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3D COMPUTER VISUALIZATION AND ANIMATION OF CANDU REACTOR CORE

by
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ABSTRACT

Three-dimensional (3D) computer visualization and animation models of typical CANDU reactor cores (Darlington, Point Lepreau) have been developed using world-wide-web (WWW) browser based tools: JavaScript, hyper-text-markup language (HTML) and virtual reality modeling language (VRML).

The 3D models provide three-dimensional views of internal control and monitoring structures in the reactor core, such as fuel channels, flux detectors, liquid zone controllers, zone boundaries, shutoff rods, poison injection tubes, ion chambers.

Animations have been developed based on real in-core flux detector responses and rod position data from reactor shutdown. The animations show flux changing inside the reactor core with the drop of shutoff rods and/or the injection of liquid poison.

The 3D models also provide hypertext links to documents giving specifications and historical data for particular components. Data in HTML format (or other format such as PDF, etc.) can be shown in text, tables, plots, drawings, etc., and further links to other sources of data can also be embedded.

This paper summarizes the use of these WWW browser based tools, and describes the resulting 3D reactor core static and dynamic models. Potential applications of the models are discussed.

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1. INTRODUCTION

The Internet and the World-Wide-Web (WWW) technology has undergone a rapid progress in the past few years. The newest development in this technology is the transition of the Web from two-dimensional (2D) to three-dimensional (3D). The introduction of the virtual-reality-modeling-language (VRML) is the key to this transition. VRML was developed by an open forum in the past four years. Its initial purpose was for developing 3D graphics to show on the Internet. The VRML Architecture Group (VAG) was formed in 1995 to shape the VRML standard. The VRML language has evolved from version 1.0 "virtual-reality-markup-language" to version 2.0 "virtual-reality-modeling-language" and is still in the process of development.

Although the VRML language is only four years old, it has already found many applications in a variety of fields. One of the most interesting application is the Mars Pathfinder Mission. The VRML 3D models allow one to view the Mars Pathfinder lander and rover, and the virtual terrain models around the Sagan Memorial Station on Mars (see <http://mars.sgi.com/vrml/vrml.html>).

VRML offers the ability to describe 3D objects (called "worlds") and combine them into scenes. It also provides the capability of interacting with online material through 3D sight and sound, simulating the way we move about in the real world, and giving us a scene of depth and perspective.

VRML 2.0 was used in developing the 3D CANDU reactor core model. The VRML models developed can be viewed with an ordinary WWW Browser along with a 3D VRML player (freeware available at <http://cosmo.sgi.com/cgi-bin/download.cgi>).

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2. VISUALIZATION TOOLS

2.1 Computer System Requirements

One striking advantage of the 3D modeling work described in this paper is that both the developing and viewing the VRML 3D models were realized using ordinary PC and inexpensive software tools, thus providing a low cost and quick prototype solution for many potential applications.

The computer system requirements, for either developing or viewing the VRML 3D models, are listed below:

- An ordinary PC with 100 MHz or higher clock speed,
- 16 MB or larger RAM space,
- Windows 95 or NT, and
- Netscape Web Browser 3.0 or higher.

Tests on a platform meeting the above requirements achieved reasonable rendering speed and quality. Larger monitors improve viewing but are not necessary.

The Microsoft Internet Explorer distributed with Windows 95 has been found incompatible with the Cosmo Player (a VRML Player with the Netscape browser), and is not recommended for viewing the 3D CANDU reactor core models.

2.2 Visualization Tools

Visualization tools used in developing and viewing the 3D models include three categories: the programming languages (VRML, HTML, JavaScript) [1], the VRML authoring tools, and the viewing software packages (WWW browsers and the plug-in VRML Players) [2].

3. THREE-DIMENSIONAL MODELS

3.1 3D Visualization Models

Figure 1 shows the visualization of reactor-detail of PLGS core. Included in reactor-detail are:

- a text string “Calandria Detail”,
- X-Y-Z axes and directions “South-North”, “Top-Bottom”, “Ease-West”,
- grid “1” to “22” and “A” to “W” (except “I”),
- lattice grid origin (as a small sphere),

- tow outer rings of fuel channels,
- fictitious zone boundaries,
- liquid zone controllers,
- RRS detectors of Channel A and C (red vertical cylinders, 3 lattice-pitch long),
- SDS1 detectors of Channels D, E, F (red vertical cylinders, 3 lattice-pitch long),
- SDS2 detectors of Channel G, H, J (red horizontal cylinders, 3 lattice-pitch long),
- flux-mapping detectors (yellow vertical cylinders, one lattice-pitch long),
- 6 ion chambers of SDS1 and SDS2 on two sides of the core (yellow horizontal),
- 28 shutoff rods of SDS1 that are normally above the core (black vertical cylinders), and
- 6 liquid poison injection tubes (white horizontal).

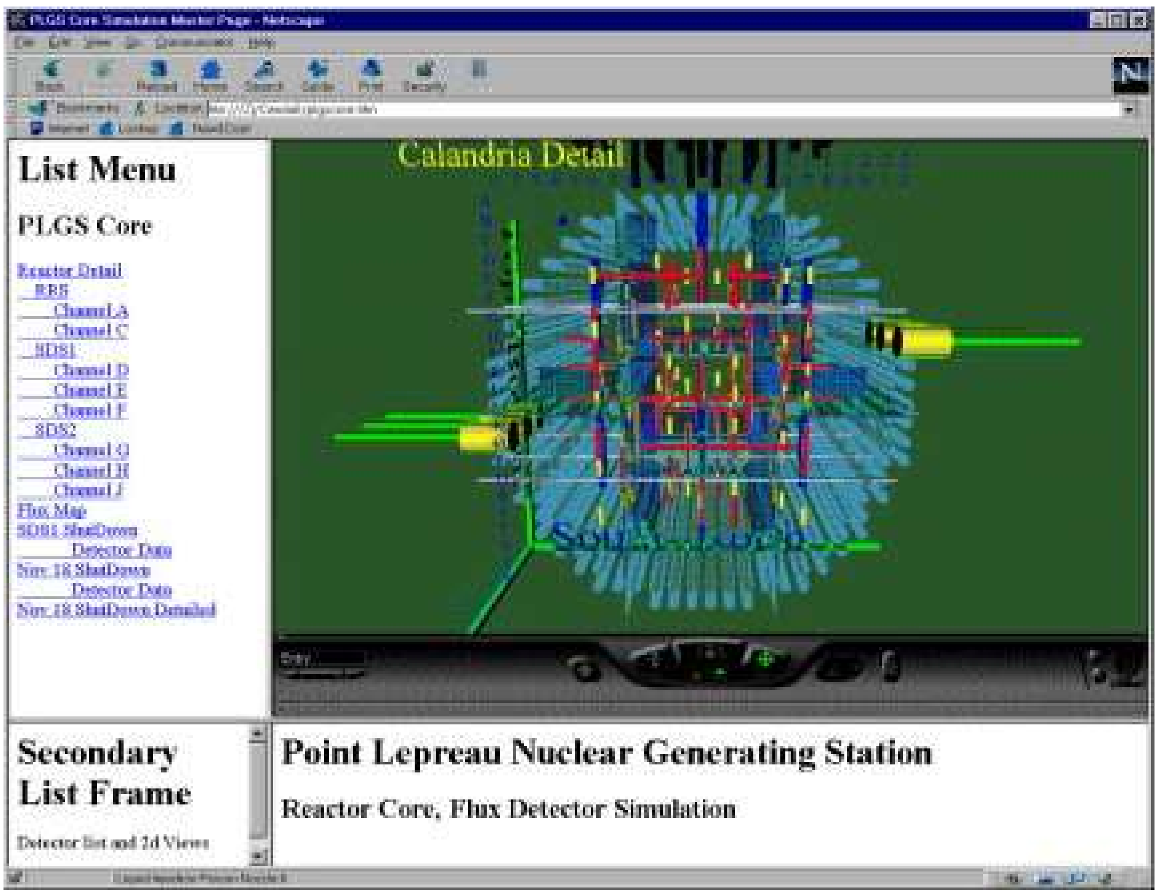

Figure 1. Reactor-detail of PLGS core

The "List Menu" frame in Figure 1 provides a list of 3D models of various subsystems of the core and the animations. Upon clicking the entry in List Menu, the corresponding 3D model is shown in the Main frame (the upper right frame). The lower left and lower right frames provide areas to show the related information hot-linked to the component in the reactor core.

Four view points were built into the 3D models that provide views from:

Entry	viewing the reactor core from east end of the core,
Top	viewing the reactor from top of the core,
Side	viewing the reactor from side of the core, or
Alternate	viewing the reactor from top and North-East of the core.

Figures 2 and 3 show the "Entry" and "Top" view of flux-mapping detector subsystem of the reactor core.

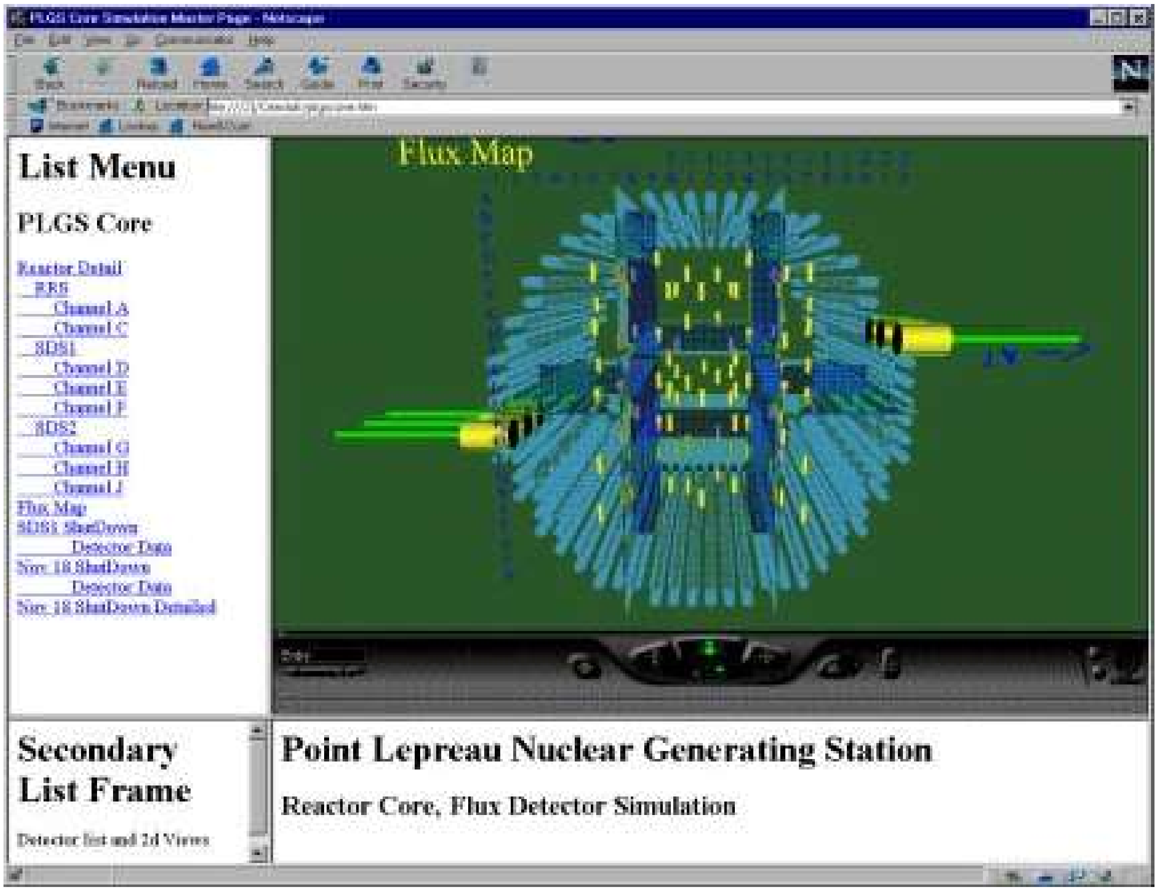

Figure 2. Flux-mapping "Entry" view point

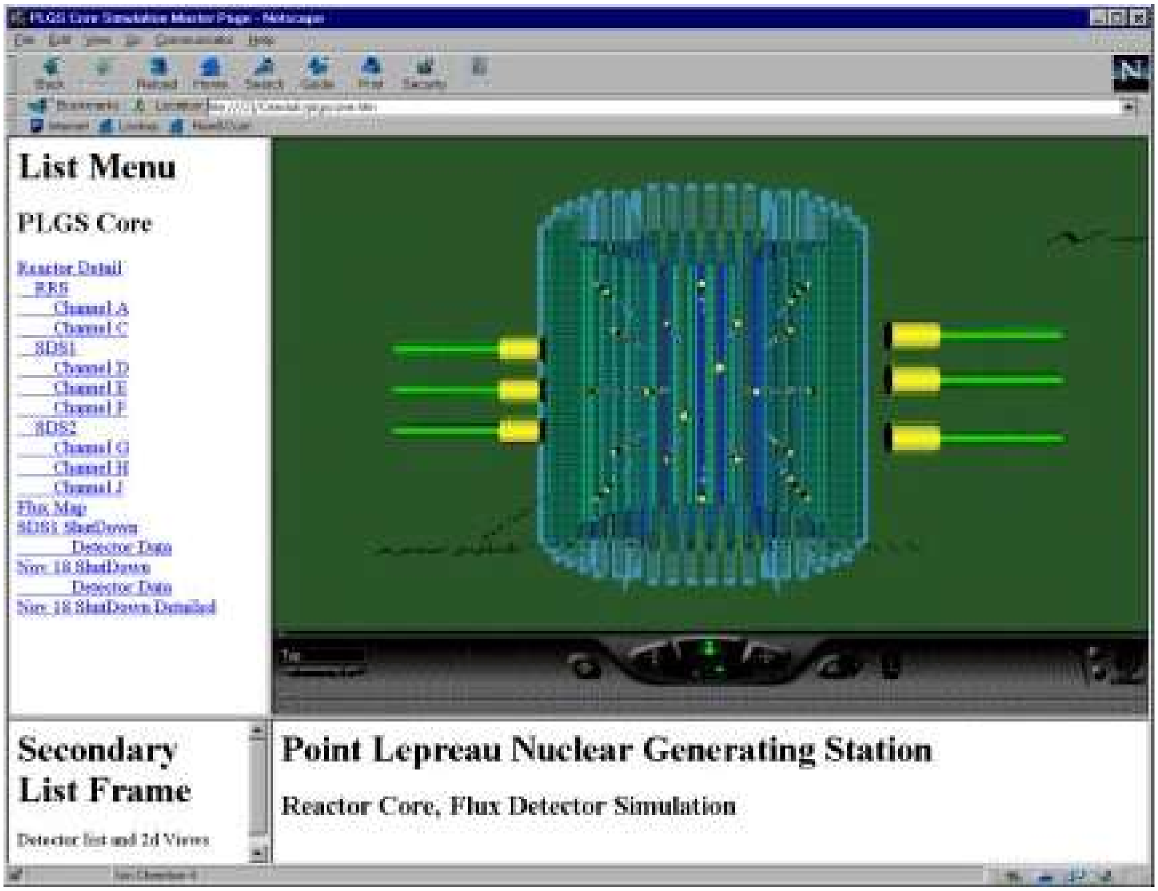

Figure 3. Flux-mapping "Top" view point

From these selectable initial view the user can walk around in the 3D world using the control functions provided by the 3D Player.

Figure 4 shows an extreme close-up view of a liquid zone controller and a Channel A RRS detector. They were shown in the d3D world in cylinder shape. The liquid zone controller detector was rendered in red color with length of 3, diameter of 0.4 (in lattice-pitch). The liquid zone controller (blue) was pointed at by the mouse and the Windows border shows the name of the name "Liquid Zone Controller, Zone 13".

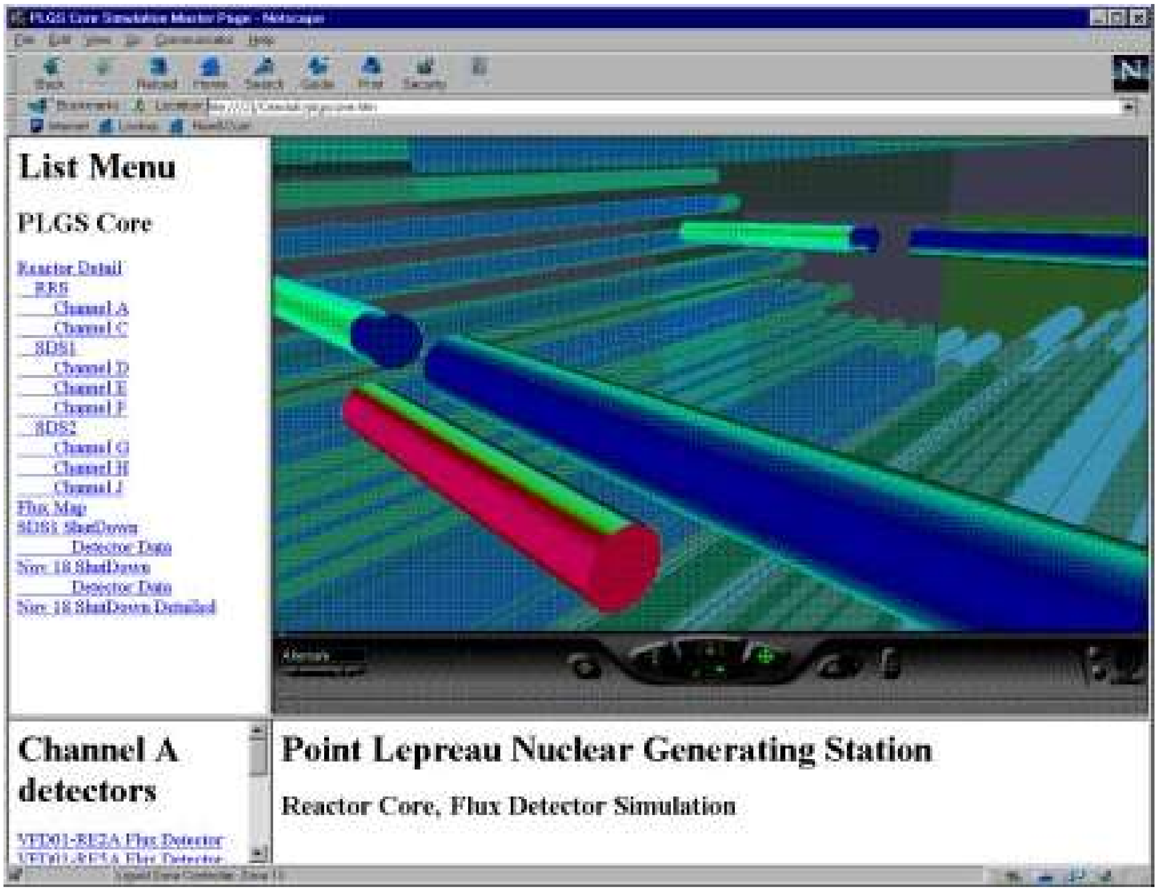

Figure 4. A Close-up view of a liquid zone controller and a Channel A detector

3.2 3D Animation Models

VRML has the capability of animating a dynamic process and that capability is further enhanced by using the JavaScript for complicated animations of live processes. This live animation capability has been employed in developing the 3D animations of reactor shutdown process. The description of how the animation is realized is given in [1].

The flux level change with the insertion of the shutoff rods or injection of liquid poison were animated. Different colors were used to indicate different flux levels in the reactor core. The detectors in the 3D scene have a continuous color change with the activation of the shutdown mechanism. The actual flux measurement during the shutdown were taken and used for color interpolation. The recorded shutoff rod positions during the shutdown were used for position interpolation that show the drop of the shutoff rods.

A column of color boxes of different color is shown as the color scale corresponding to different flux levels. From the color red to blue corresponding to five flux levels (100%, 75%, 50%, 25%, 0%).

Figure 5 shows the shutdown animation based on data from a Unit 1 SDS2 trip occurred on 1997 April 29 at DNGS. The whole process of SDS2 shutdown from 100% flux to 0% flux took about 150 millisecond. The rendering speed can be chosen for 15 seconds, or 30 seconds, to 60 seconds. Figure 5 is one snapshot in the middle of the shutdown animation. It can be seen from the color of the detectors that there is a gradient of flux levels from South to North. Since the poison was injected from South and propagated to North, the flux level reduction occurs earlier on the South side.

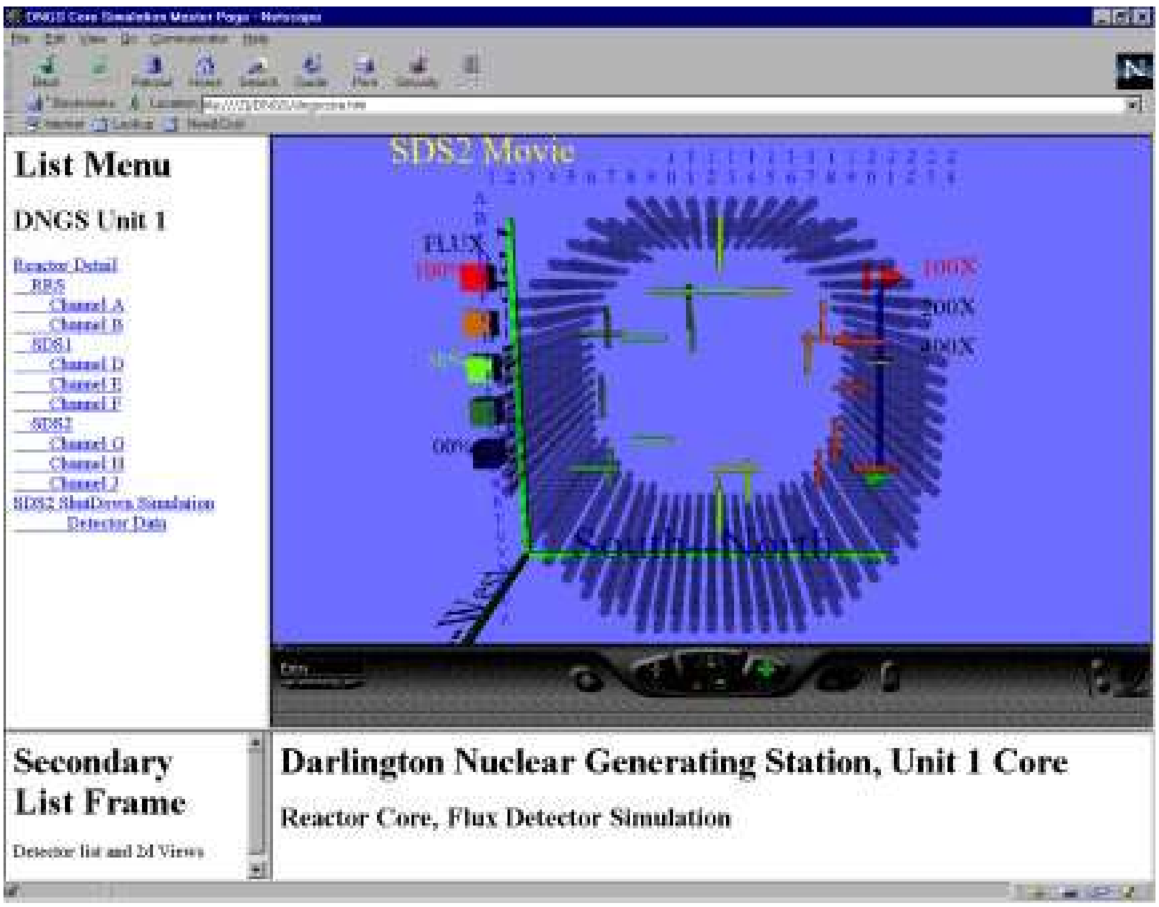

Figure 5. Animation for DNGS SDS2 shutdown

Figure 6 shows the shutdown animation based on data from a SDS1 trip occurred on 1995 December 25 at PLGS. The whole process of SDS1 shutdown from 100% flux to 0% flux took about 1.5 seconds. The rendering speed can be chosen for 15 seconds, or 30 seconds, or 60 seconds. Figure 6 is one snapshot in the middle of the shutdown animation. It can be seen that the rods were in the middle between the initial out-of-core and the "fully in" positions. There is a gradient in the flux level from top to bottom as indicated by the blue-colored detectors at the top of the core and the red-colored detectors near the bottom of the core.

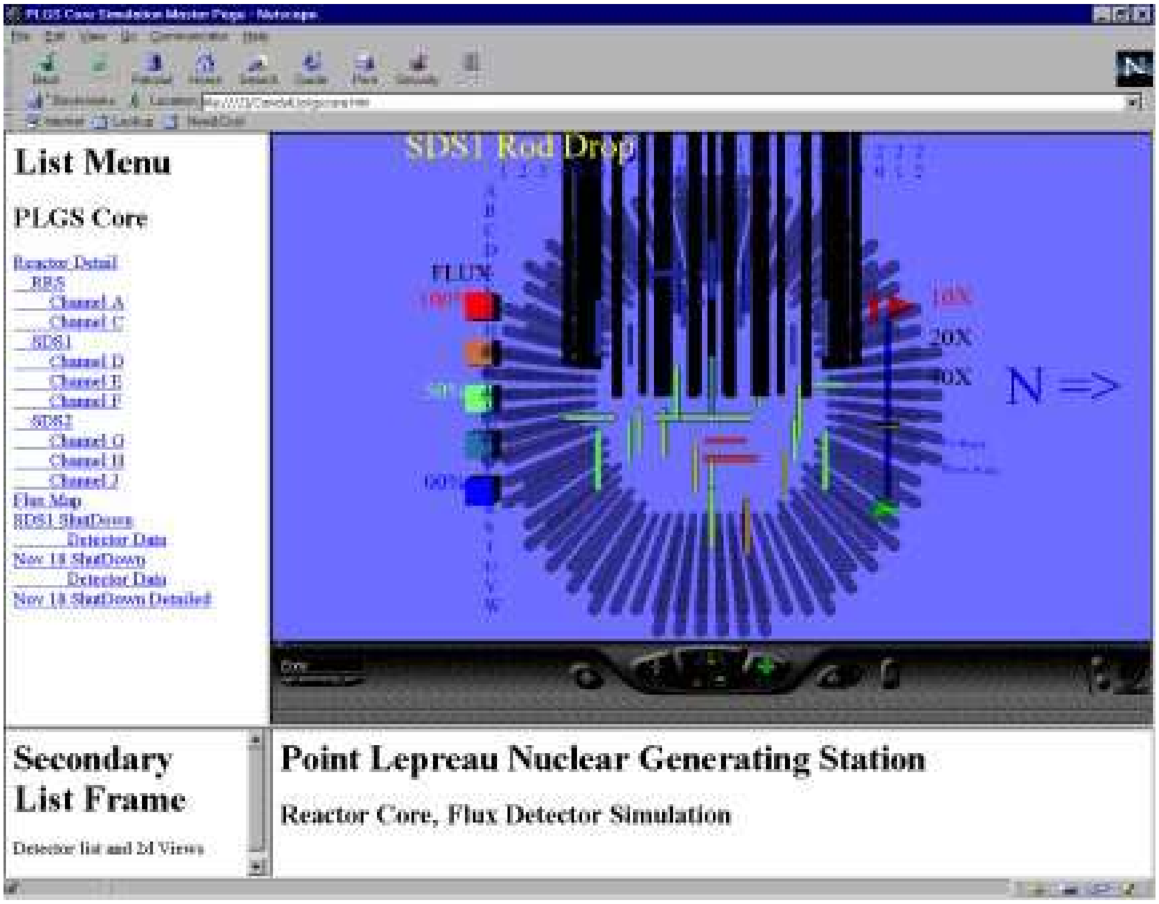

Figure 6. Scene in the middle of SDS1 shutdown animation

Figure 7 shows the shutdown animation based on data from a SDS1 and SDS2 trip occurred on 1997 November 18 at PLGS. Figure 7 shows the scene of the end of the shutdown where the rods are in the “fully in” position and the color of the detectors is blue, indicating low flux.

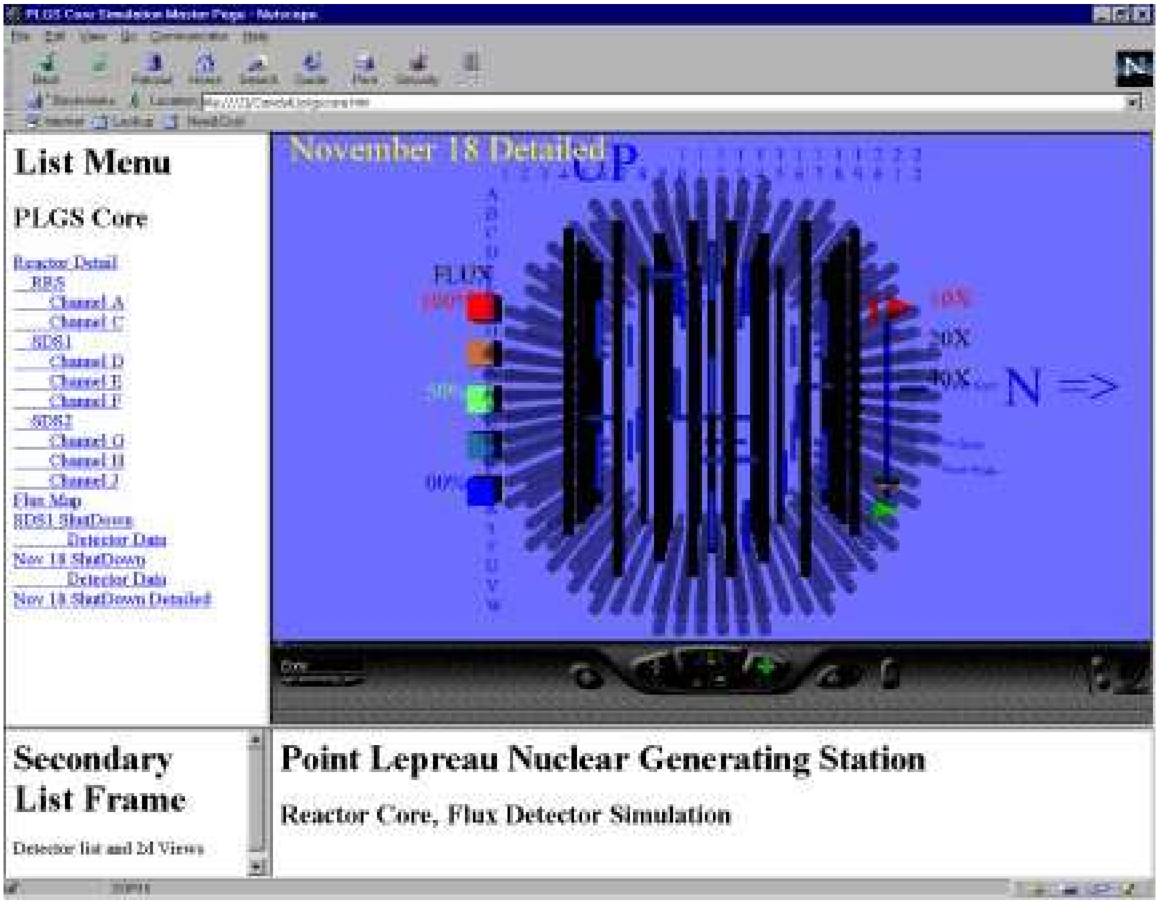

Figure 7. Scene at the end of shutdown animation

4. APPLICATIONS OF THE 3D MODELS

The low cost 3D models of a reactor core are very useful tools in a variety of applications as follows:

Training
The trainee can "walk through" the reactor core showing different mechanical and I&C parts of the core. These parts can be viewed from different angles and distances. Specific views can be selected to show perspectives of particular interest. As the pointer (a mouse) is moved over the components in a 3D scene, the user will see a change in shape of the pointer (indicating a hot link is detected) and a text description of that component in the border of the window.

Linking and organizing data
The 3D models provide an effective tool for linking and organizing data. By clicking the mouse at a time when it shows a link, the viewer brings up related information for the

component that the mouse is pointing at. Data sources that are otherwise scattered or embedded in different designing manuals, data sets, drawings can be linked together and easily retrieved. Reference document numbers, or even these documents themselves can also be organized and linked to the particular reactor component shown in the scene.

Facilitating station operation and maintenance
The enriched and well organized data source linked to the particular components enables station operation and maintenance staff to visually look at the internal of the core before performing maintenance work on a particular component, and avoid human errors in operation and maintenance.

Assisting marketing initiatives and public-relations
Marketing staff can use the 3D reactor models to show the potential customers the structure of the CANDU reactor core, and the control and safety features of a CANDU reactor. The public-relations department can also use the models in various activities dealing with the public.

5. SUMMARY

This paper describes the tools and results of 3D visualization and animation models developed for CANDU reactor core, and the potential applications of the models.

6. REFERENCES

[1] J. Hartman, J. Wernecke, “The VRML 2.0 Handbook”, Silicon Graphics Inc., Addison Wesley Publishing Company, 1996, ISBN 0-201-47944-3.

[2] Cosmo Player 2.0 On-Line Help, Silicon Graphics Inc.