

UCoMS @ LSU Progress

Center for Computation & Technology
and
Department of Petroleum Engineering

Louisiana State University

December 4, 2006





CCT Outline

- Progress
 - Grid computing: data, information, job mgmt, Grid portal
 - Applications: reservoir studies, drilling
- Deliverables
 - Toolkit development
 - Publications
 - Presentations/demos
- Awards and Grants
- Collaborations
- Plans



CCT Grid computing - data archive

Archive features:

- Generic reliable archive framework for storing large scientific data set on HPC
- Transaction control and fail-over server guarantees data integrity
- Seamless integration to portal framework



CCT Grid computing - data archive

Archive status:

- UCoMS archive is online now.
- UCoMS archive still needs pressure test with large runs.
- May end up using virtual server technology for higher archive availability.
- Successfully deployed for coastal modeling and numerical physicists.

Features:

- Multiple cluster environment
- Dynamic and static information
- Caching strategy
- User space
- Not tied to Globus

Status:

- Early version – proof-of-concept
- Usable for ResGrid
- TODO: formal cluster abstraction, integration with ResGrid



cct Grid computing - information

Input:

```
# resource_name access_way LRMS  
helix2.cct.lsu.edu SSH pbs  
mike4.cct.lsu.edu globus PBS
```



Grid computing - information

Output:

```
[cluster_name] = helix2.cct.lsu.edu  
Available_nodes = 31  
Available_cpus = 62  
Architecture = linux  
Running_jobs = 33  
Queuing_jobs = 122  
Remote_home_dir = /ibm_shark/home1/zlei
```

```
[cluster_name] = mike4.cct.lsu.edu  
Available_nodes = 465  
Available_cpus = 930  
Architecture = linux  
Running_jobs = 24  
Queuing_jobs = 18  
Remote_home_dir = /ibm_shark/home1/zlei
```

Configuration for caching:

```
#  
# SECONDS  
#  
  
DYNAMIC_FREQUENCY = 100  
STATIC_FREQUENCY = 150
```



CCT Grid computing – job mgmt.

- Objective: manipulating tasks of a single application run on multiple clusters
- Features: the same as the ones of information tool.
- Commands: task-farming, status tracking, job/task move within clusters, job/task delete, job/task rerun, ...
- Status: ongoing



CCT Grid computing – Grid portal

- Credential retrieval
- Model specification
- Uncertainty factor and level specification
- Resource selection
- Job submission
- Submitted job list
- Job template definition



cct

Grid computing – Grid portal

Will demo



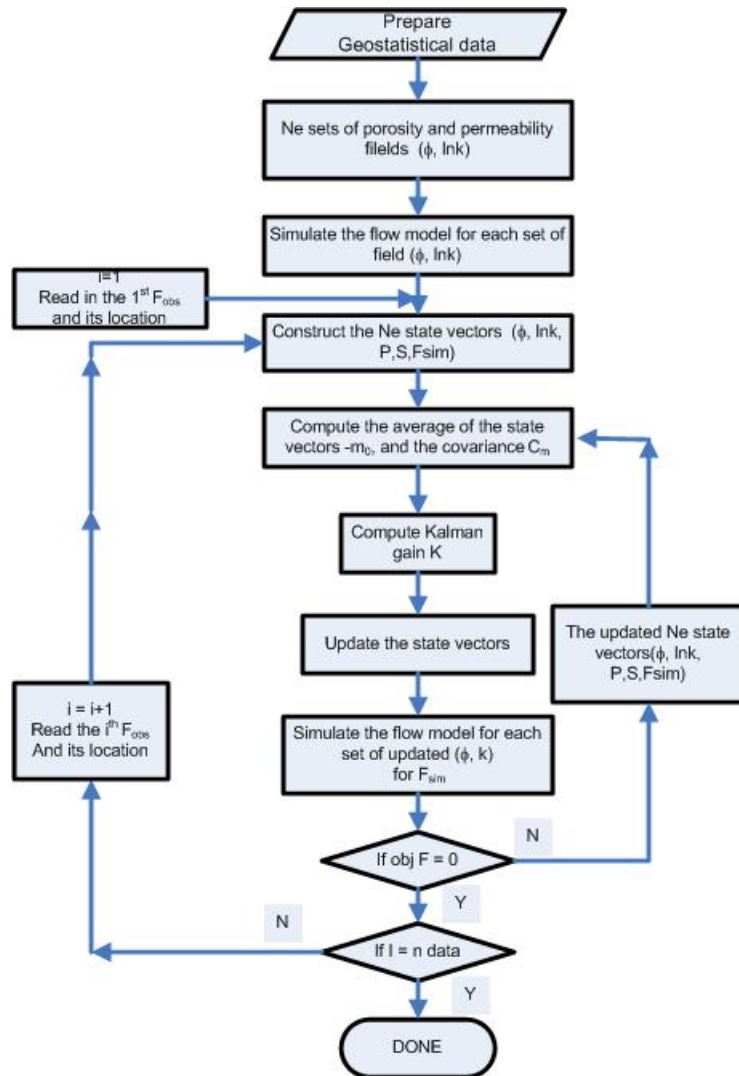
Applications – Reservoir studies

Automatic History Matching

- Continuous reservoir model update by Ensemble Kalman Filter, which is a 4-dimensional data-assimilation method that use a Monte-Carlo ensemble of short-range forecast to estimate the covariance of the forecast error.
- Main advantages: 1) It does not depend strongly on the validity of questionable hypotheses (linearity of the model dynamics); 2) It does not require an adjoint or tangent linear model.



Applications – Reservoir studies



- Working implementation of Ensemble Kalman Filter part;
- Challenge is synchronous and gigabyte data transfer problems on grid environment.

Cactus Black Oil Simulator

- Develop a black oil reservoir simulation tool in Cactus
- Study solver efficiency and issues, leveraging expertise of IPARS team members
- Improve the Cactus Code infrastructure by expanding into new areas of applications and implementing their infrastructure requirements
- Use in conjunction with other tools and utilities being developed at CCT



CCT Applications – Drilling

- Drilling Data Visualization
- Environment for Drilling Diagnostics
- Drilling Data System on Grid
- Frequency Prediction Model
- Field Sensor Integration Module for Cactus (Cactus Sensor Tools)

 CCT Deliverables – Toolkits

- Data management tool – getdata
- Execution management tool – ResGrid
- ResGrid portal
- Cactus black oil simulator
- Cactus LabView sensor thorns
- Information query tool



CCT Deliverables – publications/papers

- HPC06 Proceedings – 2 papers
- CCGrid06 Proceedings – 1 paper
- HPSEC06 Proceedings – 1 paper
- S. Kalla, C. D. White, et al. "Consistent Downscaling of Seismic Inversions to Cornerpoint Flow Models". Society of Petroleum Engineering.
- R. Duff, Y. El-Khamra. "Real Time Simulation in Grid Environments: Communicating Data from Sensors to Scientific Simulations" 2007 Digital Energy Conference & Exhibition to be held 11-APR-07 to 12-APR-07 in Houston, TX. Accepted.
- X. Li, C. White, et al. "Queues: Using Grid Computing for Simulation Studies". 2007 Digital Energy Conference & Exhibition to be held 11-APR-07 to 12-APR-07 in Houston, TX. Paper proposal accepted.
- F. Zhou, M. Xie, G. Allen, et al. "Collaborating Mechanical Design Across A Grid". Submitted to CCGrid07.
- Z. Lei, G. Allen, et al. "A Grid-enabled Problem Solving Environment for Advanced Reservoir Uncertainty Analysis." Submitted to Journal of Grid Computing.



CCT Deliverables – publications/posters

- J. Lewis, G. Allen, et al. "Building an Application Portal for Geoscience". LSU Summer Undergraduate Research Program. August 3, 2006.
- J. Lewis, G. Allen, et al. "Developing a Grid Portal for Large-scale reservoir Studies". Annual Argonne Undergraduate Symposium. Nov. 3-4, 2006.
- Z. Lei, G. Allen, et al. "Utilizing Grid Computing for Advanced Reservoir Studies". SC06 Poster.
- R. Duff, "Observation and Modeling of Identified Regimens of Torsional Vibration" 2007 American Association of Drilling Engineers, Houston, TX, April 10- 12, 2007. Accepted.



CCT Deliverables – presentations/demo

- 05 Grid computing & advanced network technologies for e-science
 - Grid introduction and fundamental review
 - Grid security and basic access
- Sandia National Lab
 - Why deep drilling is slow and expensive even in weak rocks
- Supercomputing 2006 demo



CCT Grants/Awards

- NSF DDDAS-TRP, \$220,000
- NSF TeraGrid-DAC:, 30,000 SUs.
- CCT GDP, \$32,000
- Scholarships from GGF 14 and Grid summer school.
- NSF-MRI: "Development of PetaShare: A Distributed Data Archival, Analysis and Visualization System for Data Intensive Collaborative Research", \$1M, August 1, 2006 - July 31, 2010. Gab is co-PI.
- DoD: "Testing and Modeling of Blast Response of Functionality Graded Composite Armor", \$300,000, August 15, 2006 - August 14, 2009. Zhou is SI.
- CCT GDP: "Enabling Monte Carlo", "Collaborative Grid For Mechanical Engineering", \$27,000, July 1, 2006 - June 30, 2007. Zhou is PI.



CCT Grants/Awards

- Santiago: MSI Scholarship for TeraGrid '06 - Advancing Scientific Discovery. Indianapolis. June 12 - 15 2006.
- Santiago: Scholarship to the 12th Annual SDSC Summer Institute - Taking your Science to the Next Level: On the Path to Petascale Computing. July 17 - 21 - San Diego. July 17-21.
- Promita went to GGF 18, supported by student scholarship, Sep. 11-14.
- John L. attended Argonne Undergraduate Symposium, supported by LSU computer science department scholarship, Nov. 3-4.
- Promita: Session Aide for the 2007 AAAS meeting in San Francisco. Feb 15-19, 2007



CCT Collaborations

- LSU Mechanical Engineering department
- LSU Agriculture Center
- Tefvik's group



CCT Plans

- Provide a demo version of reservoir uncertainty analysis portal.
- Provide a demonstrate version of drilling with portal, visualization and diagnostics.
- Implement history matching for reservoir studies.
- Improve status monitoring in the portal page.
- Provide the sophisticated information query tool and integrate it with the ResGrid
- Implement the multi-cluster job management toolkit.
- Collaborate with Tefvik's group to provide efficient execution and data management.

UCoMS Reservoir Studies

Xin Li, Chris White, and Yaakoub El Khamra

LSU

December 4, 2006



The logo for the Center for Computation & Technology (CCT) at Louisiana State University. It consists of a stylized 'cct' in a bold, lowercase font, with the 'c' and 't' overlapping. To the left of the text is a graphic of a 3D cube with colored faces: green on top, orange on the front, and purple on the side.

cct Components

- Applications
- Cactus BlackOil Simulator



Application Progress Using ResGrid to finish...

- 👉 **1920 simulation runs to evaluate 4 different geostatistic stochastic algorithms(LUSIM, SGSIM, HYBRID, SPECSIM). The main conclusion is SGSIM is not appropriate for permeability fields simulation when the reservoir is highly heterogeneous.**

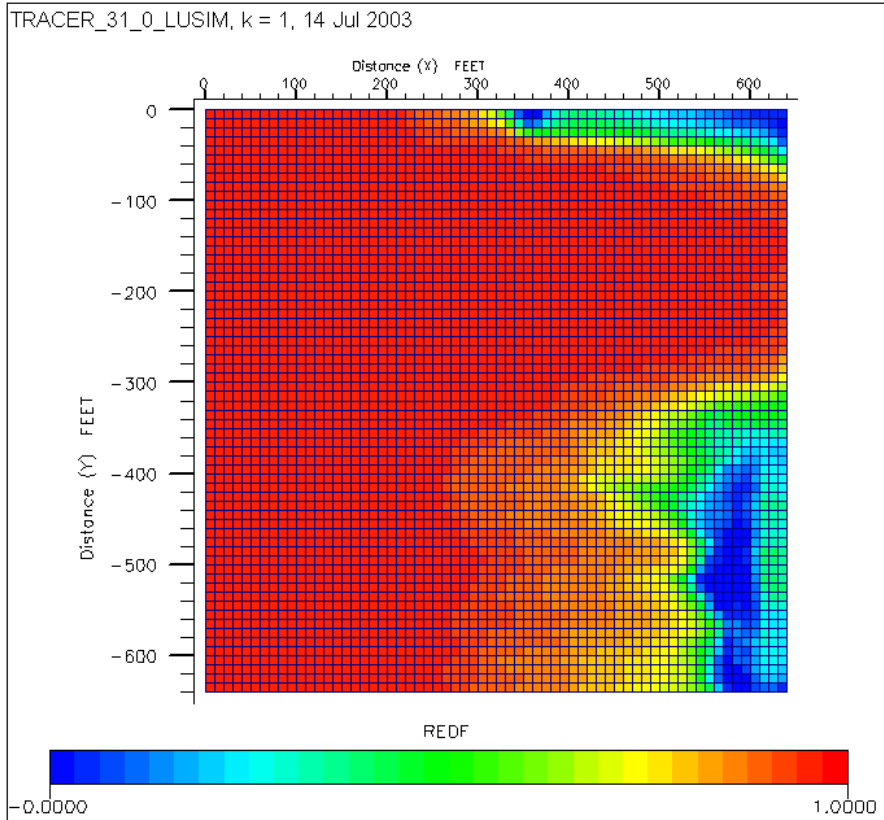


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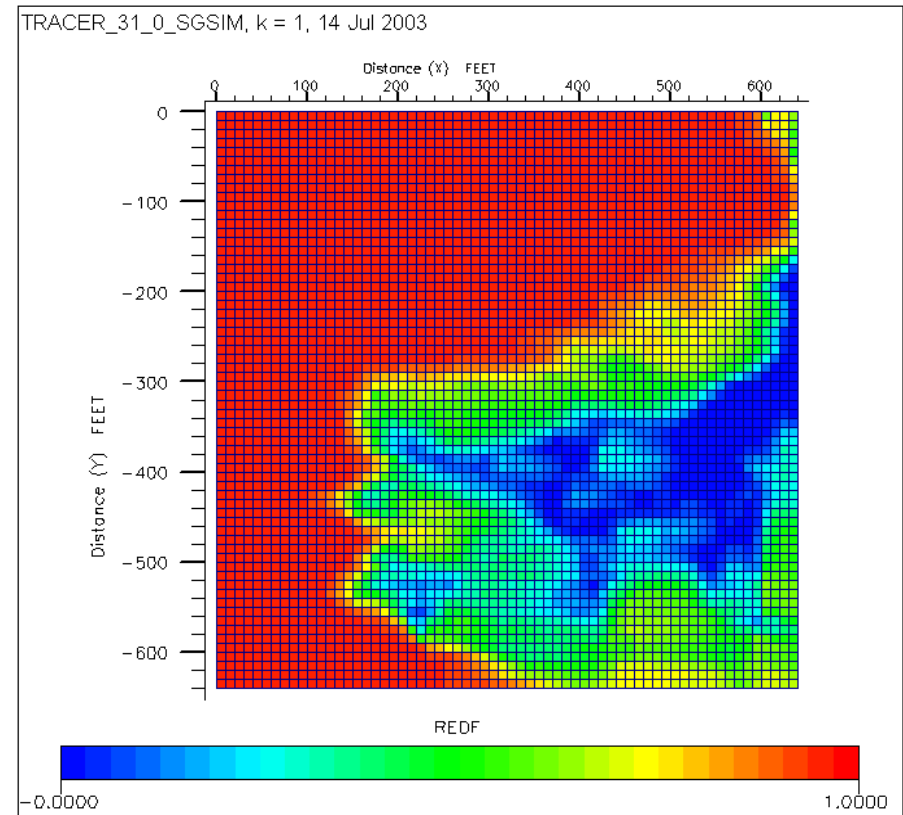
LUSIM vs. SGSIM

Result

Well Pattern I



LUSIM



SGSIM



Super Computing Application to LU Decomposition

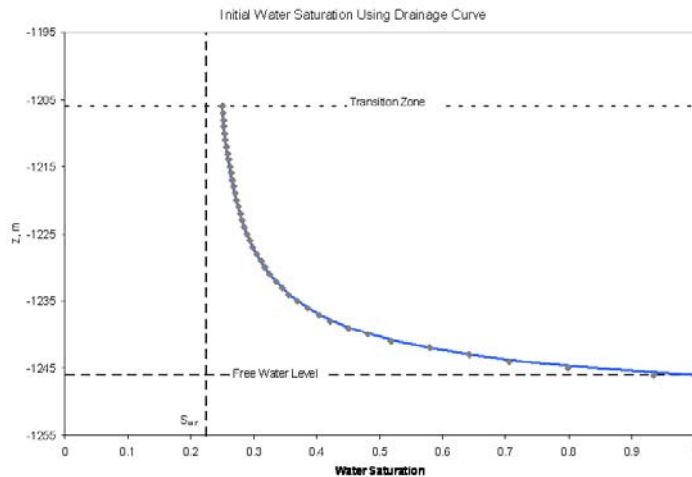
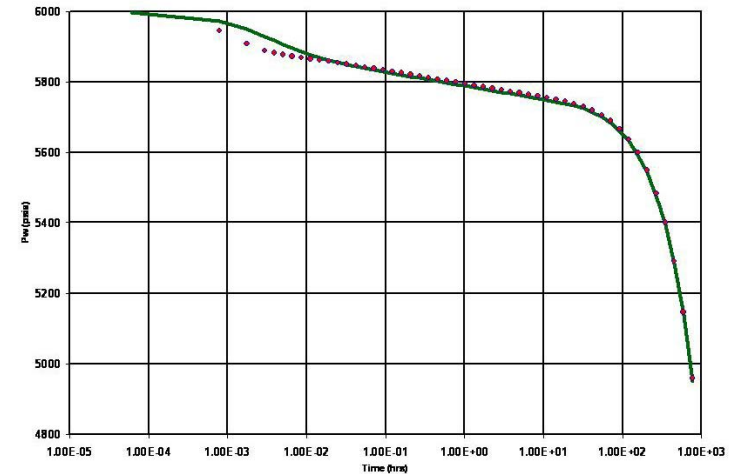
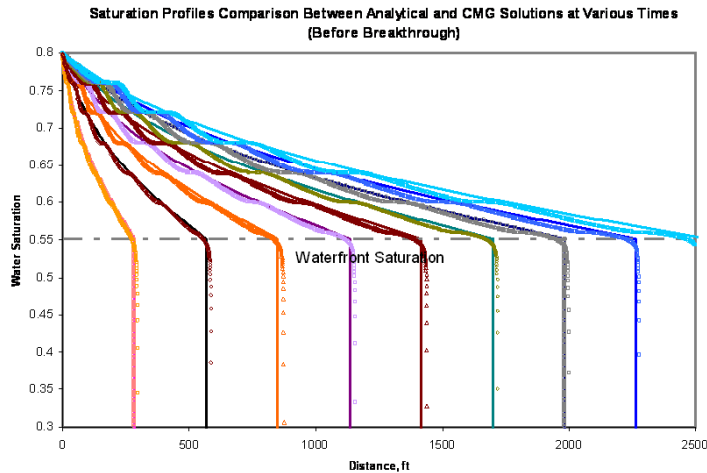
- Problem:
 - Reservoir dimension: $64 \times 64 \times 3$
 - Matrix C_{dd} : $12,288 \times 12,288$
 - Memory needed: about 5GB/simulation
 - 160 simulation runs
- Answer:
 - Santaka: shared memory architecture, single node, 32 processor ProPack 4 - SUSE Linux Enterprise Server 9 (SLES9) SSI from SGI with 1.5 GHz Intel Itanium2 processors and 128 GB RAM per system.
 - Each simulation takes about two hours.





Cactus Black Oil Validation

-displacement, diffusivity, and initialization



- Validation cases for Cactus BlackOil using analytic solutions (lines) and third-party simulator (CMG-IMEX, points).



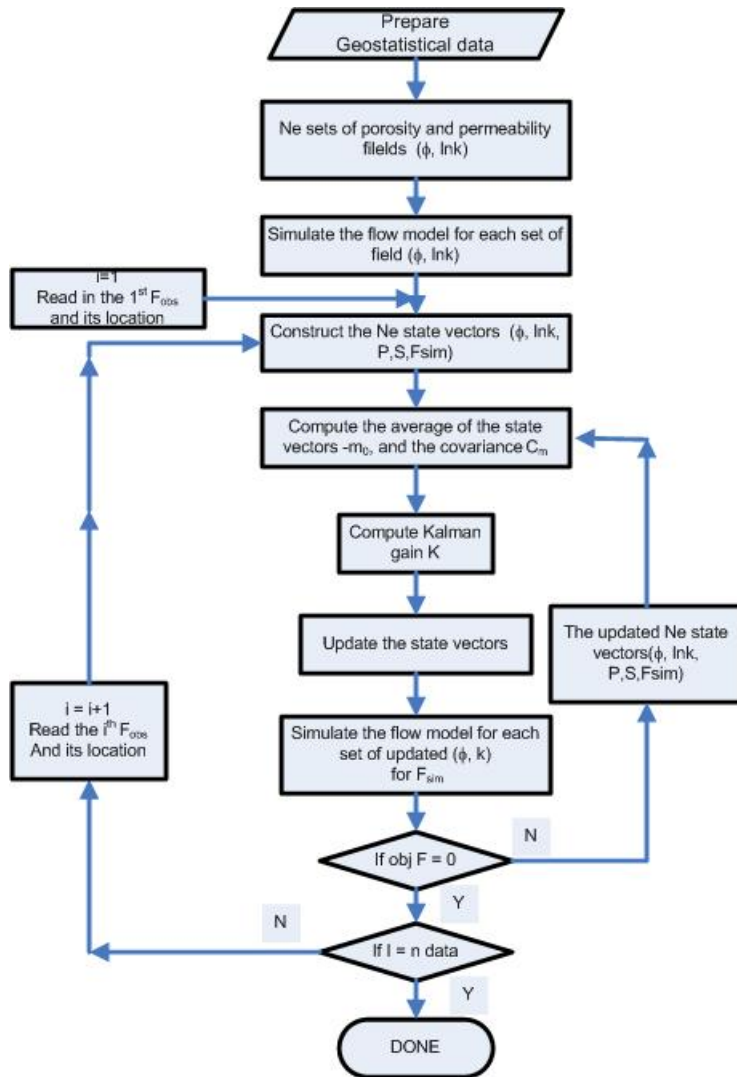
Ongoing Grid Application on Automatic History Matching

Using ResGrid to ...

- Realize continuous reservoir model update by Ensemble Kalman Filter which is a 4-dimensional data-assimilation method that use a Monte-Carlo ensemble of short-range forecast to estimate the covariance of the forecast error.
- It does not depend strongly on the validity of questionable hypotheses (linearity of the model dynamics). It does not require an adjoint or tangent linear model.



CCT Progress...



- Finish code for Ensemble Kalman Filter part;
- Challenge is synchronous and gigabyte data transfer problems on grid environment.

 CCT Cactus BlackOil

- Objectives
- Design
- Implementation
- Progress
- Future plans



Cactus BlackOil Objectives

- Develop a black oil reservoir simulation tool in Cactus
- Study solver efficiency and issues, leveraging expertise of IPARS team members
- Improve the Cactus Code infrastructure by expanding into new areas of applications and implementing their infrastructure requirements
- Use in conjunction with other tools and utilities being developed at CCT

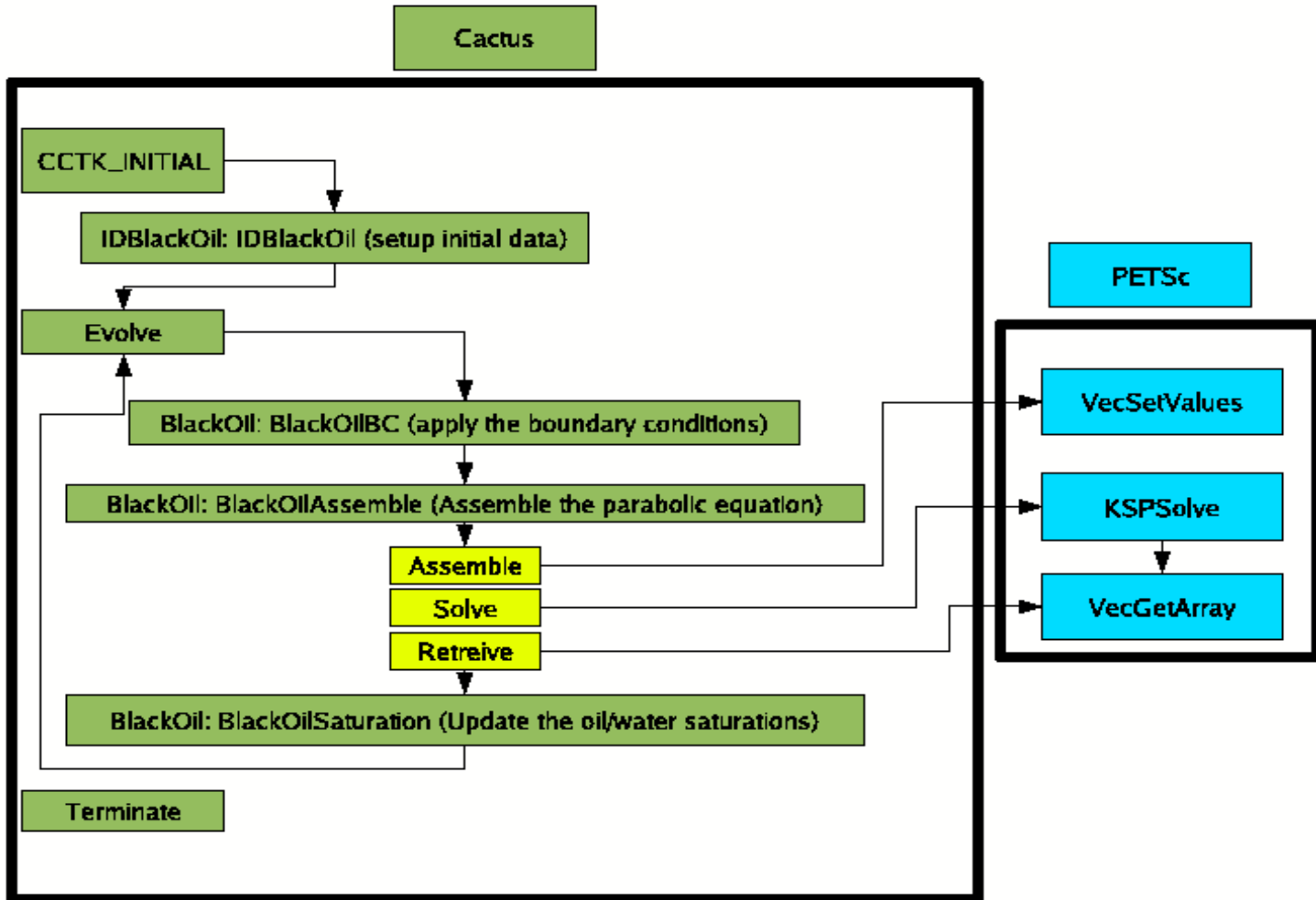


Cactus BlackOil Design

- Modular design: initial data thorn, a (soon to be) boundary conditions thorn and a solver thorn
- Use PETSc (Parallel Extensible Toolkit for Scientific Computation) as a solver
- Started out with a 2 phase flow solver in 3D
- The scheme used is IMPES: implicit pressure explicit saturation



Cactus BlackOil: Implementation





Cactus BlackOil: Implementation

- Currently Implemented in Cactus
- To checkout the thorn please checkout Cactus then:
cvs -d
:pserver:cvs_anon@cvs.cct.lsu.edu:/Frameworks co BlackOil
The password is: anon
- The implementation requires a PETSc implementation as PETSc is the primary solver



Cactus BlackOil: Progress

- Started 1.5 months ago
- Major development underway
- Implemented initial conditions, boundary conditions and evolution equations
- Implemented column boundary conditions
- Implemented PETSc direct interface to allow better efficiency and more solver options
- Code verification is well underway



Cactus BlackOil: Future Plans

- Extend the code from 2 phase flow to fully fledged 3 phase flow
- Migrate the code over to the Cactus CFDToolkit infrastructure to make use of multi-block and unstructured mesh infrastructures.
- Leverage new tools and utilities being developed at CCT: VISH for visualization, archiving, Kalman filters, sensor data streaming

UCoMS Drilling Applications

Richard Duff, Yaakoub El Khamra, and
John Rogers Smith

LSU

December 2006





cct Components

- Applications
- Cactus Sensor Tools



CCT Background

Drilling wells is the process of creating a stable hole in the ground to great depths to reach a potential energy source.

Cycle of Drilling Operations

- Sensor data (from the rig and down hole tools)
- Processing (downhole, on the rig, in the office)
- Real-time display (on the rig, in the office)
- Data storage (on the rig, in the office, at data center)
- Recovery for subsequent operations

Rate and Volume of Data

- Max rate/well: 5 Mbps

Process Response Time -- 2 to 10 seconds

To develop drilling applications to take advantage of Ubiquitous Computing (esp. GRID resources)

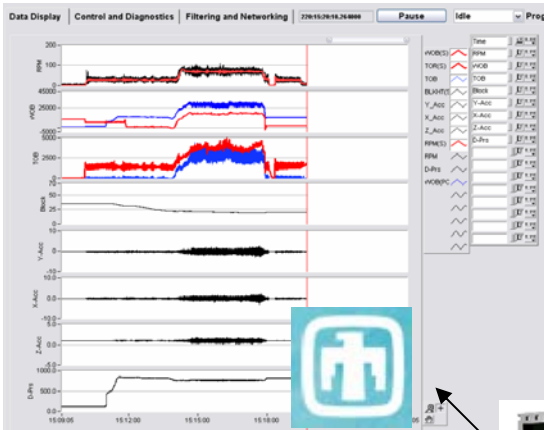
General Goal

Visualization & management of large volume, real-time & stored drilling data to improve drilling effectiveness



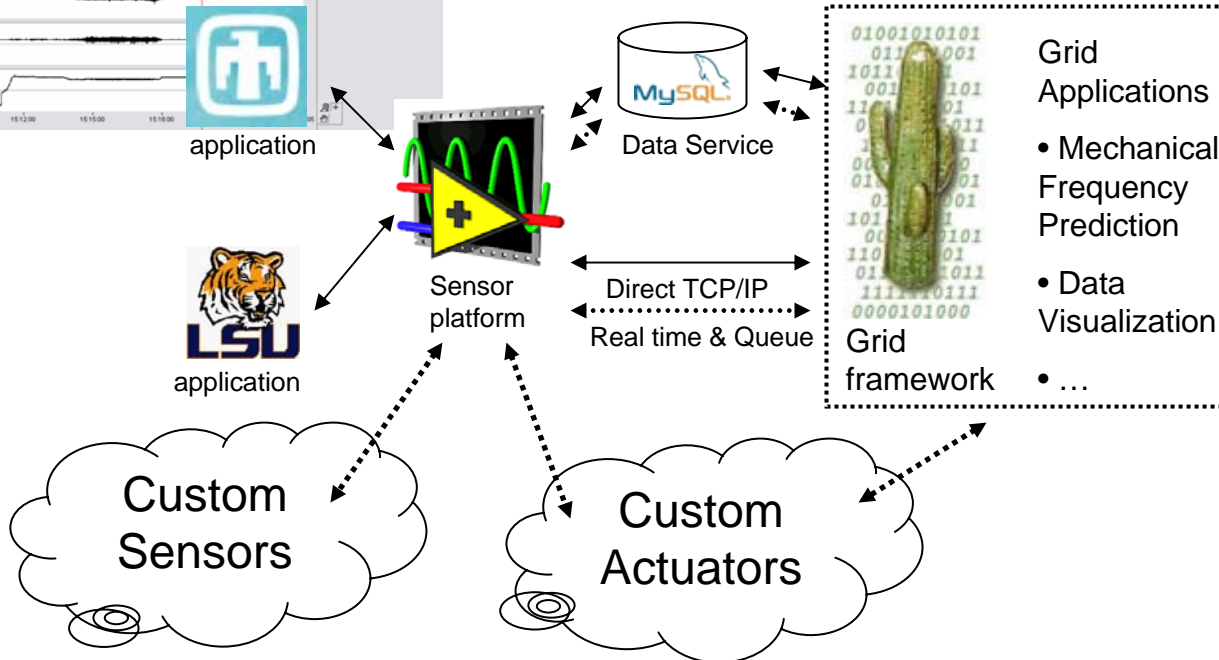
Drilling Applications

Testing of Real Time Drilling Applications




Sandia's
IDDS
over
Network

- Drilling Data Grid Management
- Sensor / Actuator Framework Interface
- Developed Sensor / Actuator Framework Interface Developed
- Predictive Control Program Moved to Grid Framework
- Prepare for Test Porting of Control Simulation to Grid Framework



Spring board to:



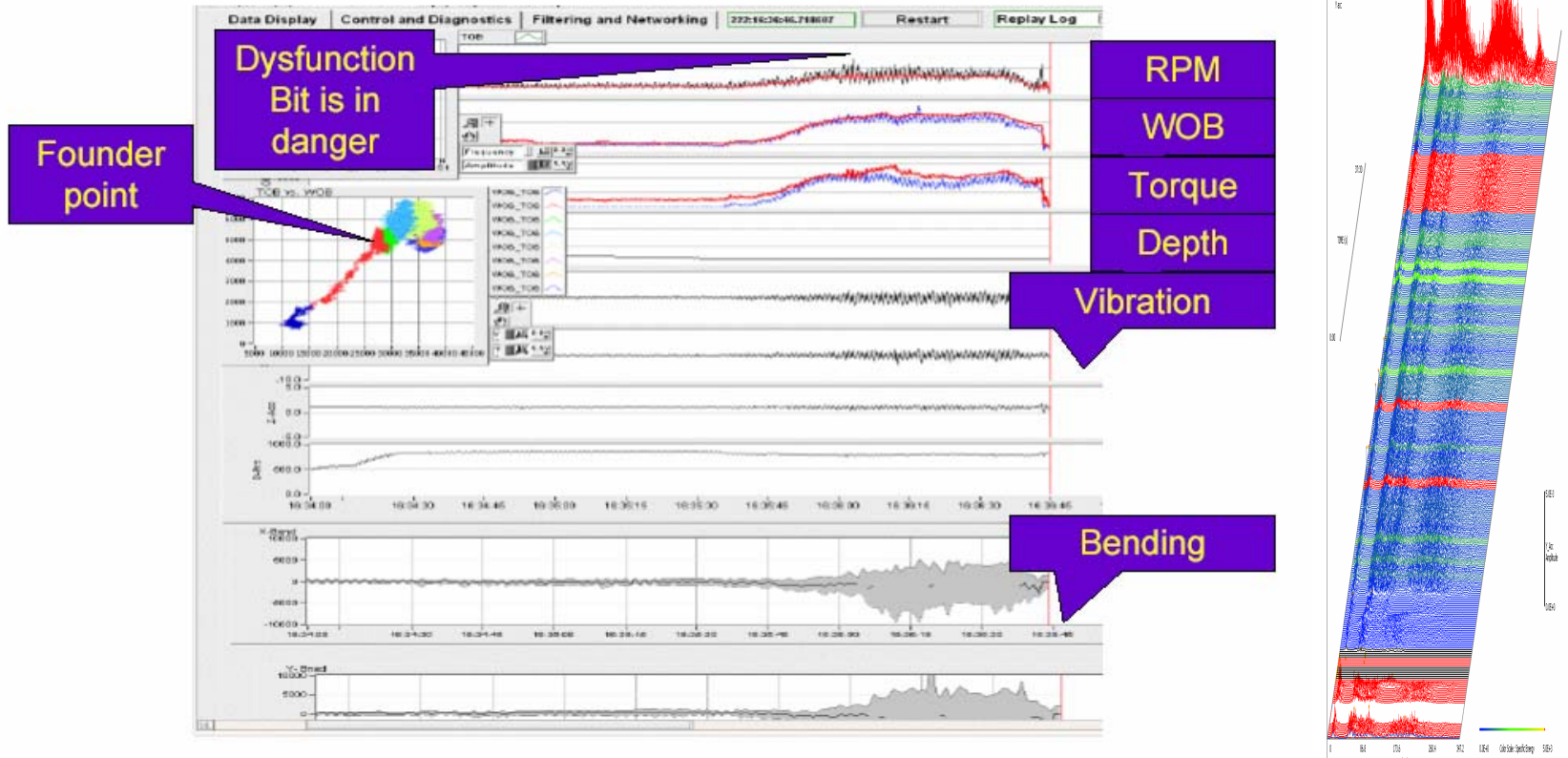
FELIX
Finite Element Librar eXperiment

To the Grid

Massive open source Finite Element Modeling

CCT Progress

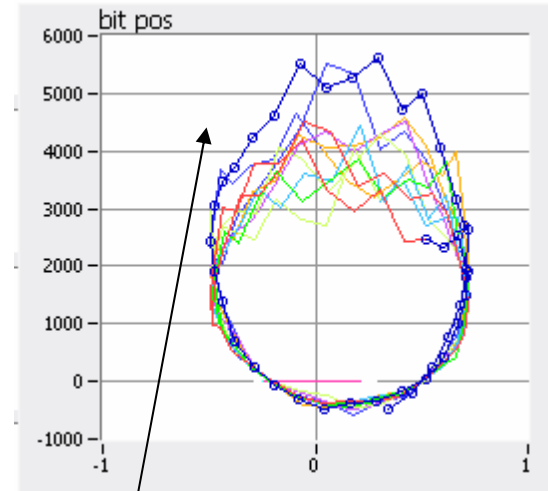
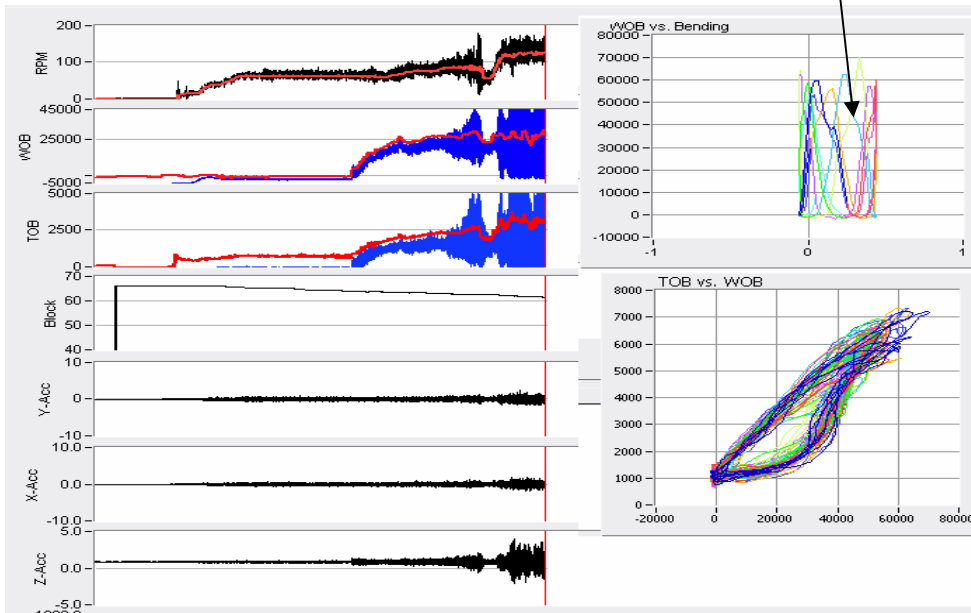
- Sandia “IDDS” (state-of-the-art visualization) enabled on GRID w/ data archive management
- Tested with 0.5 billion element data set





New Visualization Plots

- Downhole axial bounce
- Bending not synchronous with bounce
- Implies drillstring whirl
- Not visible at surface

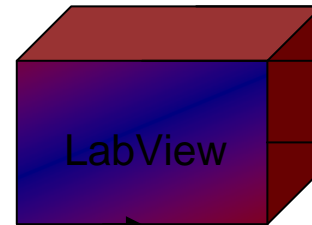
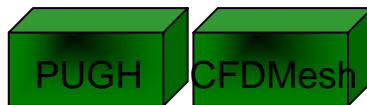
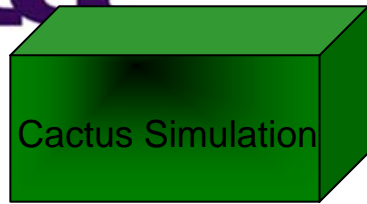


WOB * Y_acc vs. X_acc --
implies rotational
position driving axial
vibration & bending



Cactus Sensor Tools

- Lots of man hours have been put into integrating a sensor data communication tool into cactus to allow sensors to stream data directly to simulations
- This effort culminated in the development of the Cactus CommMySQL thorn which communicates to a (currently MySQL) database that stores sensor data
- Data is sent to the database from LabVIEW using shared library function calls



Sample Cactus-LabView interaction Scenario

1. Cactus Simulation Starts, LabView thorn activated
2. LabView thorn connects to the Data Server (portal)
3. LabView thorn asks the Data Server for the value of a parameter
4. Data Server relays request to Labview
5. Labview sends the Data back to the Data Server
6. Data Server sends the value back to the LabView thorn
7. LabView thorn sets the parameter to its value
8. Repeat until all parameters have values



Cactus Sensor Tools

- Currently working on an ontology definition to allow seamless transfer of knowledge not just data from sensors to simulations for both petroleum engineering and CFD
- Working implementation working for a sample drilling thorn
- Subject of 3 papers, ASTEC 2007, CAPS 2007 and SPE DEC 2007



Cactus Sensor Tools

- We also implemented WITS: Wellsite Information Transfer Specification in LabVIEW and are working on using it for to stream data for analysis in Cactus
- WITS: is a communications format used for the transfer of a wide variety of wellsite data from one computer system to another.
- It is a recommended format by which Operating and Service companies involved in the Exploration and Production areas of the Petroleum Industry may exchange data in either an online or batch transfer mode.

 CCT Plan

- Continue to develop and train associated memory modules for diagnosing drilling problems
- Continue developing portal function
- Create data streaming capability
- Run these new diagnostic applications on UCoMS test bed
- Migrate applications to and demonstrate use in UCoMS production environment