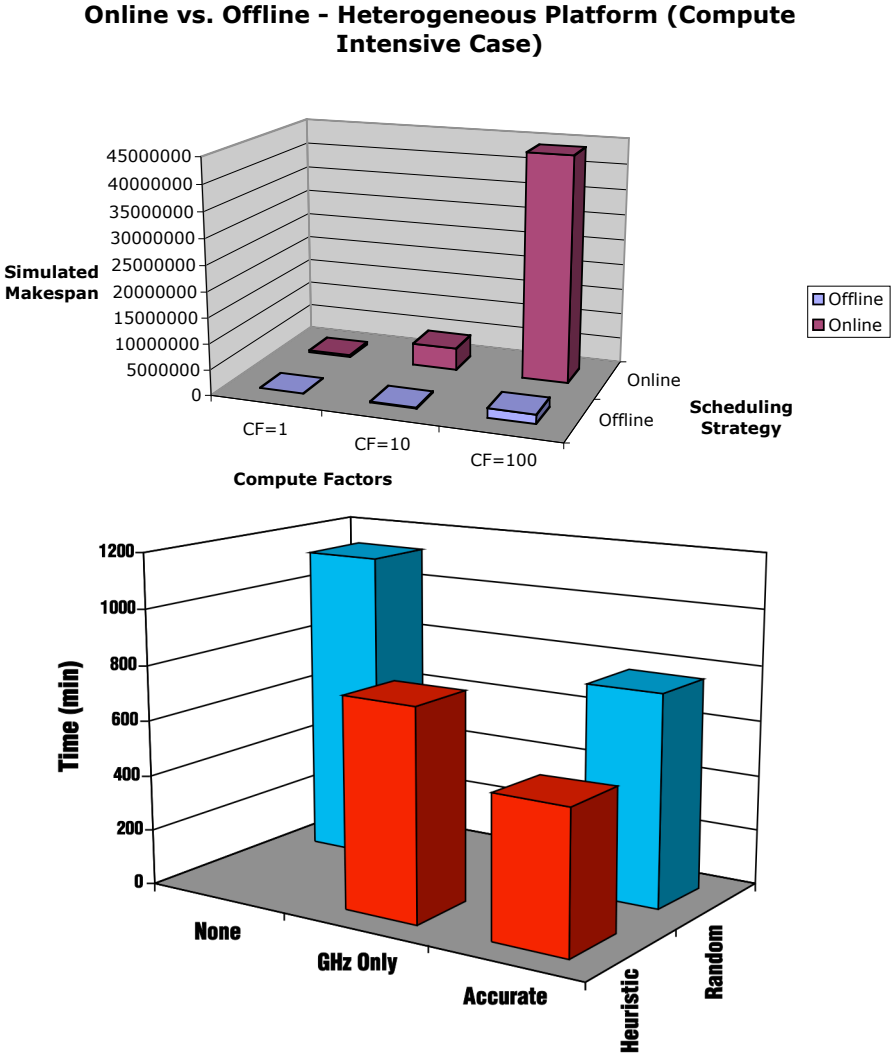
VGrADS Tool Research

- Scheduling of workflow computations
  - Off-line look-ahead scheduling dramatically improves in total time
  - Accurate performance models significantly affect quality of scheduling
  - Batch queue behavior can be predicted accurately enough for scheduling decisions
- Fault tolerance
  - Diskless checkpointing for linear algebra computations (application-specific)
  - Temporal reasoning for fault prediction
  - Optimal checkpoint frequency for iterative applications



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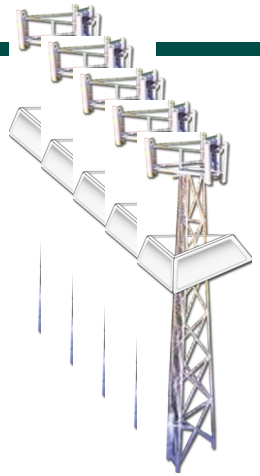
VGrADS: What's New

- SC'04
  - Scheduling EMAN application
    - Aware of performance models
- SC'05
  - Find and Bind (FAB) for resource selection
  - Scheduling EMAN application
    - Aware of batch queue predictions (and performance models)
- SC'06
  - Virtual Grid "slots" for resource availability
    - Start time + duration
    - Uses advance reservations where available
    - Uses batch queue prediction elsewhere
  - Scheduling LEAD application
    - Aware of reservations and batch queue predictions (and performance models)

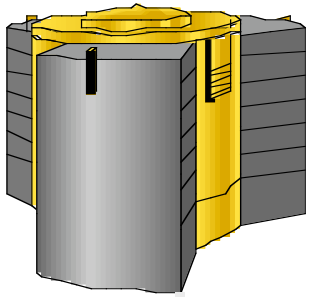
The LEAD Vision: A Paradigm Shift



DYNAMIC OBSERVATIONS

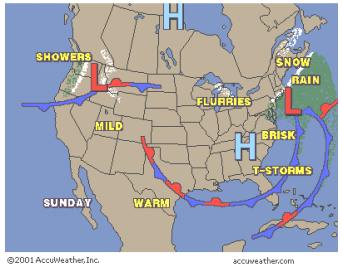
Analysis/Assimilation

Quality Control
Retrieval of Unobserved Quantities
Creation of Gridded Fields



Prediction/Detection

PCs to Teraflop Systems



Product Generation, Display, Dissemination

Models and Algorithms Driving Sensors

End Users

NWS
Private Companies
Students

The CS challenge: Build cyberinfrastructure services that provide adaptability, scalability, availability, useability, and real-time response.

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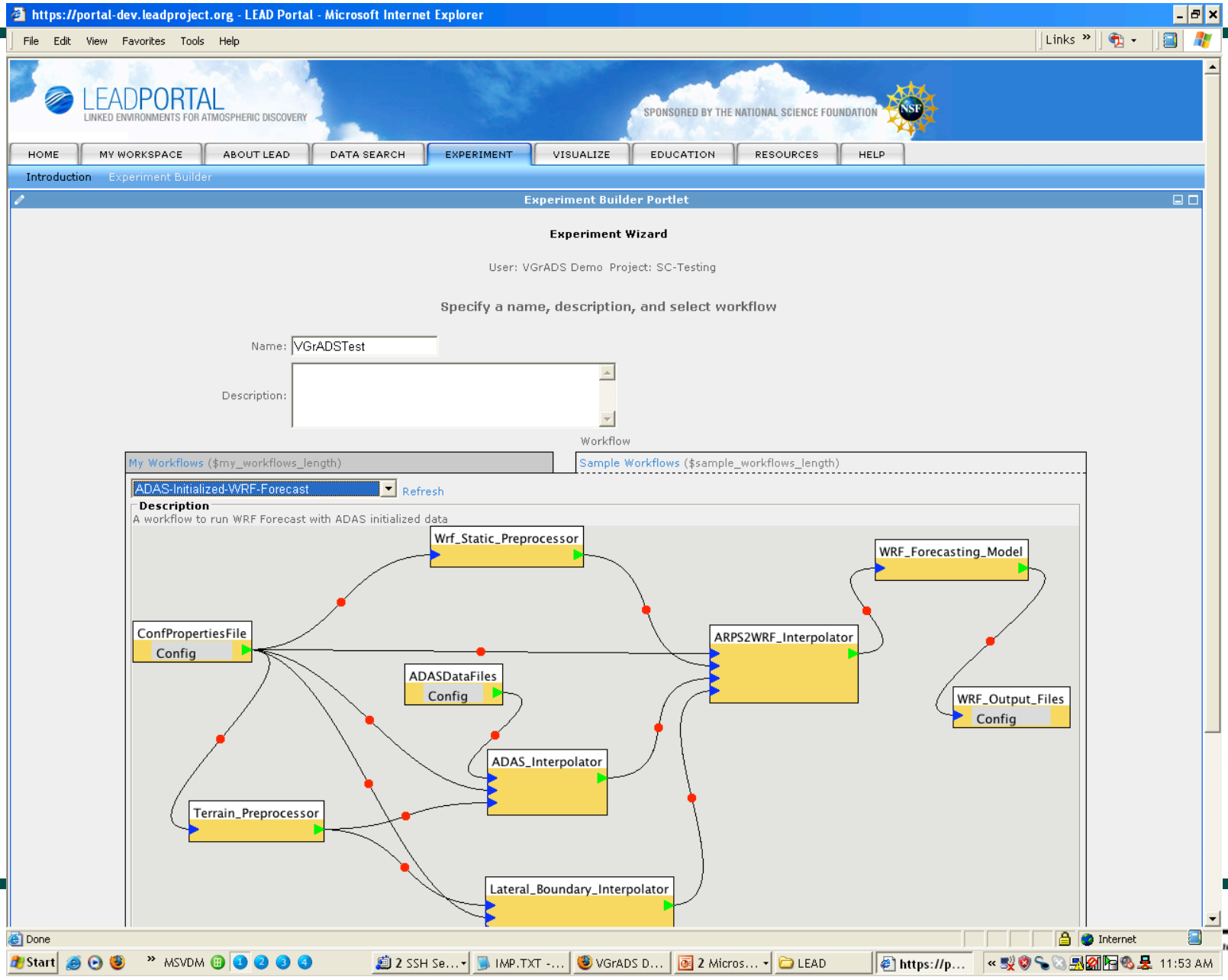
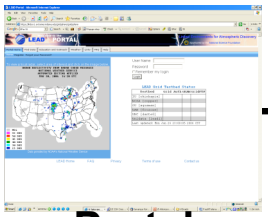
LEAD Portal – Experiment Builder



VGrADS Application Collaboration



Portal

Workflow

Workflow Configuration Service

DAG + Constraint

Annotated DAG

Schedule toward a workflow deadline

Performance Model

LEAD Resource Broker

Virtual Grid Execution System

Create Services

App. Factory

Launch Services

LEAD BPEL Workflow Engine

Application Service (per task)

Run job

Job Notification

Scheduler Mapper

Run workflow one step at a time

Workflow and File Status

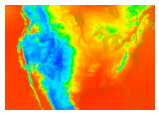
myLEAD

(subscribes to messages from the broker and knows what magic to do with input/output files and talks to RLS/DRS

Event Broker

Batch Queue Prediction

Adaptation



LEAD

Linked Environments for Atmospheric Discovery

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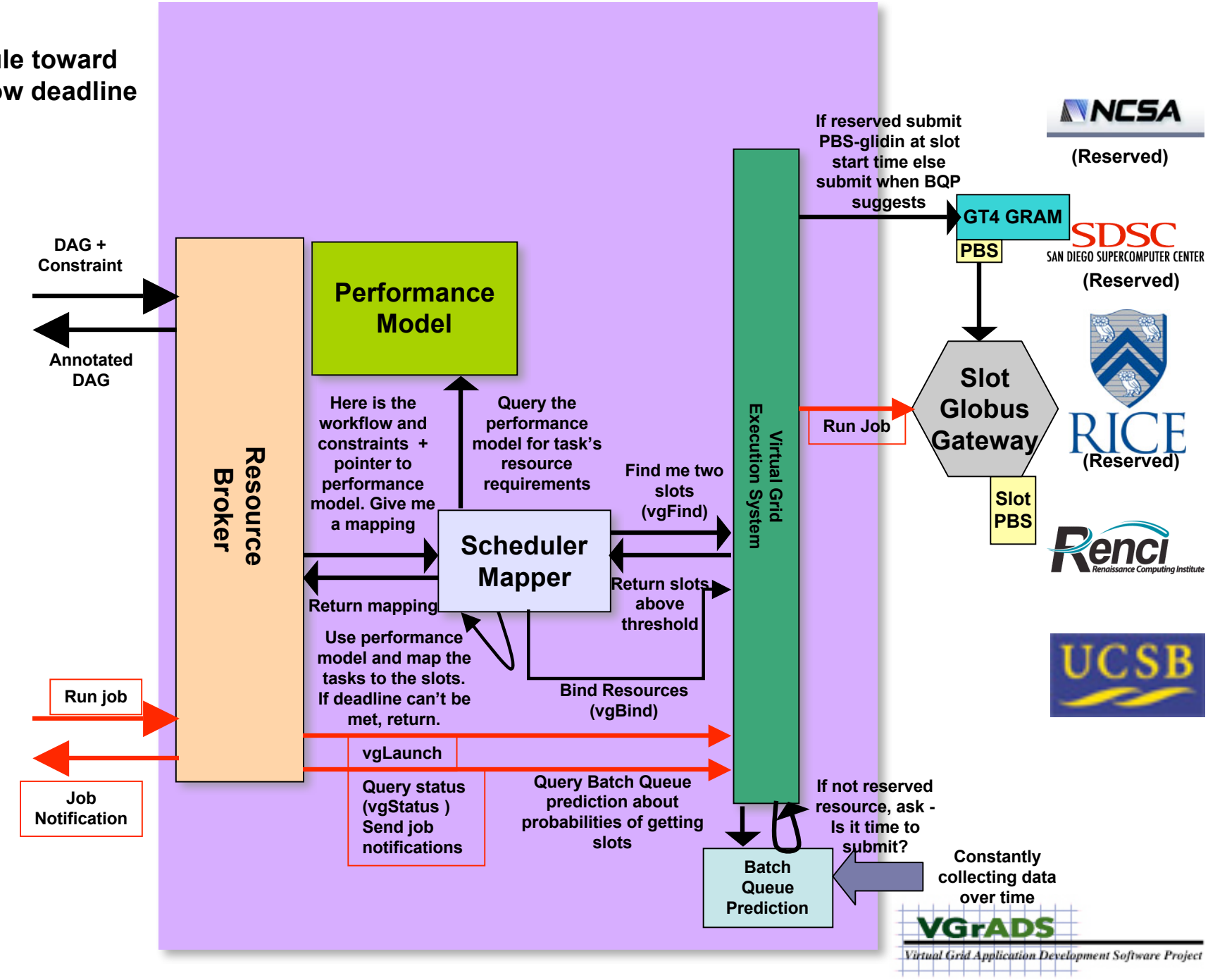
Schedule toward a workflow deadline



Some Future Challenges

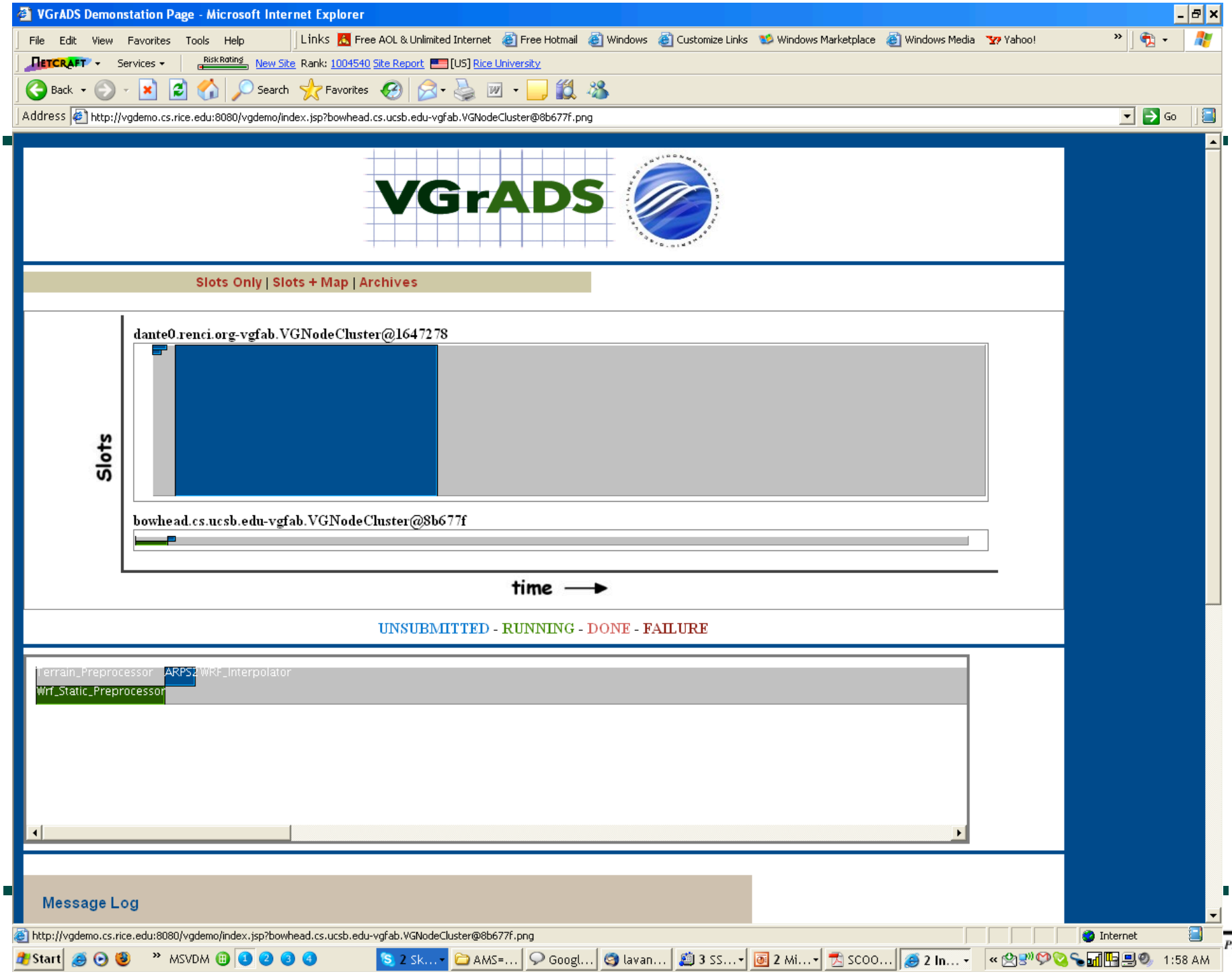
- Parallelism in the LEAD workflow manager
  - Parallel steps in different slots or within one slot
- Accurate Slot Requests Through Preliminary Scheduling
  - Minimization of wasted slot time
    - Accurate scheduling, better queue prediction
    - Dynamic adaptation of slot reservations
  - Requires some form of resource equivalence:
    - For step B, I need the equivalent of 200 Opterons, where 1 Opteron = 3 Itanium = 1.3 Power 5 (from perf models)
- Increased Schedule Robustness
  - Minimizing variation along the critical path
- Scheduling to Minimize Cost
  - In the presence of cycle exchange rates
  - Get the minimum-cost resources to solve the problem by the given deadline

VGrADS at SC'06

- Booth Talks and Demos
  - Tuesday, noon - GCAS booth (1825)
  - Tuesday, 2:30 - USC booth (2246) [Not live]
  - Wednesday, 1:00 - SDSC booth (1915)
  - Thursday, 10:30 - RENCI booth (1143)
  - What you'll see
    - LEAD running on several clusters
    - Scheduler mapping LEAD components to slots
    - vgES managing slots via batch queue prediction
- Papers
  - "Improving Grid Resource Allocation via Integrated Selection and Binding" by Kee, et al. - Wednesday, 10:30
  - "Toward a Doctrine of Containtment: Grid Hosting with Adaptive Resource Control" by Ramakrishnan, et al. - Wednesday, 11:00
  - "Evaluation of a Workflow Scheduler Using Integrated Performance Modeling and Batch Queue Wait Time Prediction" by Nurmi, et al. - Thursday, 2:00

Launching from the LEAD Portal

- Work in Progress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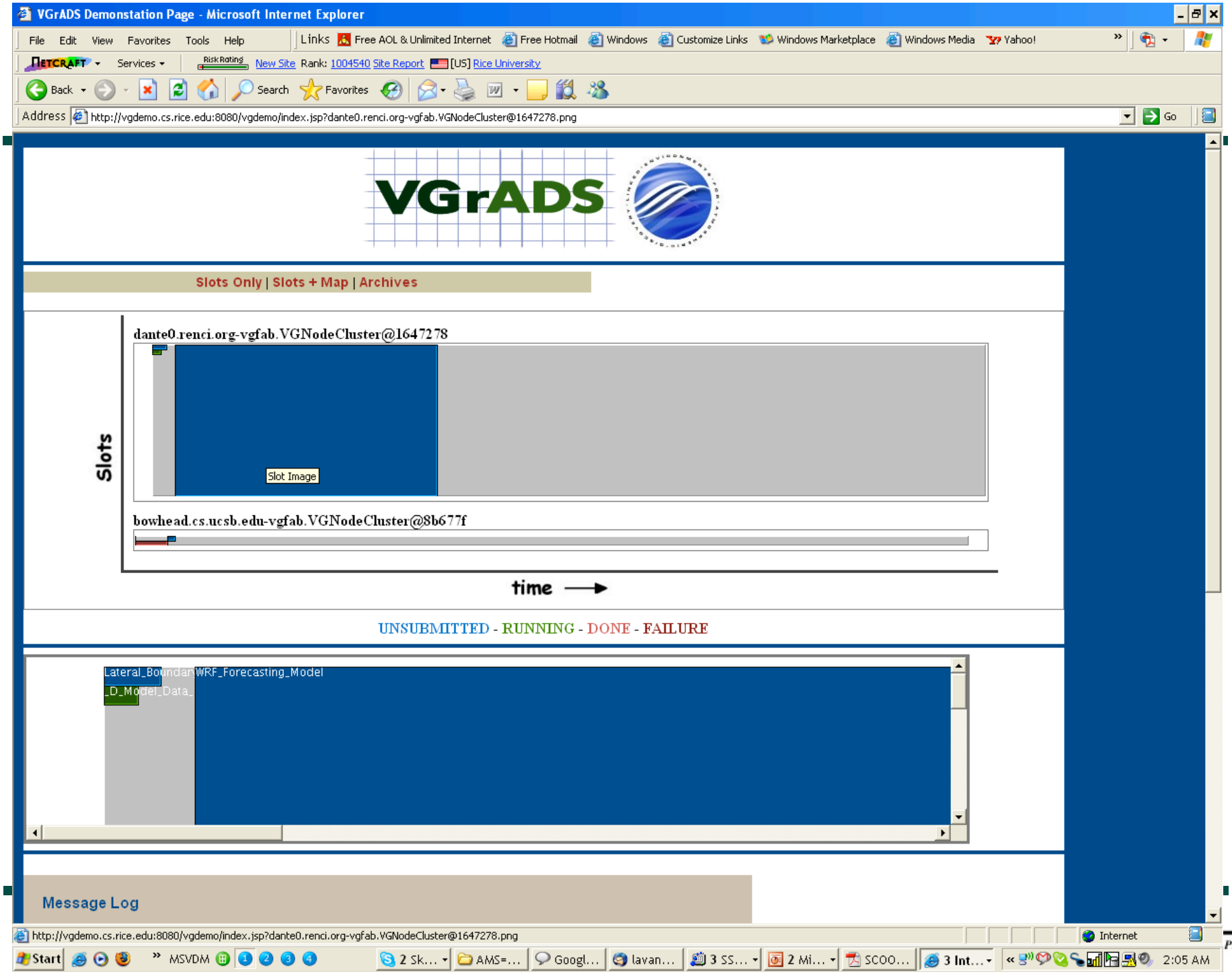
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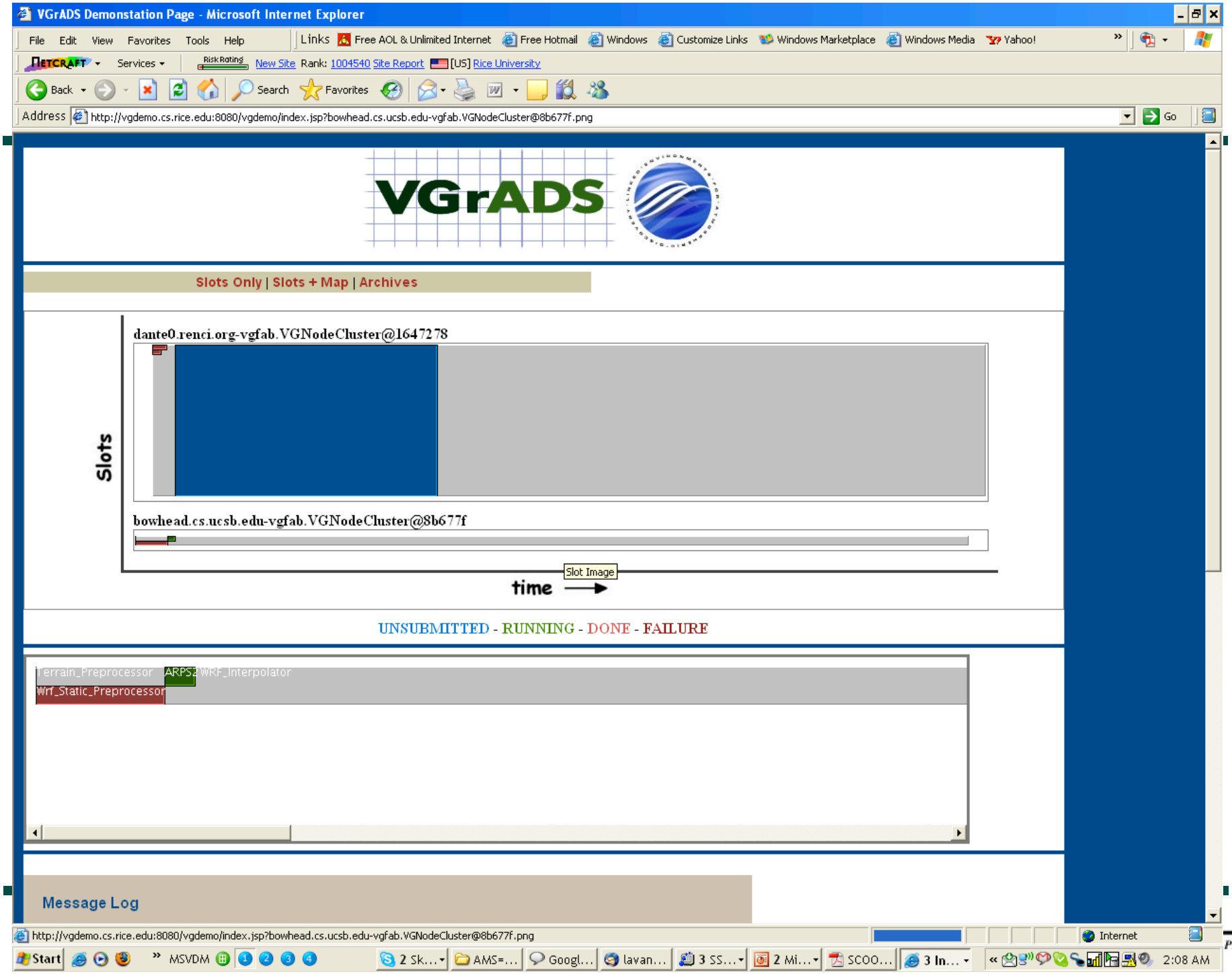
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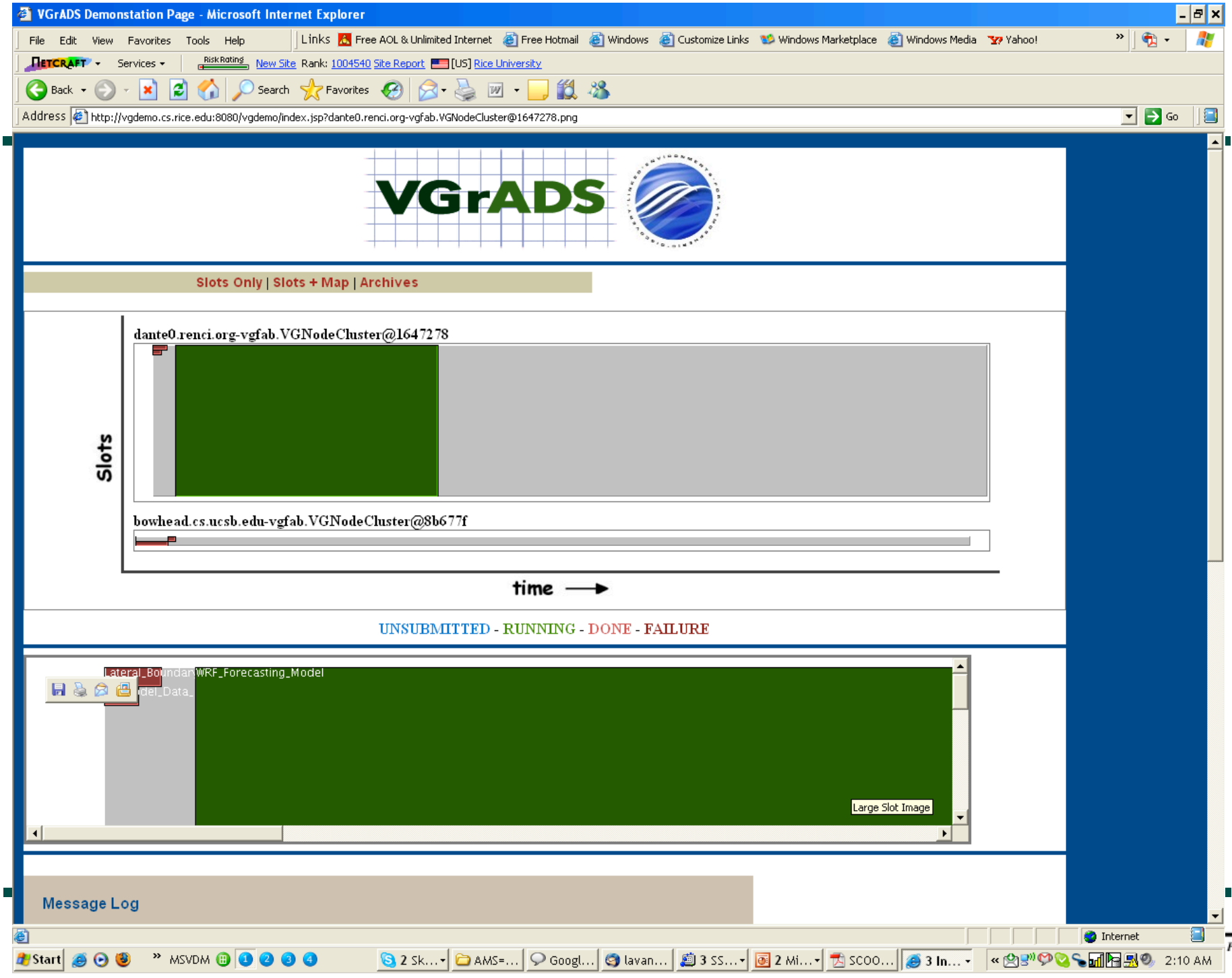
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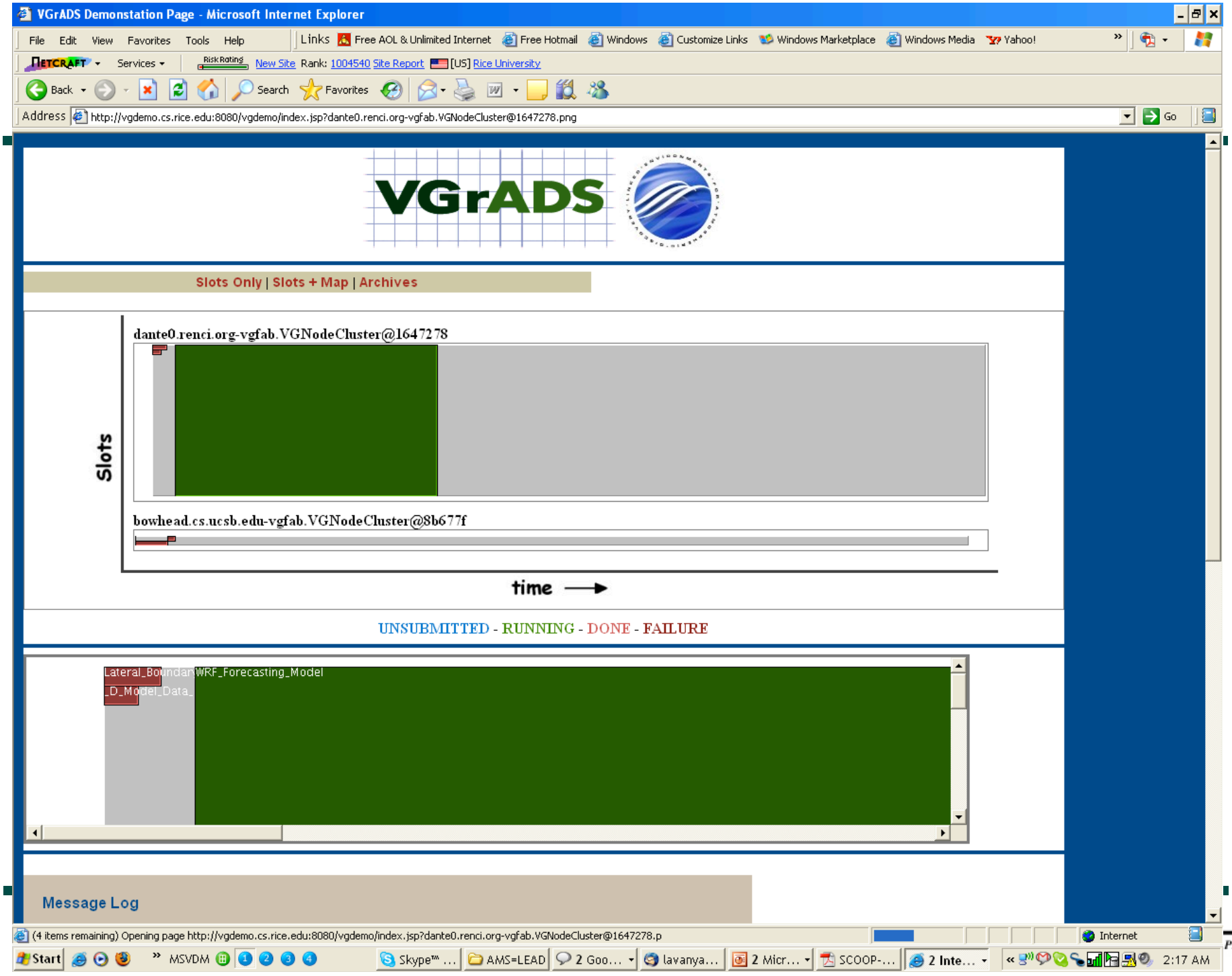
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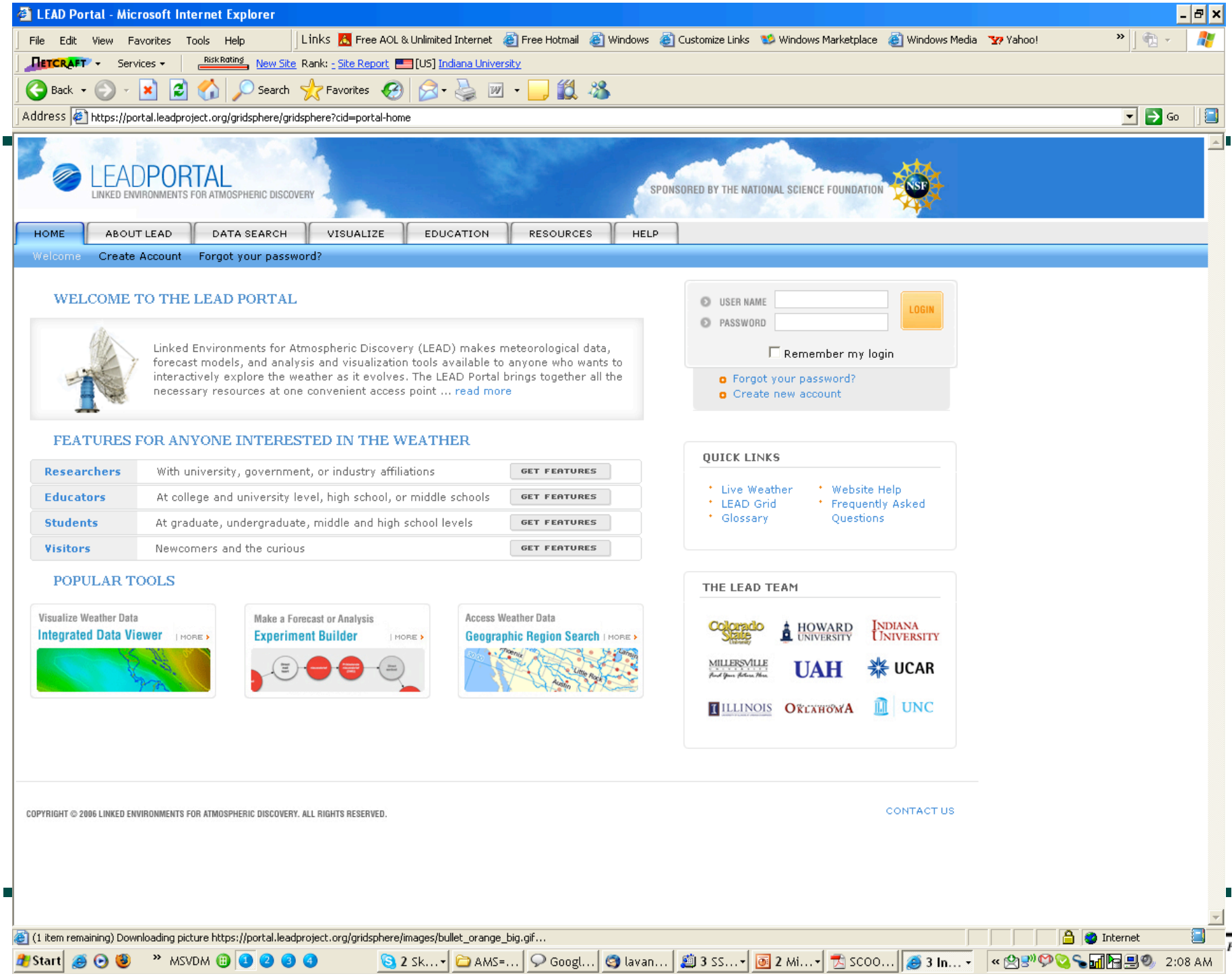
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Make a Forecast or Analysis
Experiment Builder | MORE
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Geographic Region Search | MORE
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Remember my login
Forgot your password?
Create new account
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Live Weather
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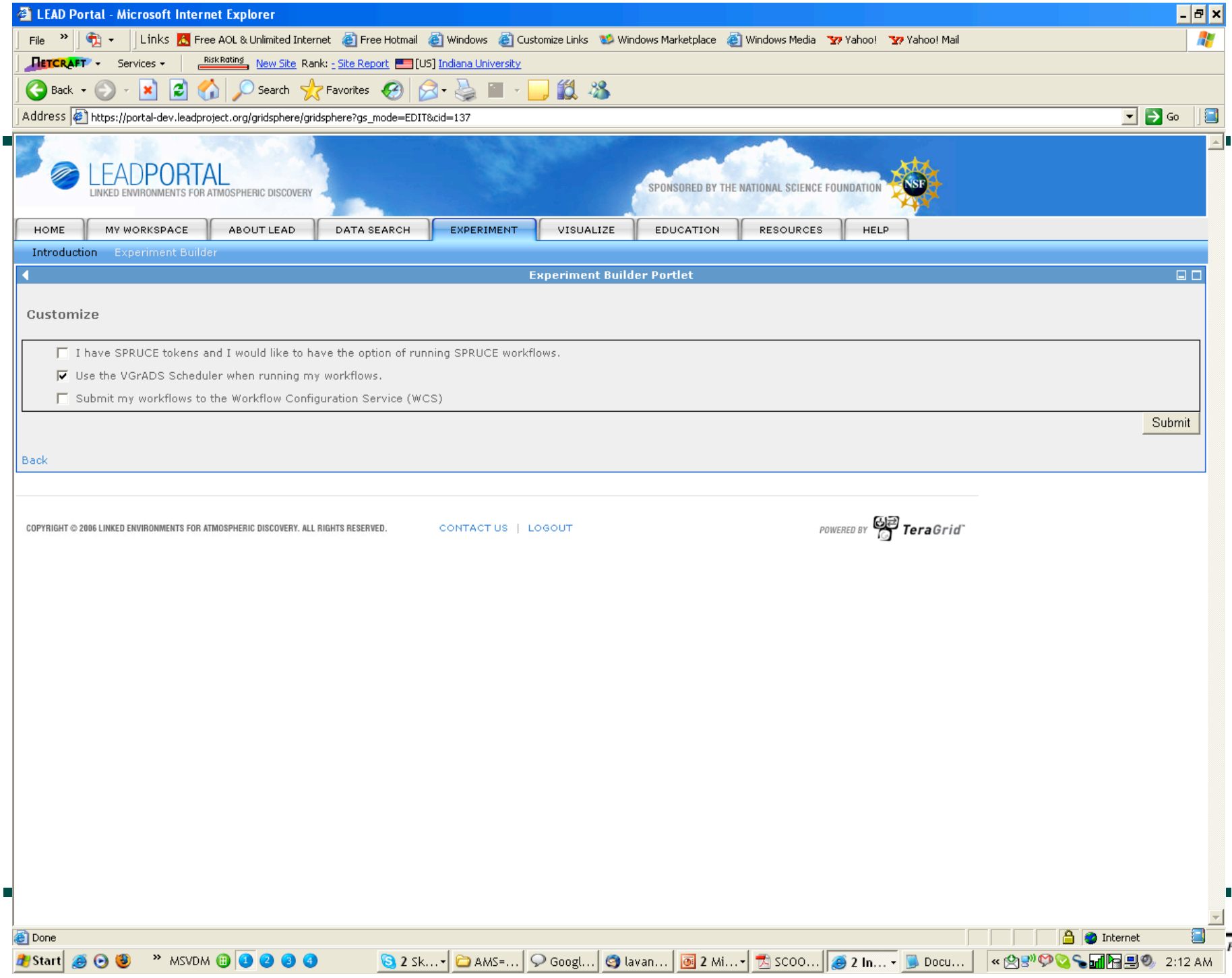
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Introduction
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Experiment Builder Portlet
Customize
I have SPRUCE tokens and I would like to have the option of running SPRUCE workflows.
Use the VGrADS Scheduler when running my workflows.
Submit my workflows to the Workflow Configuration Service (WCS)
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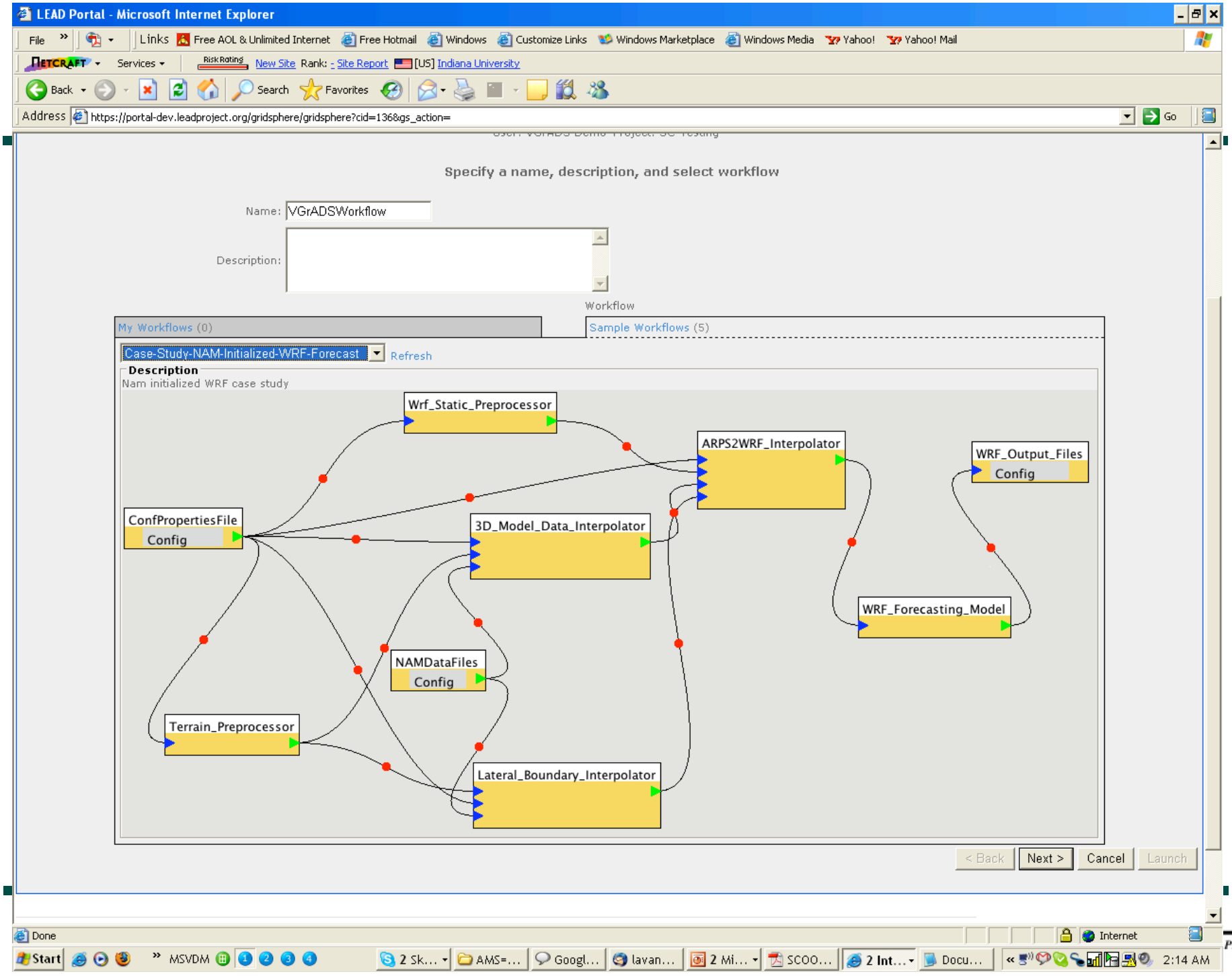
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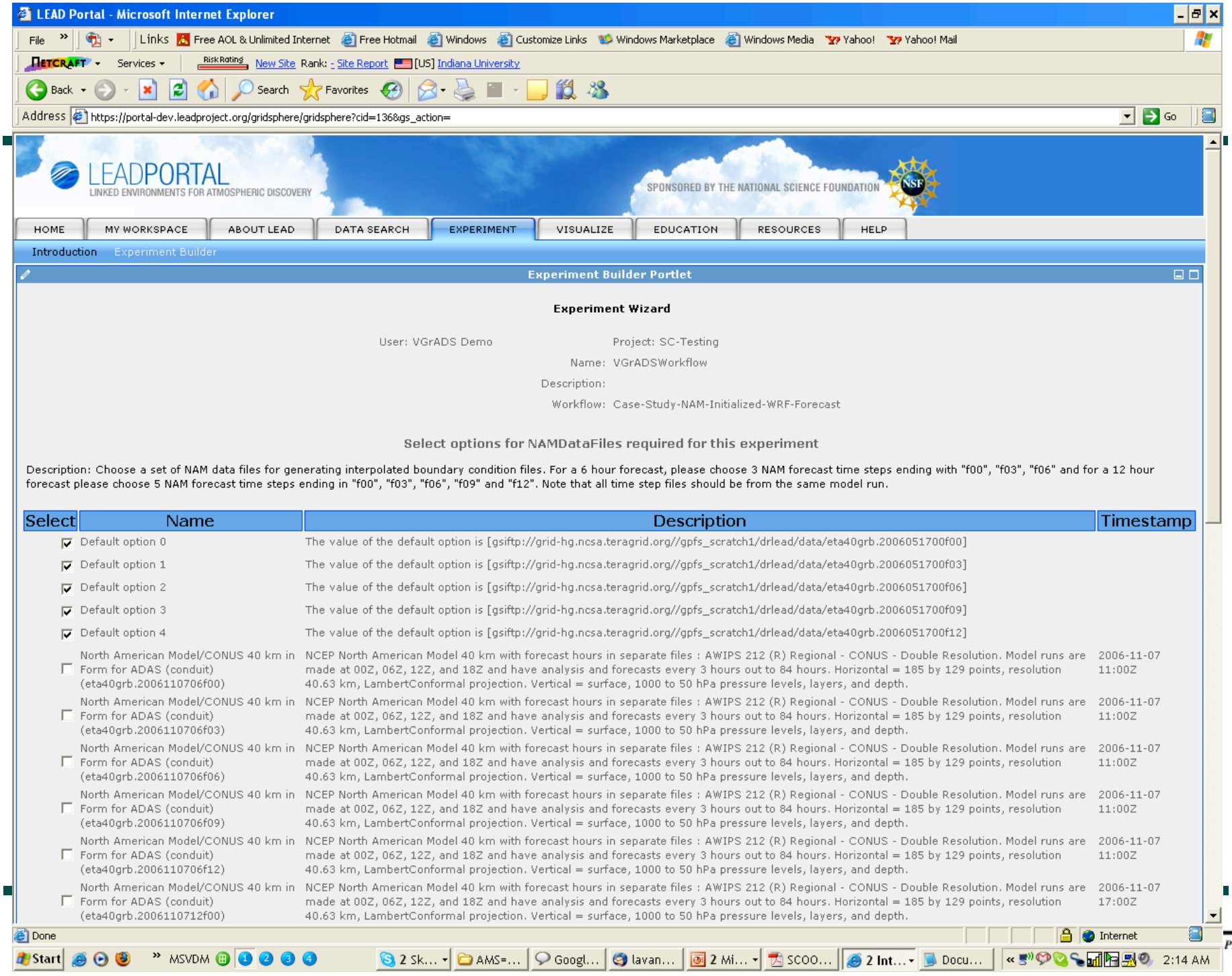
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Experiment Builder Portlet
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User: VGrADS Demo
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Name: VGrADSWorkflow
Description:
Workflow: Case-Study-NAM-Initialized-WRF-Forecast
Select options for NAMDataFiles required for this experiment
Description: Choose a set of NAM data files for generating interpolated boundary condition files. For a 6 hour forecast, please choose 3 NAM forecast time steps ending with "f00", "f03", "f06" and for a 12 hour forecast please choose 5 NAM forecast time steps ending in "f00", "f03", "f06", "f09" and "f12". Note that all time step files should be from the same model run.
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North American Model/CONUS 40 km in Form for ADAS (conduit) (eta40grb.2006110706f00)
NCEP North American Model 40 km with forecast hours in separate files : AWIPS 212 (R) Regional - CONUS - Double Resolution. Model runs are made at 00Z, 06Z, 12Z, and 18Z and have analysis and forecasts every 3 hours out to 84 hours. Horizontal = 185 by 129 points, resolution 40.63 km, LambertConformal projection. Vertical = surface, 1000 to 50 hPa pressure levels, layers, and depth.
2006-11-07 11:00Z
North American Model/CONUS 40 km in Form for ADAS (conduit) (eta40grb.2006110706f03)
NCEP North American Model 40 km with forecast hours in separate files : AWIPS 212 (R) Regional - CONUS - Double Resolution. Model runs are made at 00Z, 06Z, 12Z, and 18Z and have analysis and forecasts every 3 hours out to 84 hours. Horizontal = 185 by 129 points, resolution 40.63 km, LambertConformal projection. Vertical = surface, 1000 to 50 hPa pressure levels, layers, and depth.
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NCEP North American Model 40 km with forecast hours in separate files : AWIPS 212 (R) Regional - CONUS - Double Resolution. Model runs are made at 00Z, 06Z, 12Z, and 18Z and have analysis and forecasts every 3 hours out to 84 hours. Horizontal = 185 by 129 points, resolution 40.63 km, LambertConformal projection. Vertical = surface, 1000 to 50 hPa pressure levels, layers, and depth.
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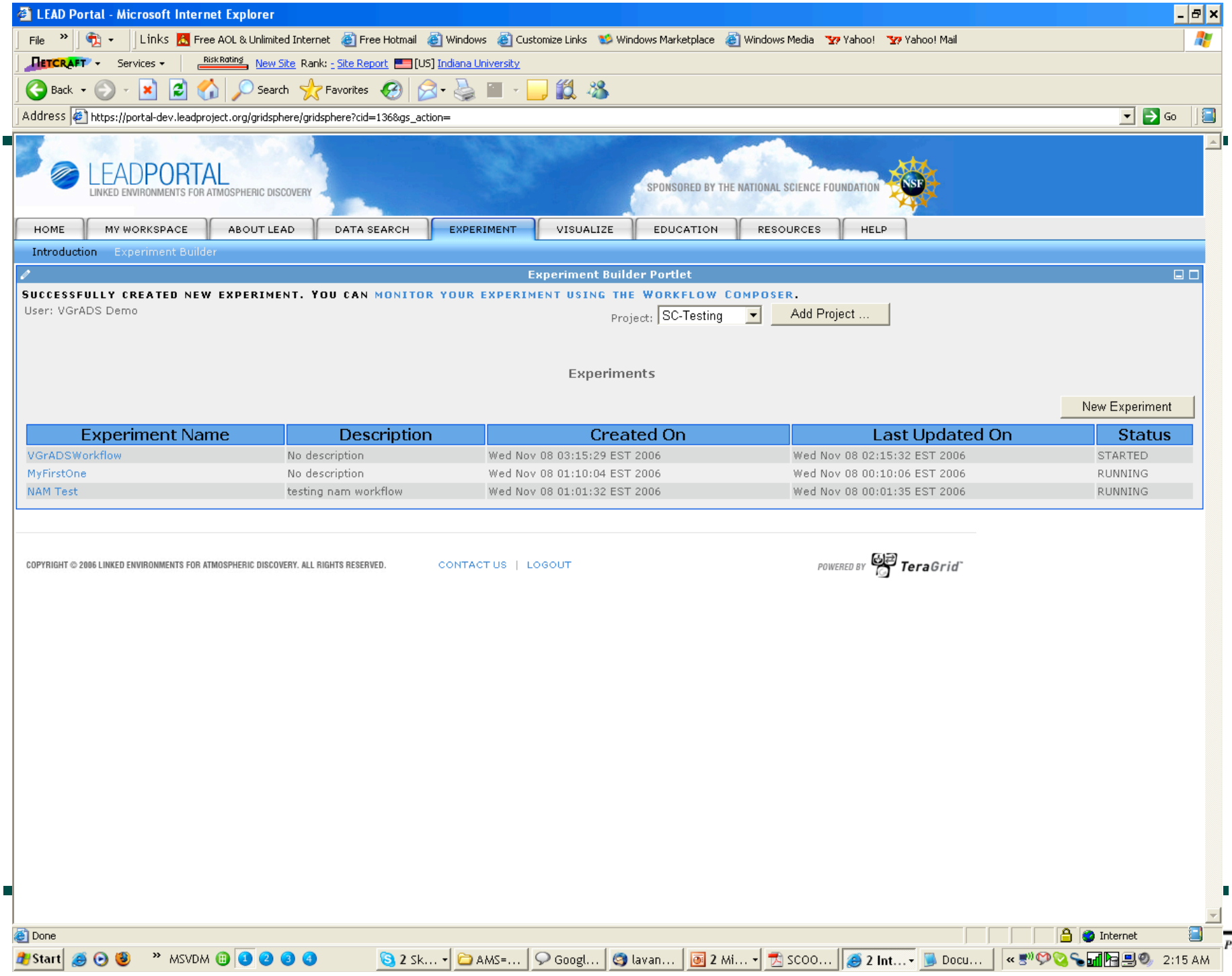
NCEP North American Model 40 km with forecast hours in separate files : AWIPS 212 (R) Regional - CONUS - Double Resolution. Model runs are made at 00Z, 06Z, 12Z, and 18Z and have analysis and forecasts every 3 hours out to 84 hours. Horizontal = 185 by 129 points, resolution 40.63 km, LambertConformal projection. Vertical = surface, 1000 to 50 hPa pressure levels, layers, and depth.
2006-11-07 11:00Z
North American Model/CONUS 40 km in Form for ADAS (conduit) (eta40grb.2006110712f00)
NCEP North American Model 40 km with forecast hours in separate files : AWIPS 212 (R) Regional - CONUS - Double Resolution. Model runs are made at 00Z, 06Z, 12Z, and 18Z and have analysis and forecasts every 3 hours out to 84 hours. Horizontal = 185 by 129 points, resolution 40.63 km, LambertConformal projection. Vertical = surface, 1000 to 50 hPa pressure levels, layers, and depth.
2006-11-07 17:00Z
Done
Internet
Start
2:14 AM


LEAD Portal - Microsoft Internet Explorer
https://portal-dev.leadproject.org/gridsphere/gridsphere?cid=136&gs_action=
LEADPORTAL
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HOME
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RESOURCES
HELP
Introduction
Experiment Builder
Experiment Builder Portlet
SUCCESSFULLY CREATED NEW EXPERIMENT. YOU CAN MONITOR YOUR EXPERIMENT USING THE WORKFLOW COMPOSER.
User: VGrADS Demo
Project: SC-Testing
Add Project ...
Experiments
New Experiment
Experiment Name
Description
Created On
Last Updated On
Status
VGrADSWorkflow
No description
Wed Nov 08 03:15:29 EST 2006
Wed Nov 08 02:15:32 EST 2006
STARTED
MyFirstOne
No description
Wed Nov 08 01:10:04 EST 2006
Wed Nov 08 00:10:06 EST 2006
RUNNING
NAM Test
testing nam workflow
Wed Nov 08 01:01:32 EST 2006
Wed Nov 08 00:01:35 EST 2006
RUNNING
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POWERED BY TeraGrid
Done
Internet
Start
2:15 AM

Scheduling with Batch Queues

- Last Year: VGrADS supported scheduling using estimated batch queue waiting times
  - Batch queue estimates are factored into communication time
    - E.g., the delay in moving from one resource to another is data movement time + estimated batch queue waiting time
  - Unfortunately, estimates can have large standard deviations
- This Year: limiting variability through two strategies:
  - Resource reservations: partially supported on the TeraGrid and other schedulers
  - In advance queue insertion: submit jobs before data arrives based on estimates
    - Can be used to simulate advance reservations
- Exploiting this requires a preliminary schedule indicating when the resources are needed
  - Problem: how to build an accurate schedule when exact resource types are unknown

Preliminary Scheduling Solution

- Use performance models to specify alternative resources
  - For step B, I need the equivalent of 200 Opterons, where 1 Opteron = 3 Itanium = 1.3 Power 5
    - Equivalence from performance model
- This permits an accurate preliminary schedule because the performance model standardizes the time for each step
  - Scheduling can then proceed with accurate estimates of when each resource collection will be needed
  - Makes advance reservations more accurate
    - Data will arrive neither too early or too late
- It may provide a mixture to meet the computational requirements, if the specification permits
  - Give me a loose bag of tight bags containing the equivalent of 200 Opterons, minimize the number of tight bags and the overall cost
    - Solution might be 150 Opterons in one cluster and 150 Itaniums in another