Fault Tolerance and Recovery of Scientific Workflows on Computational Grids

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Anirban Mandal
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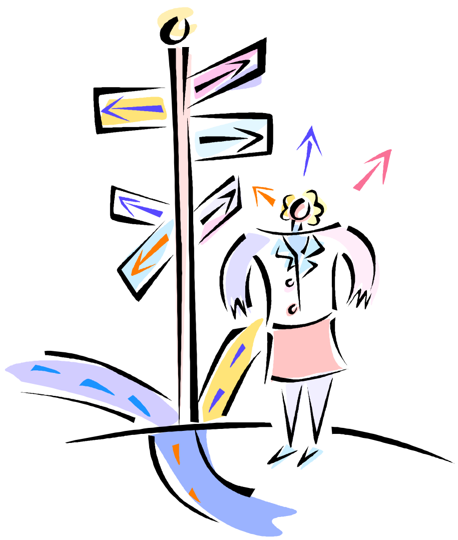
Resilience'08, May 22, 2008

Presentation Outline

- **Motivation and rationale**
- **Fault tolerance and recovery service**
- **Algorithms**
  - **migration, over-provisioning**
- **Evaluation with LEAD**
- **Conclusion**



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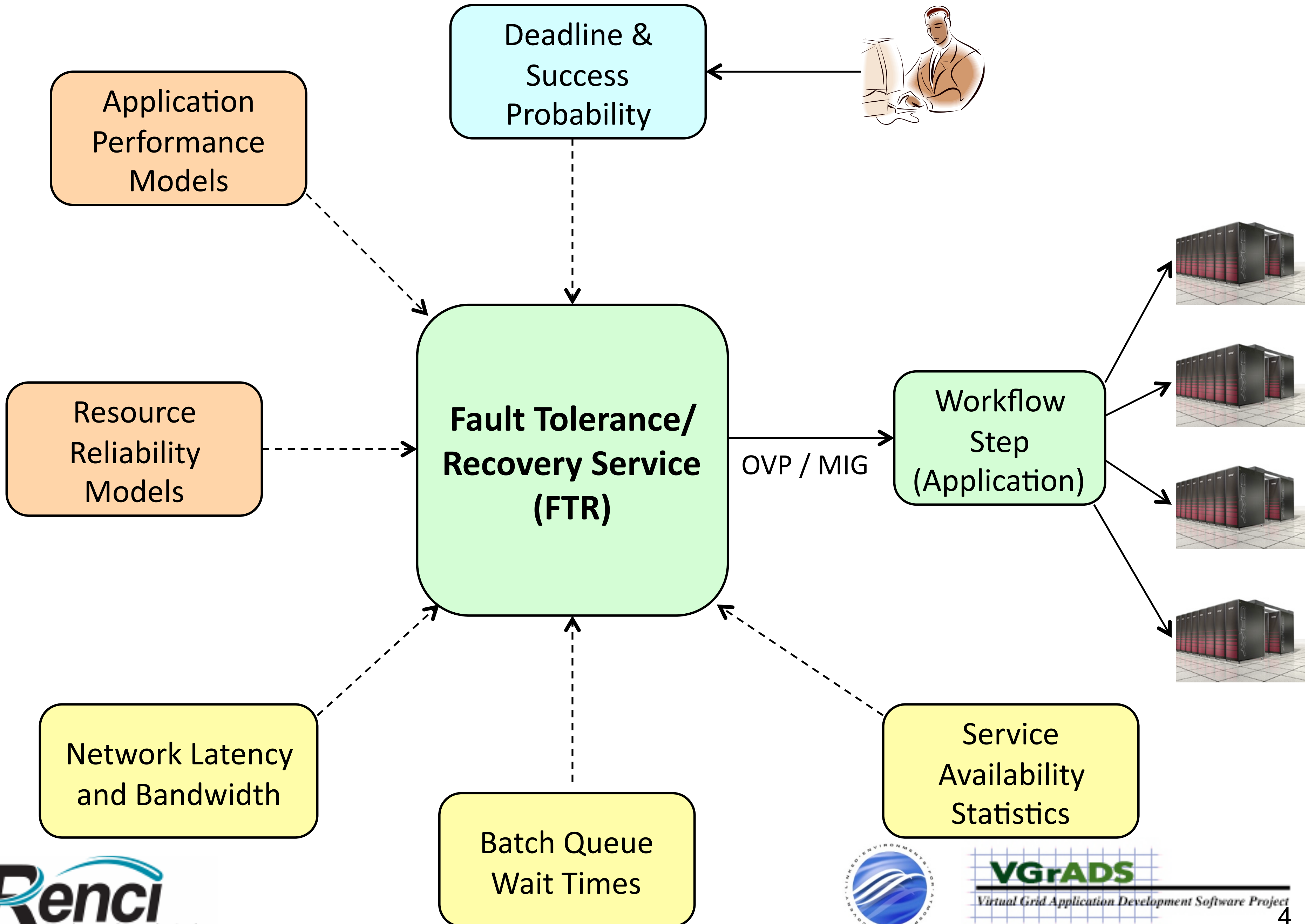
Motivation

- **Reliability and performance are related**
  - **failure is the limiting case of poor performance**
  - **both involve measures of behavior over time**
- **Large, complex workflows are sensitive to failures**
  - **faults are the norm, rather than exceptions**
    - distributed systems, services and resources
  - **completion "guarantees" are problematic**
    - workflow completion is probabilistic in the presence of faults
- **Many time-critical workflows are deadline driven**
  - **severe weather events, disaster response, …**



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FTR Service

- Resource models
  - MDS for static resource characteristics
  - NWS for network latency and bandwidth between resources
  - QBETS for batch queue wait time prediction on resources
  - simple reliability models
- Application models
  - based on simple parametric historical performance models
- Deadline of workflow steps
- Success probability
  - expected probabilistic completion guarantee
- Grid services' availability
  - core middleware services like WS-GRAM, GridFTP

FTR Algorithms

- **Notation**

  p_i : failure probability of resource i (eg. 1 hr. failure probability)

  h_i : expected execution cost of application on resource i
    - expected queue wait time
    - expected computation time
    - expected communication time

  x : required success probability

  d : required deadline

  m_i : failure probability of application (based on reliability model)

- **Resource i represents (queue, #nodes) combinations**
- **Use a simple reliability model**
  - **assumption : resource failures are independent over time**
  - **resource failures follow a binomial distribution**

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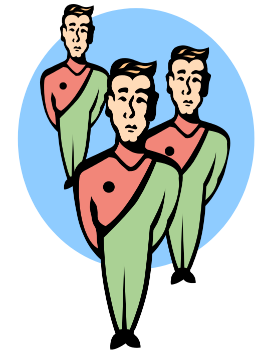
Over Provisioning



- **Find**
  - **degree and resources for over-provisioning**
- **Number of application copies**
  - **meet a deadline *d* with a success probability *x***
- **Solve the following optimization problem**

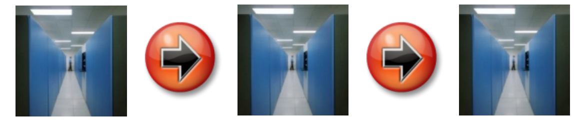
For given *[1..M]* resources, find a partition $P = \{s_1, s_2 \ldots s_n\}$ of *[1..M]* such that

$$1 - m_{s1} * m_{s2} * \ldots m_{sn} \geq x \;\land\; |P| \text{ is minimum} \land \max \{h_{s1} \ldots h_{sn}\} \leq d$$

Probability of failure

Minimum number of resources meeting deadline

Migration



- **Find the best migration path**
  - **Best resource chain**
- **Solve the following optimization problem**

For given *[1..M]* resources, find a partition $P = \{s_1, s_2 \ldots s_n\}$ such that

$\mathbf{1 - m_{s1} * m_{s2} * \ldots m_{sn} \geq x \ \wedge \ |P|}$ **is minimum** $\wedge$ **sum**$\mathbf{(h_{s1} + \ldots h_{sn}) \leq d}$,

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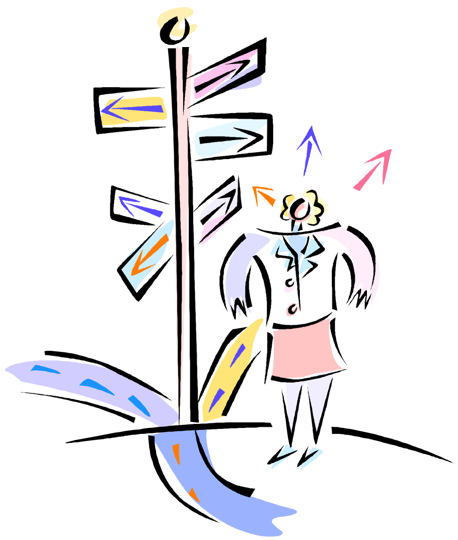

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LEAD – Linked Environment and Atmospheric Discovery

- **Integrated scalable framework for dynamic and adaptive meso-scale weather prediction**
  - computations continually steered by new weather data
  - responds to decision-driven inputs from users
  - steers remote observing technologies to optimize data collection for problem at hand
  - consists of analysis, visualization and data-mining tools
- **Framework consists of**
  - Teragrid resources at NCSA, UC and IU
  - weather data repositories (static and dynamic)
  - web portal for user interaction
  - http://portal.leadproject.org

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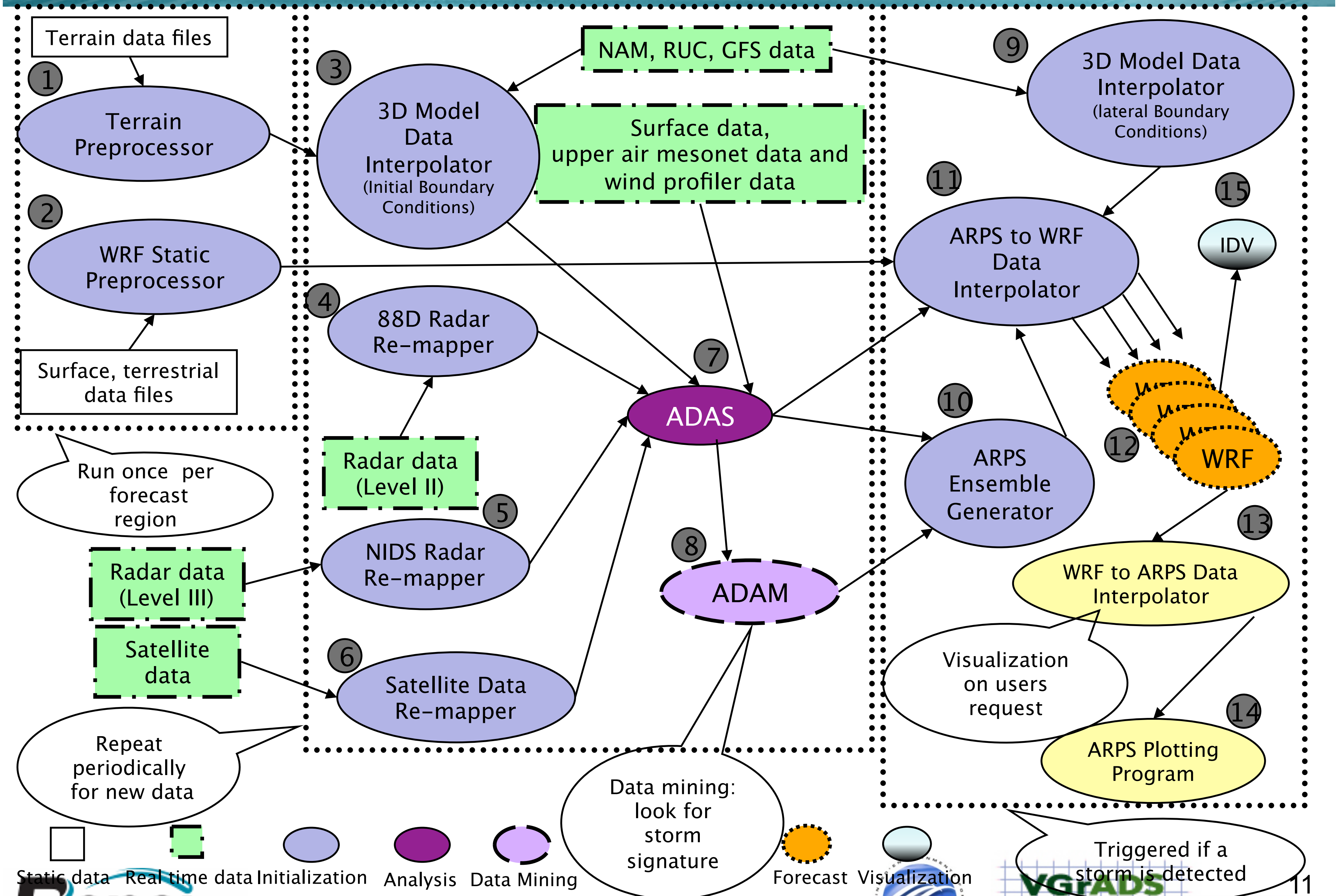
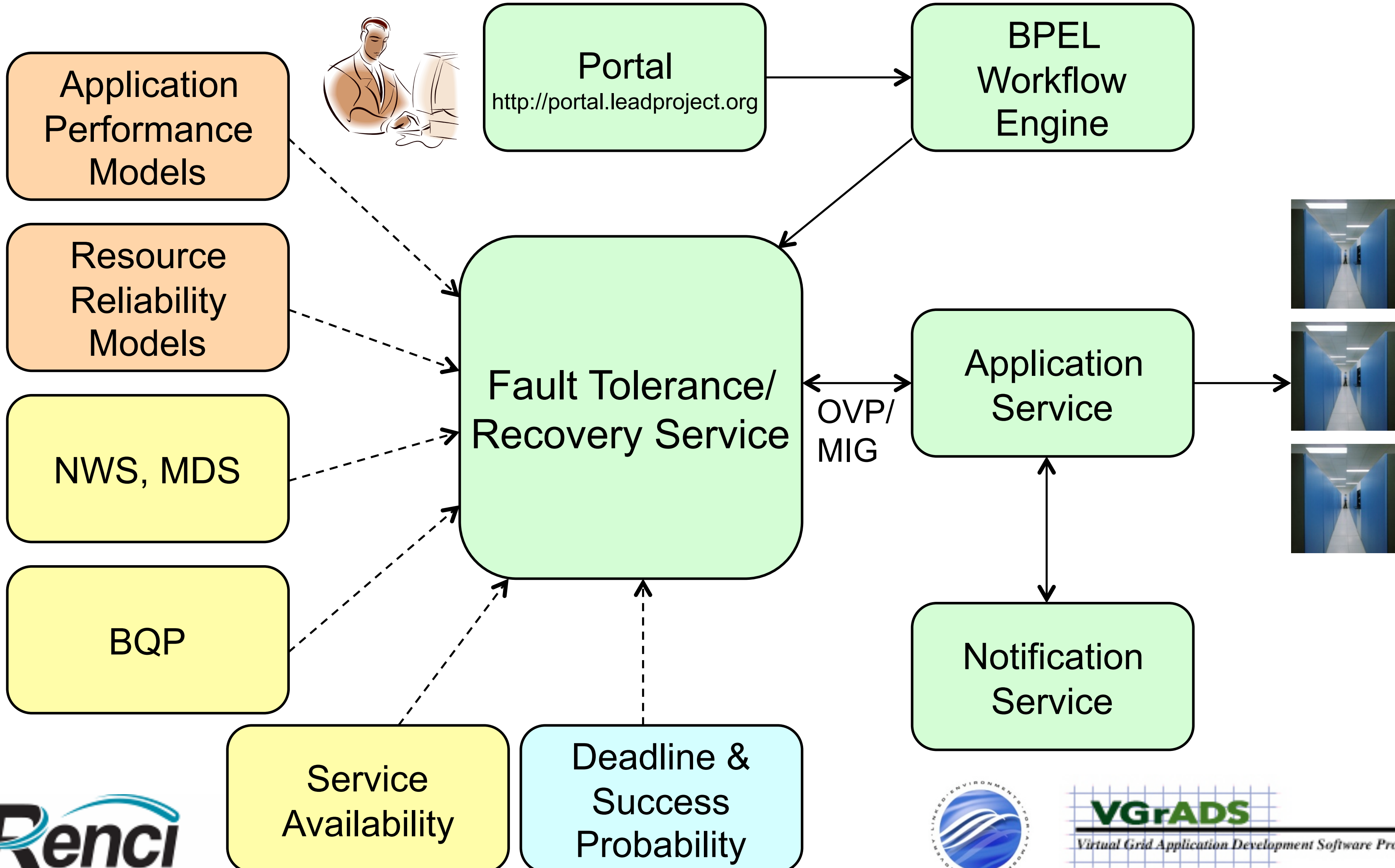
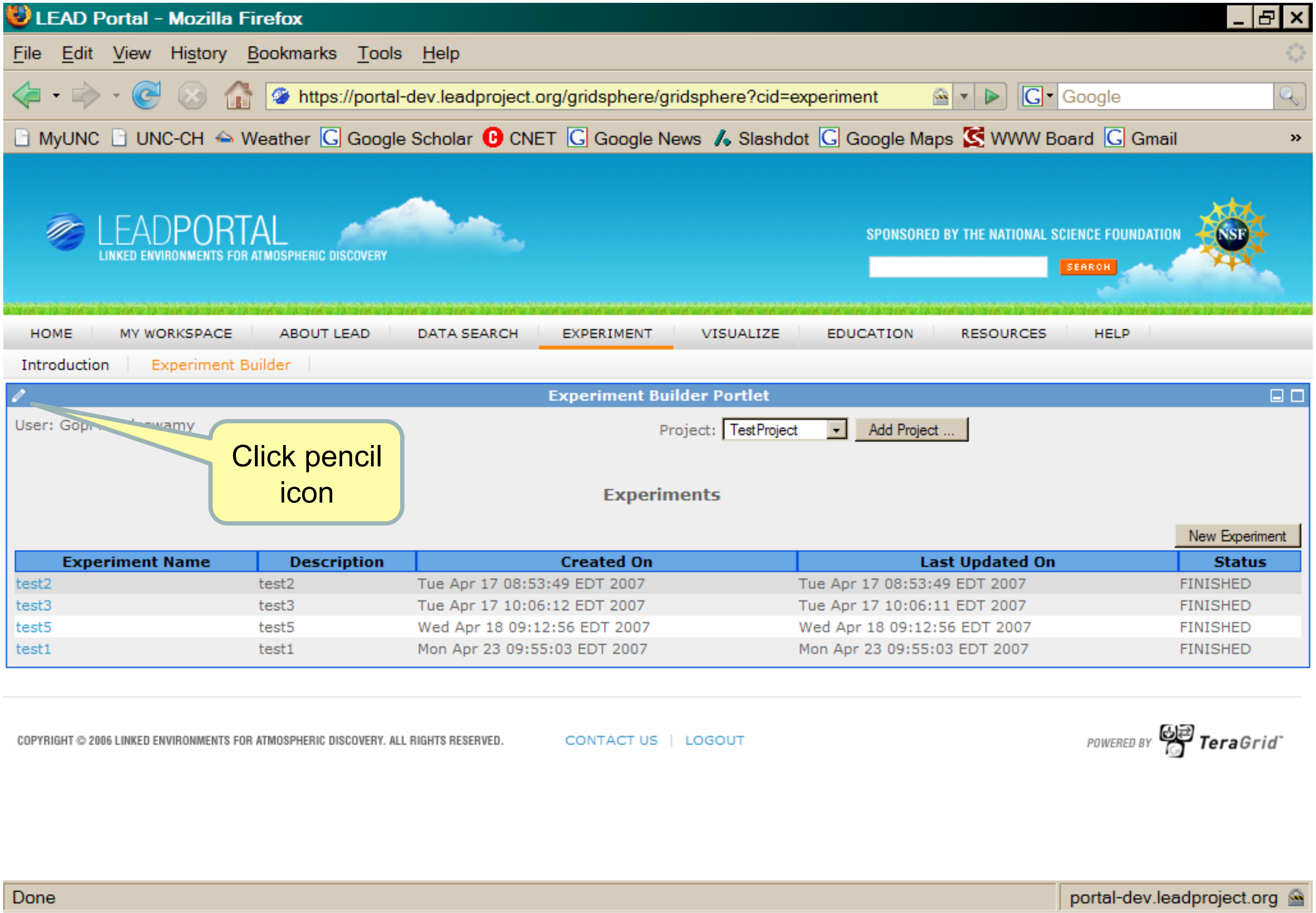

Terrain data files
1
Terrain Preprocessor
2
WRF Static Preprocessor
Surface, terrestrial data files
Run once per forecast region
3
3D Model Data Interpolator (Initial Boundary Conditions)
NAM, RUC, GFS data
Surface data, upper air mesonet data and wind profiler data
4
88D Radar Re-mapper
Radar data (Level II)
5
NIDS Radar Re-mapper
Radar data (Level III)
Satellite data
6
Satellite Data Re-mapper
Repeat periodically for new data
7
ADAS
8
ADAM
Data mining: look for storm signature
9
3D Model Data Interpolator (lateral Boundary Conditions)
11
ARPS to WRF Data Interpolator
15
IDV
10
ARPS Ensemble Generator
12
WRF
13
WRF to ARPS Data Interpolator
Visualization on users request
14
ARPS Plotting Program
Triggered if a storm is detected
Static data
Real time data
Initialization
Analysis
Data Mining
Forecast
Visualization

Simplified Architecture: LEAD





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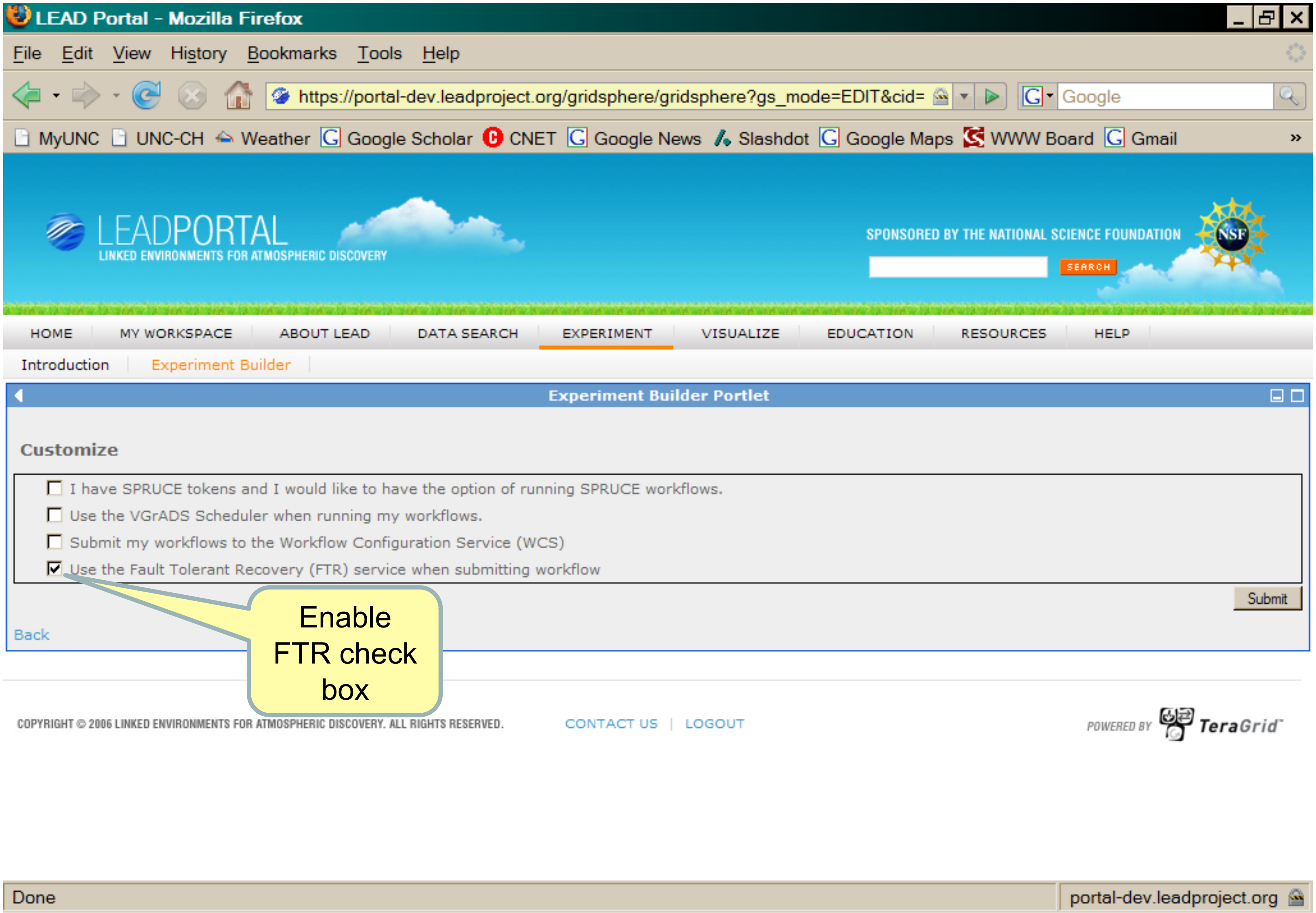

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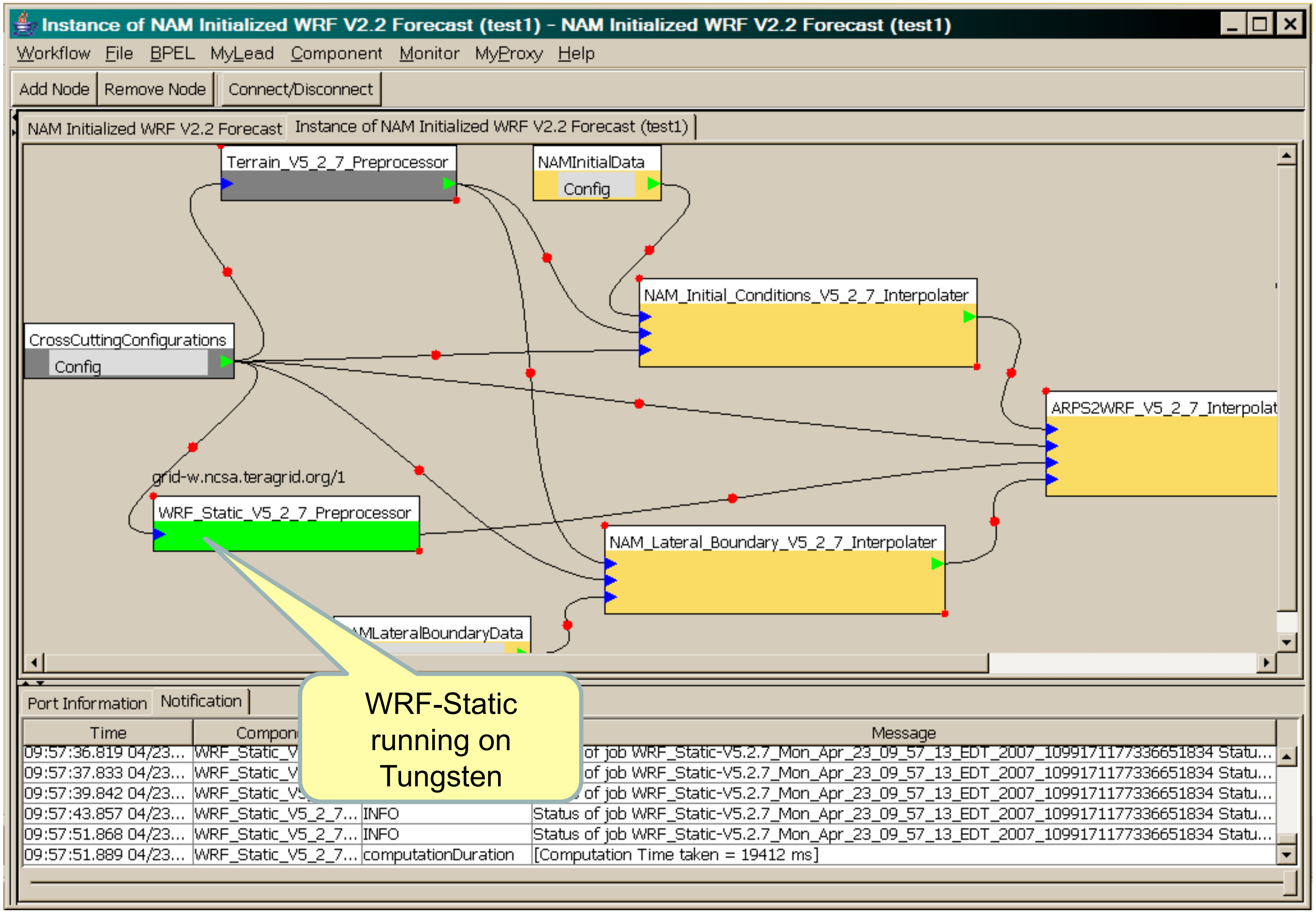
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Workflow File BPEL MyLead Component Monitor MyProxy Help
Add Node
Remove Node
Connect/Disconnect
NAM Initialized WRF V2.2 Forecast
Instance of NAM Initialized WRF V2.2 Forecast (test1)
Terrain_V5_2_7_Preprocessor
NAMInitialData
Config
NAM_Initial_Conditions_V5_2_7_Interpolater
CrossCuttingConfigurations
Config
ARPS2WRF_V5_2_7_Interpolat
grid-w.ncsa.teragrid.org/1
WRF_Static_V5_2_7_Preprocessor
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MLateralBoundaryData
Port Information
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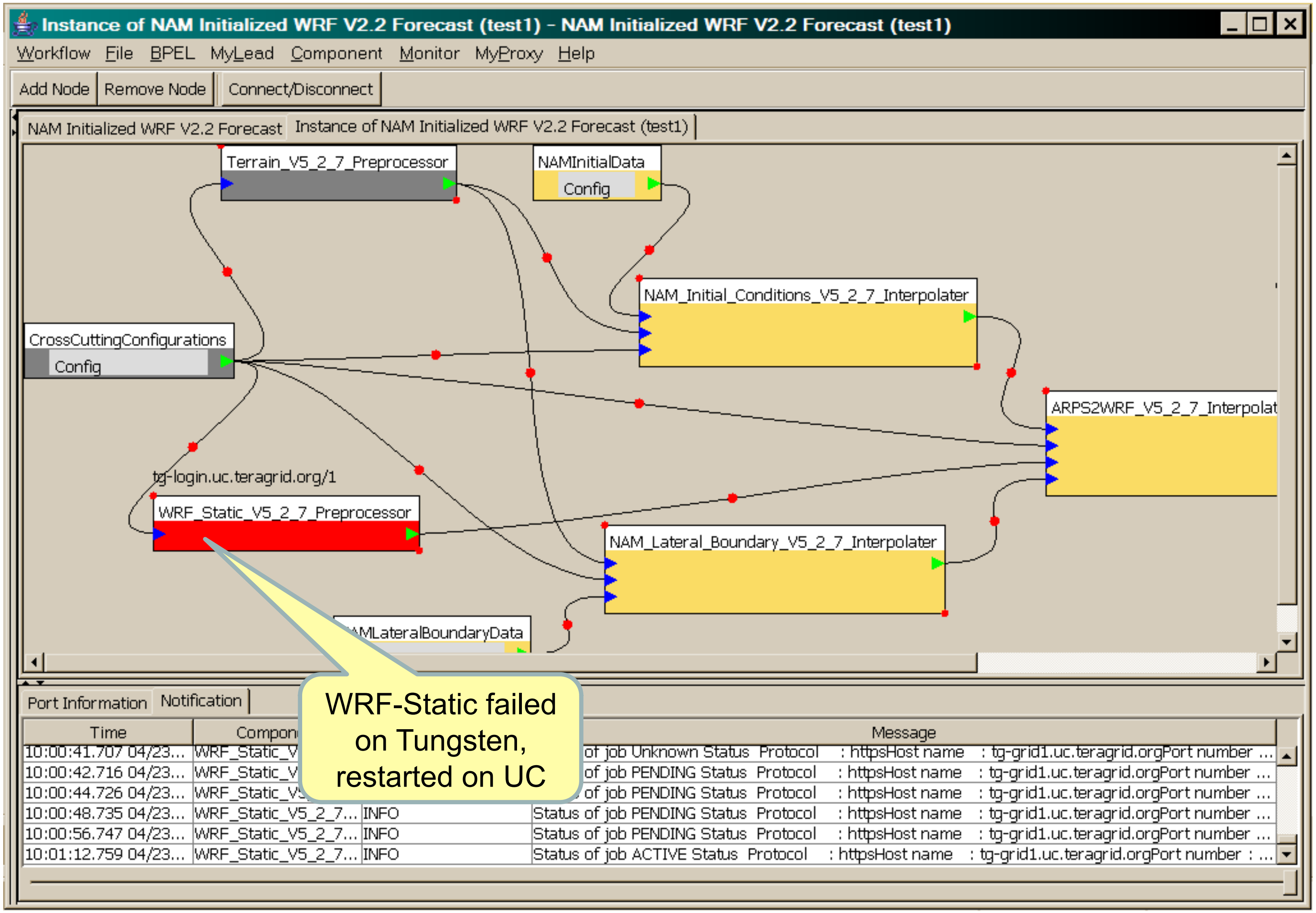
Message
09:57:36.819 04/23... WRF_Static_V of job WRF_Static-V5.2.7_Mon_Apr_23_09_57_13_EDT_2007_1099171177336651834 Statu...
09:57:37.833 04/23... WRF_Static_V of job WRF_Static-V5.2.7_Mon_Apr_23_09_57_13_EDT_2007_1099171177336651834 Statu...
09:57:39.842 04/23... WRF_Static_V of job WRF_Static-V5.2.7_Mon_Apr_23_09_57_13_EDT_2007_1099171177336651834 Statu...
09:57:43.857 04/23... WRF_Static_V5_2_7... INFO Status of job WRF_Static-V5.2.7_Mon_Apr_23_09_57_13_EDT_2007_1099171177336651834 Statu...
09:57:51.868 04/23... WRF_Static_V5_2_7... INFO Status of job WRF_Static-V5.2.7_Mon_Apr_23_09_57_13_EDT_2007_1099171177336651834 Statu...
09:57:51.889 04/23... WRF_Static_V5_2_7... computationDuration [Computation Time taken = 19412 ms]
WRF-Static running on Tungsten



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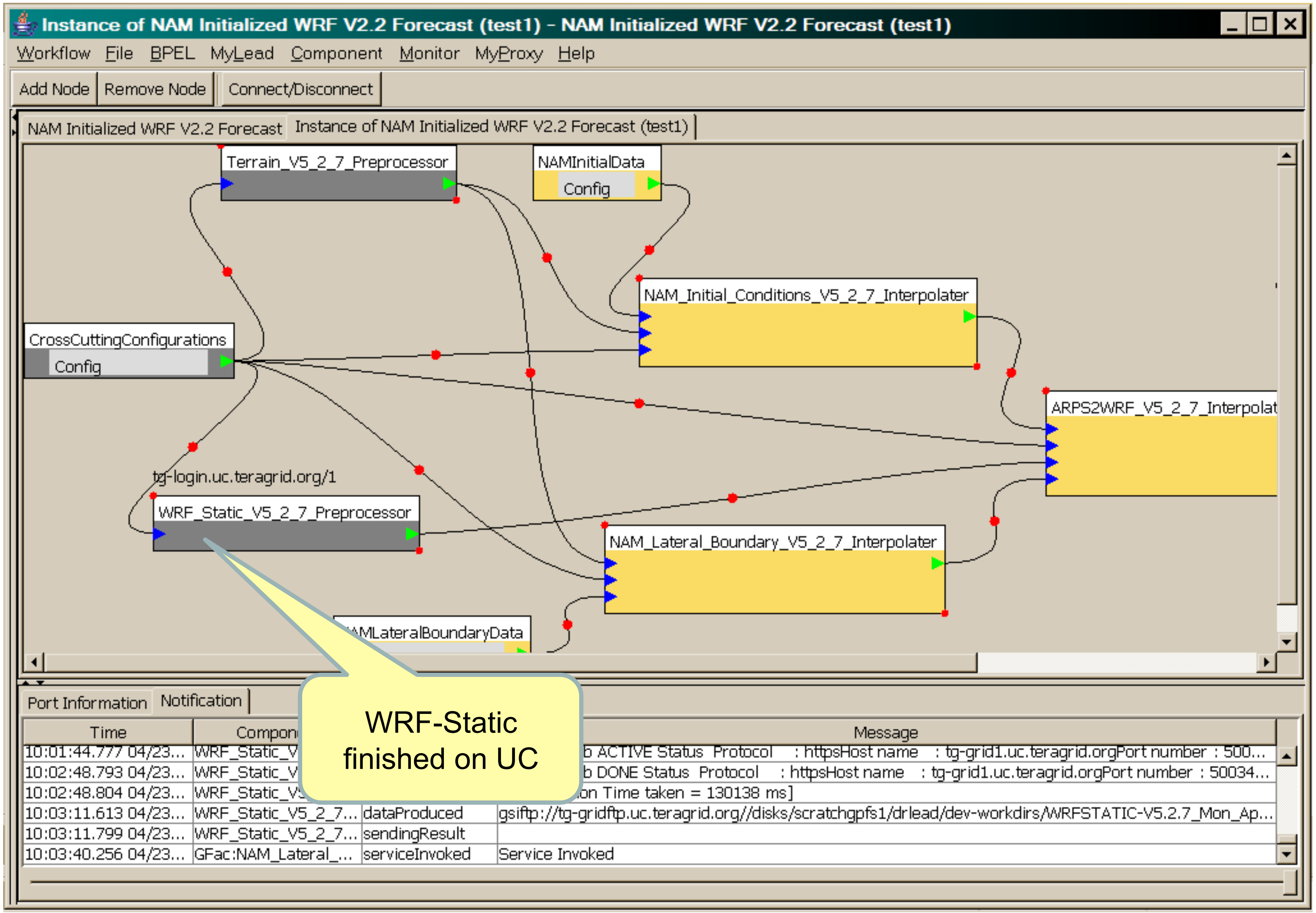
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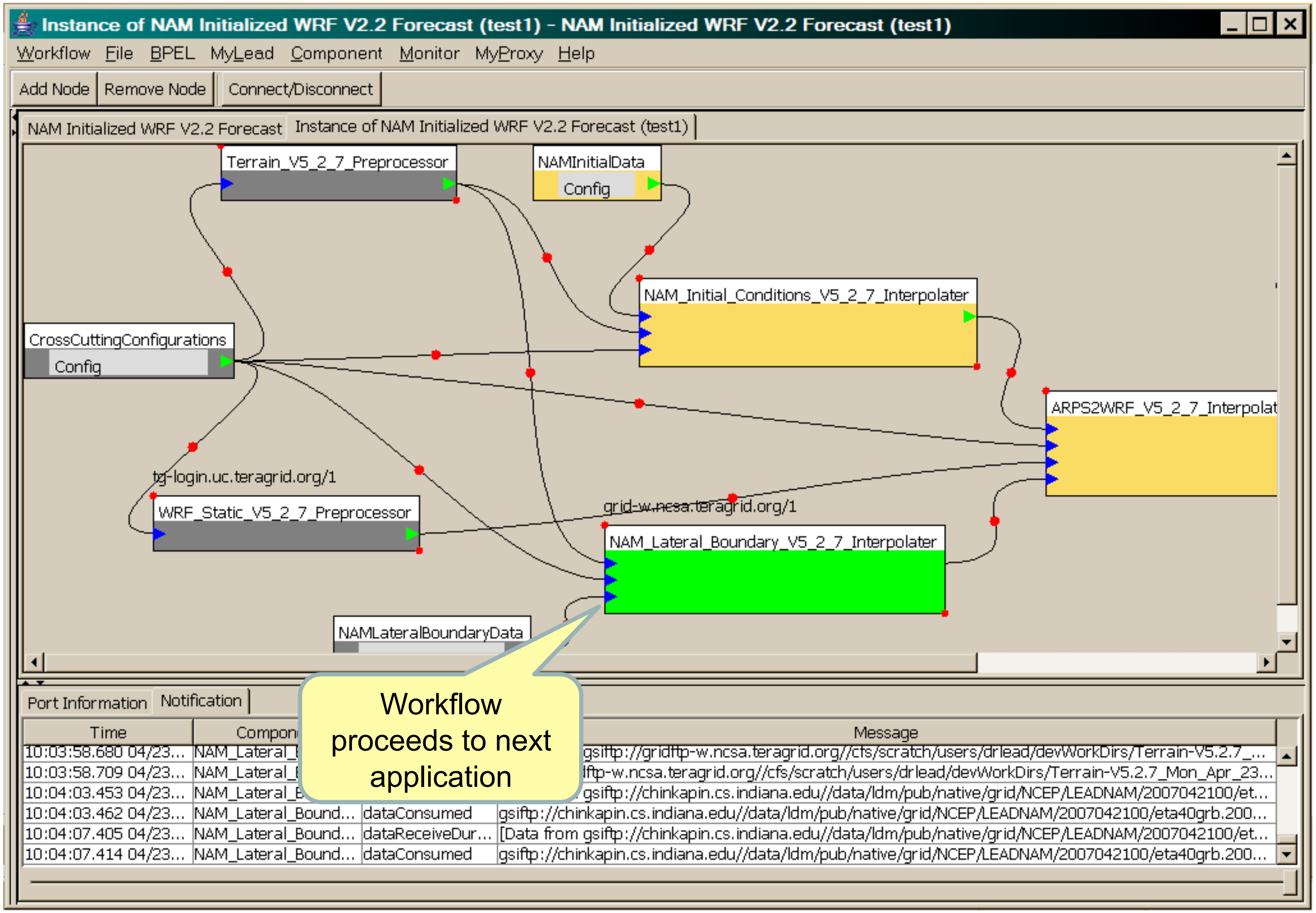
NAM_Lateral_Boundary_V5_2_7_Interpolater
MLateralBoundaryData
Port Information
Notification
Time
Compon
Message
10:01:44.777 04/23...
WRF_Static_V
b ACTIVE Status Protocol : httpsHost name : tg-grid1.uc.teragrid.orgPort number : 500...
10:02:48.793 04/23...
WRF_Static_V
b DONE Status Protocol : httpsHost name : tg-grid1.uc.teragrid.orgPort number : 50034...
10:02:48.804 04/23...
WRF_Static_V
on Time taken = 130138 ms]
10:03:11.613 04/23...
WRF_Static_V5_2_7...
dataProduced
gsiftp://tg-gridftp.uc.teragrid.org//disks/scratchgpfs1/drlead/dev-workdirs/WRFSTATIC-V5.2.7_Mon_Ap...
10:03:11.799 04/23...
WRF_Static_V5_2_7...
sendingResult
10:03:40.256 04/23...
GFac:NAM_Lateral_...
serviceInvoked
Service Invoked
WRF-Static finished on UC



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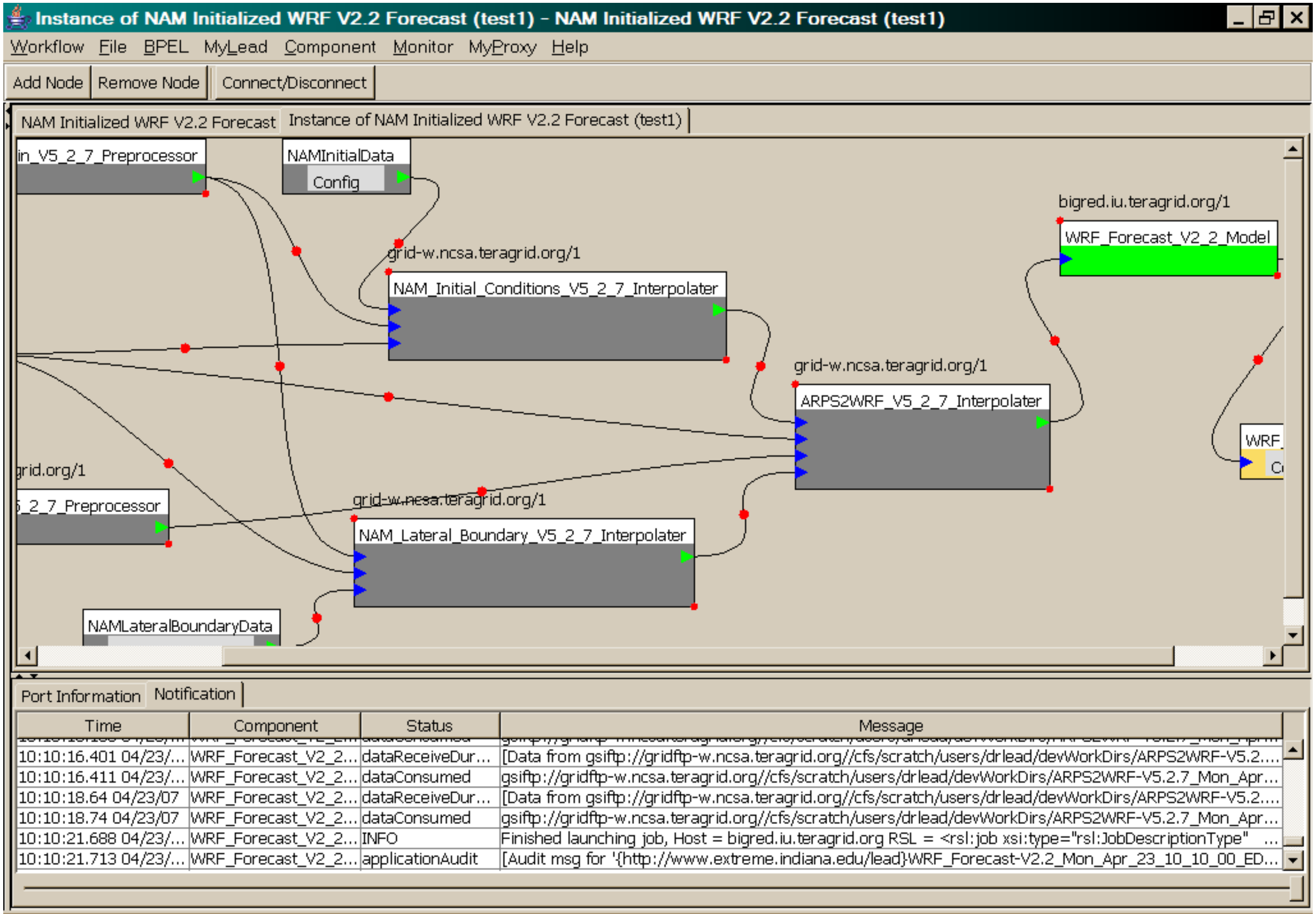
Message
10:03:58.680 04/23...
10:03:58.709 04/23...
10:04:03.453 04/23...
10:04:03.462 04/23... NAM_Lateral_Bound... dataConsumed gsiftp://chinkapin.cs.indiana.edu//data/ldm/pub/native/grid/NCEP/LEADNAM/2007042100/eta40grb.200...
10:04:07.405 04/23... NAM_Lateral_Bound... dataReceiveDur... [Data from gsiftp://chinkapin.cs.indiana.edu//data/ldm/pub/native/grid/NCEP/LEADNAM/2007042100/et...
10:04:07.414 04/23... NAM_Lateral_Bound... dataConsumed gsiftp://chinkapin.cs.indiana.edu//data/ldm/pub/native/grid/NCEP/LEADNAM/2007042100/eta40grb.200...
Workflow proceeds to next application



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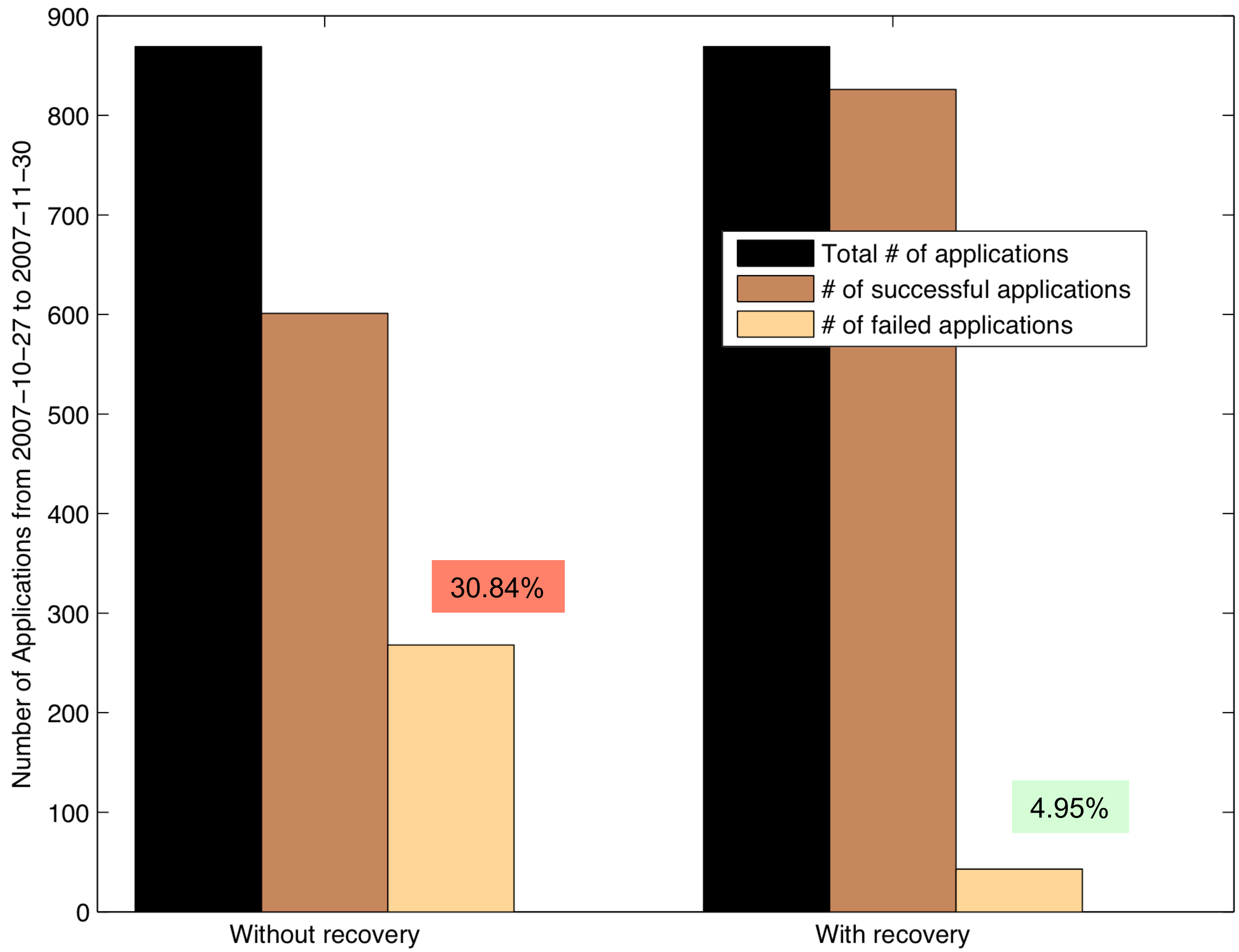
Results: Workflow Step Failure Rate



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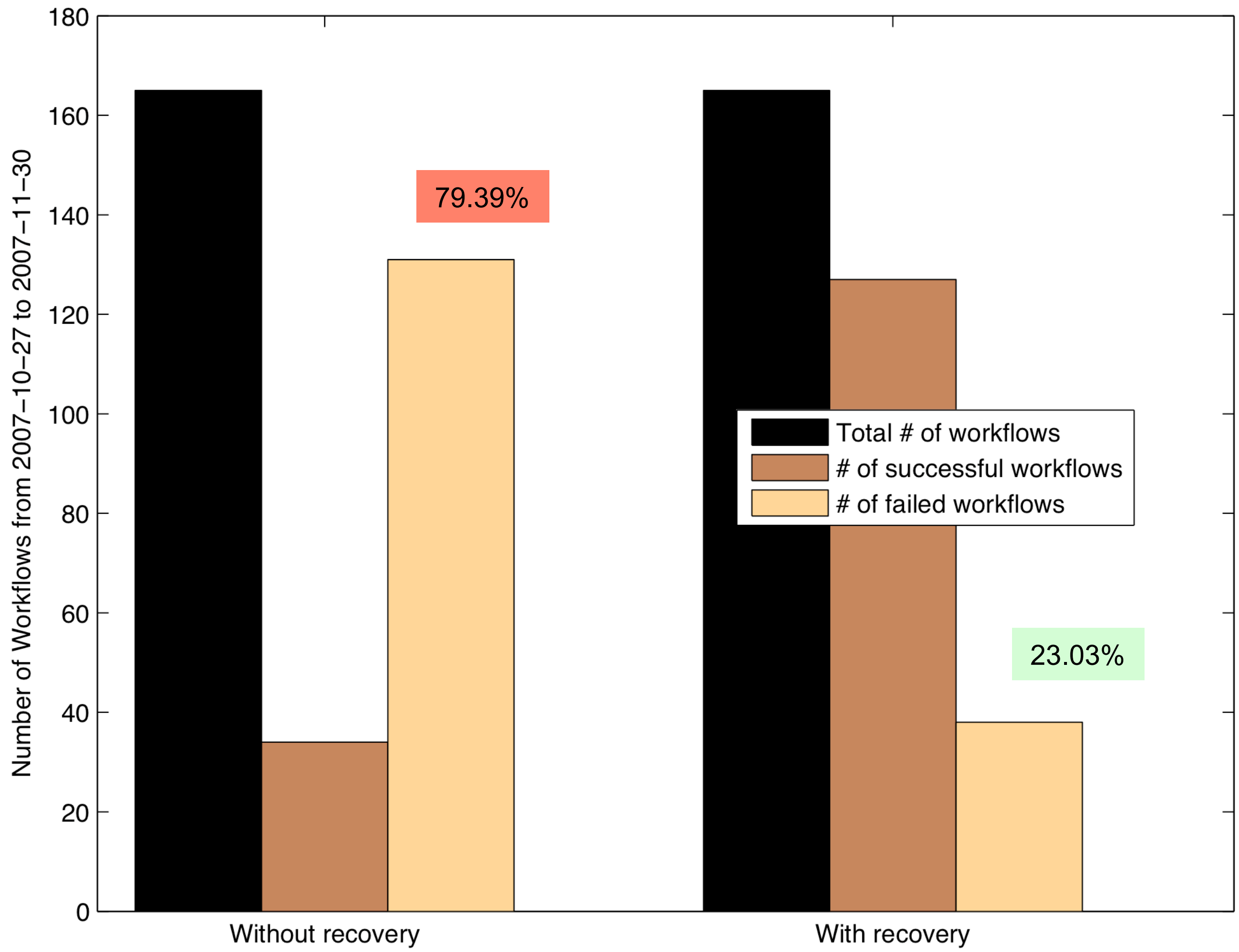

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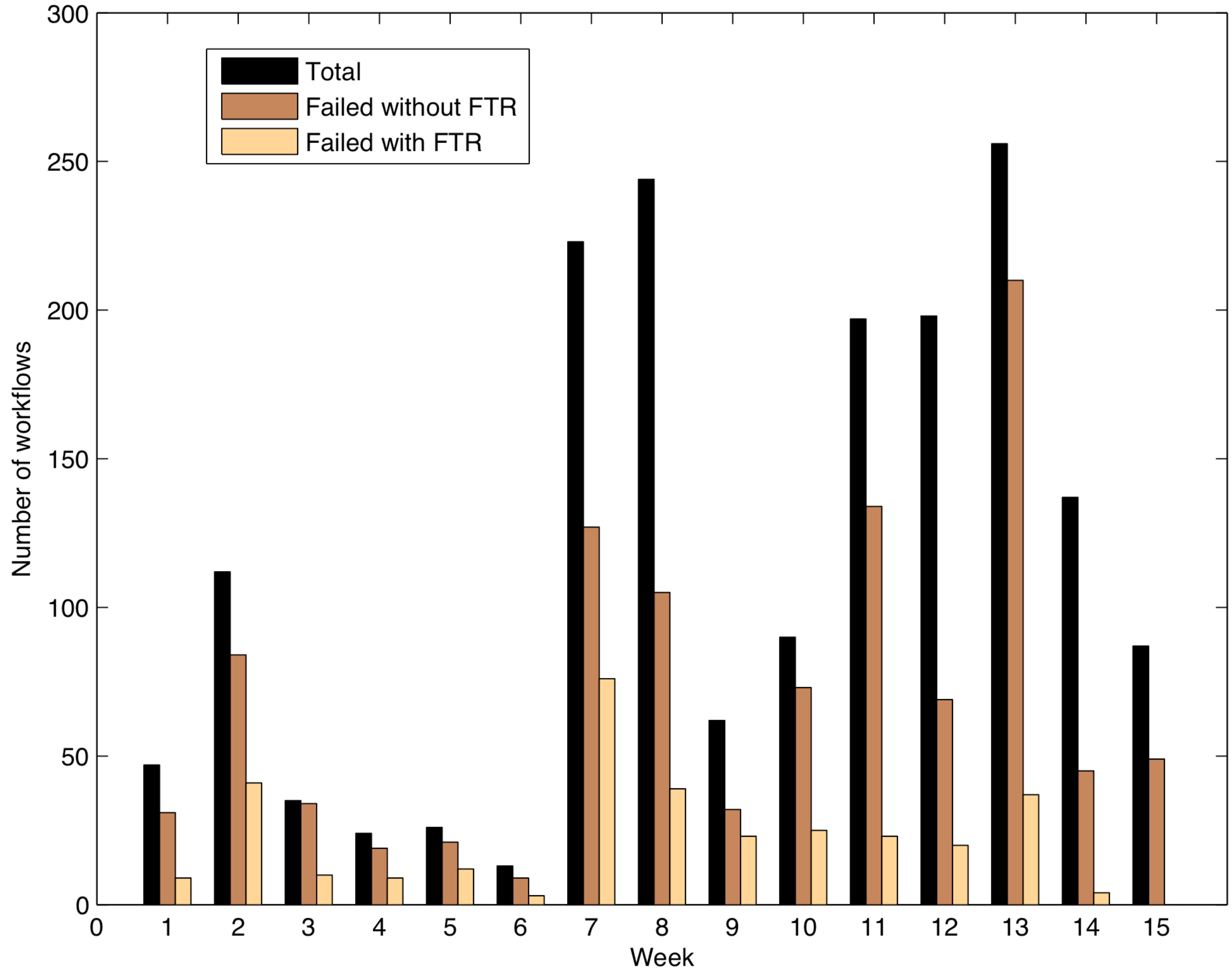
Weekly Statistics (past 5 months)



Conclusions

- **Developed a fault tolerance and recovery (FTR) service**
  - **delivers reliable execution of workflows on grids**
    - under deadline and success probability constraints
  - **uses migration and over-provisioning techniques**
- **Deployed FTR with LEAD production infrastructure**
  - **transparent to users**
- **Results from LEAD workflows show**
  - **Reduction of application failure rate from 31% to 5%**
  - **Reduction of workflow failure rate from 80% to 23%**
- **Future work**
  - **accurate reliability estimates of resources**
  - **other fault-tolerance techniques for different workflow types**

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Questions ?

Thank you..

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