# Advanced Flux Visualization and Virtual Reality for Reservoir Engineering

***An ACTI Proposal***


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## 1.0 Statement of Problem

Accurately determining the mechanisms of recovery in a hydrocarbon reservoir will directly effect the recovery efficiency of a given reservoir. In order to gain an understanding of a reservoir, the engineer uses a variety of tools to assist in the interpretation of simulation data. Of particular relevance to this proposal are software tools used to visualize flux. With current technology, visualization of flux is represented with arrows, one per component, at each reservoir grid block. The result of such visualization is hard-to-interpret images containing hundreds of thousands of arrows. In addition, the user interface itself is a barrier to the success of advanced software tools. Visualization tools often require three- or six-dimensional parameters which, using current technology, are most often specified using a mouse (a two-dimensional device) or a keyboard (a zero-dimensional device). By creating better tools for flux visualization, combined with advanced user interfaces which minimize barriers in the human-machine interface, reservoir simulations can be better understood, hence better strategies for reservoir production devised.

## 2.0 Assessment of Current Technology

### 2.1 Flux Visualization

It is difficult to visualize three-dimensional flux though porous media using a two-dimensional representation of the three-dimensional flux generated by the reservoir simulation. With current methodology, having three flux arrows representing each of the three phases (oil, gas, and water) at each grid block results in having hundreds of thousands of flux arrows in a single image for a full-field simulation model. Incorporate a highly faulted structure and the three-dimensional flux becomes even more difficult to assimilate. Furthermore, petroleum technologists are constantly asked to review more production scenarios or alternatives in shorter periods of time, thereby increasing the need for more effective ways to interpret simulation results. The need to transform the vast amounts of simulation results into easily understood images is crucial to improving their effectiveness. An effective display of the interblock flow and flux vectors is currently not available in any commercial reservoir simulation post-processor.

## 2.2 Virtual Reality

The media has painted a picture of Virtual Reality (VR) that portrays users wearing Head Mounted Displays (HMDs) and Data Gloves. The devices, rather than the underlying technology, have captured the public's attention. The fundamental premise of VR is simple and can be quickly brought to bear on day-to-day problems in scientific computing. VR is an interface technology, analogous to a window-system-based, point-and-click interface, in which the user specifies three- or six-dimensional information in a way which is intuitive.

Previous work in combining VR with scientific visualization has ranged the gamut from multi-million dollar, single user systems (see [1]), multi-viewer systems (see [2]), to low-cost, desktop VR for controlling a reservoir simulator (see [3],[4]). By concentrating on desktop implementations of VR interfaces that use low-cost, off-the-shelf devices, this technology can quickly migrate from the research laboratory or the video game arcade onto the desks of scientists and engineers. For example, many visualization tools require three- or six-dimensional information: slicers, data probes, particle advection, streamline origin points, camera positions, etc. At present, the status quo is to use the mouse (a two-dimensional device) or keyboard (a zero-dimensional device) to specify each of these parameters.

# 3.0 Technical Approach

All principals will participate in each stage of research, development and commercialization of both flux visualization and VR input. The approach to be used capitalizes upon the strengths of each of the participants: the knowledge and experience base of reservoir engineering at BP; the experience base of commercial geoscience visualization software at WA; the experience base and established track record of LBL as a leader in visualization and VR research.

## 3.1 Flux Visualization

We will investigate the use of alternate visualization techniques for flux, including alternate geometric icons, combining an iconic representation of flux flow with visualization of component concentration, and exploring the use of a scalar value representing multi-component flux as a form of data reduction. The initial prototypes of these algorithms will be built at LBL in Modular Visualization Environment (see [5]) and later ported to production software. The methodology for deriving the combined flux data will be done at BP.

## 3.2 VR Input

A low-cost, six-dimensional VR input device will be used to control general visualization parameters, such as viewpoint, as well as closely coupled with the new algorithm for flux visualization. Among the requirements used in designing and implementing this VR Input interface are: X-windows interface (support for networked VR); inexpensive input device; and modular VR tools that will be later integrated into commercial software.

## 4.0 Tasks

- Derive scalar representation of combined-component flux.
- Evaluate latest in VR Input devices.
- R&D of prototype VR Input device driver code, modular tools.
- R&D of prototype for flux visualization (includes user interaction via VR Input device)
- Commercialization of VR Input tools and flux visualization.
- Publish research papers describing results in both petroleum and scientific computing journals.

## 5.0 Participant Contributions

- LBL: Project coordination, co-development of flux visualization algorithms, initial implementation of VR-input handlers, research of flow-visualization techniques.
- BP: Test data for flux visualization algorithms, co-development of flux visualization algorithms, co-development of scalar combined-phase flux data.
- WA: Co-development of flux visualization algorithms, provide development environment for sample implementation of flux visualization and VR input control of visualization tools, development environment for implementation of VR-input control of simulation parameters, which includes two user licenses for 3DVIEW for use solely at LBL, co-development of scalar combined-phase flux data.

## 6.0 Plan for Commercialization

Implementations of advanced visualization techniques for flux visualization and modular tools for VR input will be made available to the public in two forms:

- Commercially available and supported software: Western Atlas' 3DVIEW.
- AVS and Khoros Modules (Modular Visualization Environments): source code available via anonymous ftp.

The results of the R&D that form the technological base for these implementations will be presented in research papers to be published in both petroleum and scientific computing journals.

## 7.0 Funding Profile

**FY95** Total: $205K from DOE/ACTI

- LBL - $100K personnel (1/2 FTE)
  $75K equipment
  $20K travel
  $10K 3rd party software licenses
- BP - $1128K Proprietary and test data.
  1/4 FTE

- WA - $100K test-bed environment (to LBL)
  1/4 FTE

**FY96** Total: $60K from DOE/ACTI

- LBL - $50K personnel (1/4 FTE)
  $10K travel
- BP - 1/8 FTE
- WA - 1/8 FTE
  $20K maintenance on 3DVIEW

## 8.0 Deliverables

**FY95**

- Demonstration of flux visualization algorithm in 3DVIEW and AVS/Khoros modules.
- Article in technical journal describing Flux Visualization algorithms.
- Release of Flux visualization algorithm using AVS/Khoros modules.
- Release of Flux visualization algorithm in 3DVIEW.
- Demonstration of modular VR-input.
- Article in technical journal describing modular VR-input.

**FY 96**

- Release of AVS/Khoros modules implementing modular VR-input.
- Release of 3DVIEW implementing modular VR-input.

## 9.0 References

[1] Bryson, S. and Levit, C., "The Virtual Windtunnel: An Environment for the Exploration of Three-Dimensional Unsteady Flows", *Proceedings of IEEE Visualization 91,* pp. 17-24.

[2] Cruz-Niera, C., et al., "Scientists in Wonderland: A Report on Visualization Applications in the CAVE Virtual Reality Environment", *Proceedings of IEEE 1993 Symposium on Research Frontiers in Virtual Reality*, pp. 59-66.

[3] Bethel, W., Jacobsen, J. and Holland, P. "Site Remediation in a Virtual Environment", *Proceedings of IS&T/SPIE Symposium on Electronic Imaging Science and Technology,* January 1994.

[4] Jacobsen, J., Bethel, W., Datta Gupta, A., and Holland, P., "Petroleum Reservoir Simulation in a Virtual Environment", accepted for presentation at the 1995 Symposium on Reservoir Simulation, San Antonio, Texas, February 1995.

[5] Upson, C., et al., "The Application Visualization System: A Computational Environment for Scientific Visualization", *IEEE Computer Graphics and Applications,* Volume 9, Number 4, July 1989.