1 Introduction
This paper presents a remote rendering application that involves the extension of the Visualization Toolkit (vtk) and the Video Conferencing Tool (vie) for use in remote rendering complete with interaction from the remote site using the vie user interface. Vtk is an open source C++ library, with Tel, Python, and Java bindings for computer graphics, image processing, and visualization [3]. Vtk provides a higher level of support, beyond the traditional low-level libraries, for creating visualization applications. Vtk includes algorithms to support the visualization of scalars, vectors, and tensors. Vic is a flexible tool built by Lawerence Berkeley National Laboratory for real-time video conferencing over the Internet [2]. Vic's user interface is built as Tcl% script embedded in the applications. This allows developers to prototype changes to the interface in a simple and straightforward manner.

2 Remote Rendering
The vic source code was modified to stream output from interaction with its window to a given port on a given machine. This stream is then received by a standard vtk application augmented with a network-based interactor. This allows multiple sites to interact using the standard vtk interactor controls with the remote vtk application via the vic window. Figure 1 shows a diagram of the system.

The output of the vtk application at this point is scan converted from the server machine and streamed into a standard video capture card for broadcast on a multicast address. This application allows a remote user to have direct control of the application without concern about the rendering power of the host machine. The user is able to interact in realtime with a one million-polygon model from a standard desktop PC. Figure 2 shows a snapshot of the remote rendering output and the output as seen in the vic window.

Users need only to apply a set of patches to the vic source code and recompile for the remote site. Users with existing vtk applications need only to replace their current vtkfnteractor with a vtkNetworkInteractor to address the remote user interaction. As mentioned before, the current implementation requires the scan conversion of output for video streaming, but a new version is under way that will create a new vtkRenderer for generating the network video stream. This will be based on ANL's CAVEav library that generates synthetic video streams from within a CAVE application for multicast broadcast [1] using the vic tool.

3 Conclusion
This system provides a large community of users with the capability of remote visualization, with interactivity at the remote site using existing tools and infrastructure. The extensions to vtk will be made available to the community, allowing any developer to plug the networked-based interactor into existing or future vtk applications. In addition, since the source code will be made available, developers will have the opportunity to extend the functionality. We have begun to develop the networked rendering side enabling users to use this tool wherever they have the most graphics horsepower and connect to other users for remote viewing without the need for the scan conversion.

4 Acknowledgments
Special thanks to Tony Lavoie for the additions and improvements he has made to the initial prototype. Additionally we thank the members of the Access Grid community that have field tested the system. This work was supported by the Mathematical, Information, and Computational Sciences Division subprogram of the Office of Advanced Scientific Computing Research, U.S. Department of Energy.

NEUTRONIC FEASIBILITY STUDIES USING U-Mo DISPERSION FUEL (9 Wt % Mo, 5.0 gU/cm³) FOR LEU CONVERSION OF THE MARIA (POLAND), IR-8 (RUSSIA), AND WWR-SM (UZBEKISTAN) RESEARCH REACTORS

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INTRODUCTION

- The motivation to consider LEU conversion applications using 8-9 gU/cm$^3$ rolled fuel plates and 5-6 gU/cm$^3$ extruded fuel tubes is based on:

  - Good results from RERTR irradiation tests of small-sample U-Mo Al-based dispersion fuels for Mo weight fractions of 7-10% and burn-ups to 70%.

  - Existing experience in fabricating high-volume-loaded dispersion fuels.

- U-9Mo (9 wt % Mo) dispersion fuel has been used in the Russian AM nuclear power plant since the 1950’s.

- These LEU conversion studies use:

  - U-9Mo Al-based dispersion fuel
  - Meat density = 5.00 gU/cm$^3$
  - U-9Mo volume fraction = 32.5%

- Three Russian-designed research reactors with extruded fuel elements have been analyzed for LEU conversion with this U-9Mo fuel. They are:

  - MARIA reactor (Swierk, Poland)
  - IR-8 reactor (Moscow, Russia)
  - WWR-SM reactor (Ulugbek, Uzbekistan)
Horizontal Cross Section of the MARIA Reactor
M6 Fuel Assembly

![Diagram of M6 Fuel Assembly]

M6 Fuel Assembly Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HEU</th>
<th>LEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{235}$U Enrichment, wt %</td>
<td>80.0</td>
<td>19.7</td>
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<tr>
<td>Fuel Meat</td>
<td>UAl-Alloy</td>
<td>U-9Mo Al</td>
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<tr>
<td>Uranium Density in Meat, g/cm$^3$</td>
<td>1.28</td>
<td>5.00</td>
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<tr>
<td>Dispersant Volume Fraction, %</td>
<td>28.3</td>
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<td>Meat/Clad/Element Thickness, mm</td>
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<td>.60/.70/2.00</td>
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<td>Coolant Channel Thickness, mm</td>
<td>2.05</td>
<td>2.05</td>
</tr>
<tr>
<td>Length of Fuel Meat, mm</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>$^{235}$U Mass per Fuel Assembly, g</td>
<td>350</td>
<td>506</td>
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</table>
Horizontal Cross Section of the IRT-3M and IRT-4M Fuel Assemblies

8-Tube FA  
6-Tube FA

IRT-3M Fuel Assembly Parameters
(For the IR-8 and WWR-SM Reactors)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HEU-1</th>
<th>HEU-2</th>
<th>LEU</th>
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<tr>
<td>$^{235}$U Enrichment, wt %</td>
<td>90.0</td>
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<td>19.75</td>
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<tr>
<td>Fuel Meat</td>
<td>UO$_2$-Al</td>
<td>UO$_2$-Al</td>
<td>U-9Mo Al</td>
</tr>
<tr>
<td>Uranium Density in Meat, g/cm$^3$</td>
<td>1.07</td>
<td>2.51</td>
<td>5.00</td>
</tr>
<tr>
<td>Dispersant Volume Fraction, %</td>
<td>12.1</td>
<td>28.5</td>
<td>32.5</td>
</tr>
<tr>
<td>Meat/Clad/Element Thickness, mm</td>
<td>.40/ .50/1.40</td>
<td>.50/ .45/1.40</td>
<td>.50/ .45/1.40</td>
</tr>
<tr>
<td>Coolant Channel Thickness, mm</td>
<td>2.05</td>
<td>2.05</td>
<td>2.05</td>
</tr>
<tr>
<td>Length of Fuel Meat, mm</td>
<td>580</td>
<td>580</td>
<td>580</td>
</tr>
<tr>
<td>$^{235}$U Mass per Fuel Assembly, 6/8 tube, g</td>
<td>264/300</td>
<td>309/351</td>
<td>339/385</td>
</tr>
</tbody>
</table>

Note: U-9Mo is a U-Mo alloy containing 9 wt % Mo.
MARIA REACTOR
16 FUEL ASSEMBLY REFERENCE CORE CONFIGURATION
(GRAPHITE REFLECTOR OUTSIDE Be MATRIX)

IR-8 Reactor Core Configuration

6-tube FA with vertical experiment channel
6-tube FA with channel and shim-safety rod
6-tube FA with channel and safety rod
Beryllium block with channel and automatic regulating rod
Beryllium block with hole for experiment channel
WWR-SM Reactor Core Configuration

1 2 3 4 5 6 7 8

8

7

6

5

4

3

2

1

6-tube FA with vertical experiment channel

6-tube FA with channel and shim/safety rod

8-tube FA with vertical experiment channel

Beryllium block with hole for experiment channel

Solid beryllium block
Analytical Methods and Codes

**MCNP Code**: Used for Fresh Fuel Monte Carlo Calculations for Detailed Reactor Models Including Beam Tubes.

**WIMS-ANL Code**: Used to Generate Burnup-Dependent 7-Group Cross Sections from ENDF/B-VI Data.

**DIF3D Code**: Three-Dimension Diffusion Calculations Used to Determine DIF3D/MCNP Excess Reactivity Bias Factors.

MARIA Research Reactor
EOEC Reactivity and $^{235}$U Burnup vs Equilibrium Cycle Length

HEU (80.0%) Fuel: U-AL Alloy, 1.28 gU/cm$^3$, 350g $^{235}$U/FA
LEU (19.7%) Fuel: U-9Mo-Al, 5.00 gU/cm$^3$, 506g $^{235}$U/FA
Clad Thickness vs Uranium Density for a Fixed Cycle Length of 9.22 fpd's and a Fixed Average $^{235}$U Discharge Burnup of 45.0% (MARIA Research Reactor)

(Uranium Density in Fuel Meat, (g/cc)

Clad Thickness, (mm)

U-9Mo Volume Fraction in Fuel Meat, (%)

$^{235}$U Mass per Fuel Assembly is 418 g)

(235U Mass per Fuel Assembly is 418 g)
WWR-SM Research Reactor
EOEC Reactivity vs Equilibrium Cycle Length
(IRT-3M 6- and 8-Tube Fuel Assemblies)

- HEU (90%) UO₂-Al, 1.07 gU/cc
- HEU (36%) UO₂-Al, 2.51 gU/cc
- LEU (19.75%) U-9Mo Al, 5.00 gU/cc
- LEU (19.75%) U-9Mo Al, 5.30 gU/cc

Cycle Length, (full power days)
SUMMARY AND CONCLUSIONS

For the same EOEC excess reactivity as the HEU (80 or 90%) reference fuel, LEU U-9Mo Al-dispersion fuel (5.00 gU/cm³, 32.5% U-9Mo by volume) matches or exceeds the performance of the reference fuel for the MARIA, IR-8, and WWR-SM research reactors. LEU fuel element thicknesses are the same as the HEU reference fuel.

MARIA Research Reactor:

- The annual consumption of FA's is reduced by a factor of 2.
- The \(^{235}\text{U}\) peak discharge burnup is 72%.
- Thermal neutron fluxes in sample positions are reduced by 7%.

For the same clad thickness, meat thickness, and discharge burnup as the 80%-enriched M6 FA's, a LEU U-9Mo density of about 6 gU/cm³ would be needed.

IR-8 Research Reactor:

- The annual consumption of FA's is reduced by about 11%.
- The peak \(^{235}\text{U}\) discharge burnup is 64%.
- Thermal neutron fluxes in beryllium reflector sample positions are reduced by about 6%.

To match the performance of 36%-enriched UO₂-Al IRT-3M FA's, the LEU U-9Mo fuel density would need to be increased to 5.05 gU/cm³.
SUMMARY AND CONCLUSIONS
(CONTINUED)

WWR-SM Research Reactor:

- The annual consumption of FA's is nearly the same as for the 90%-enriched reference fuel.
- The peak $^{235}\text{U}$ discharge burnup is 40% for the 6-tube and 64% for the 8-tube IRT-3M FA's.
- Thermal neutron fluxes in sample positions are reduced by 8%.

To match the performance of 36%-enriched UO$_2$-Al IRT-3M FA's now in use, the LEU U-9Mo fuel density would need to be increased to $\approx 5.4$ gU/cm$^3$.

Full-size LEU U-9Mo (5.0 gU/cm$^3$) M6 and IRT-3M Al-dispersion fuel assemblies need to be fabricated, irradiated and examined before they are qualified for use in the MARIA, the IR-8, and the WWR-SM research reactors.