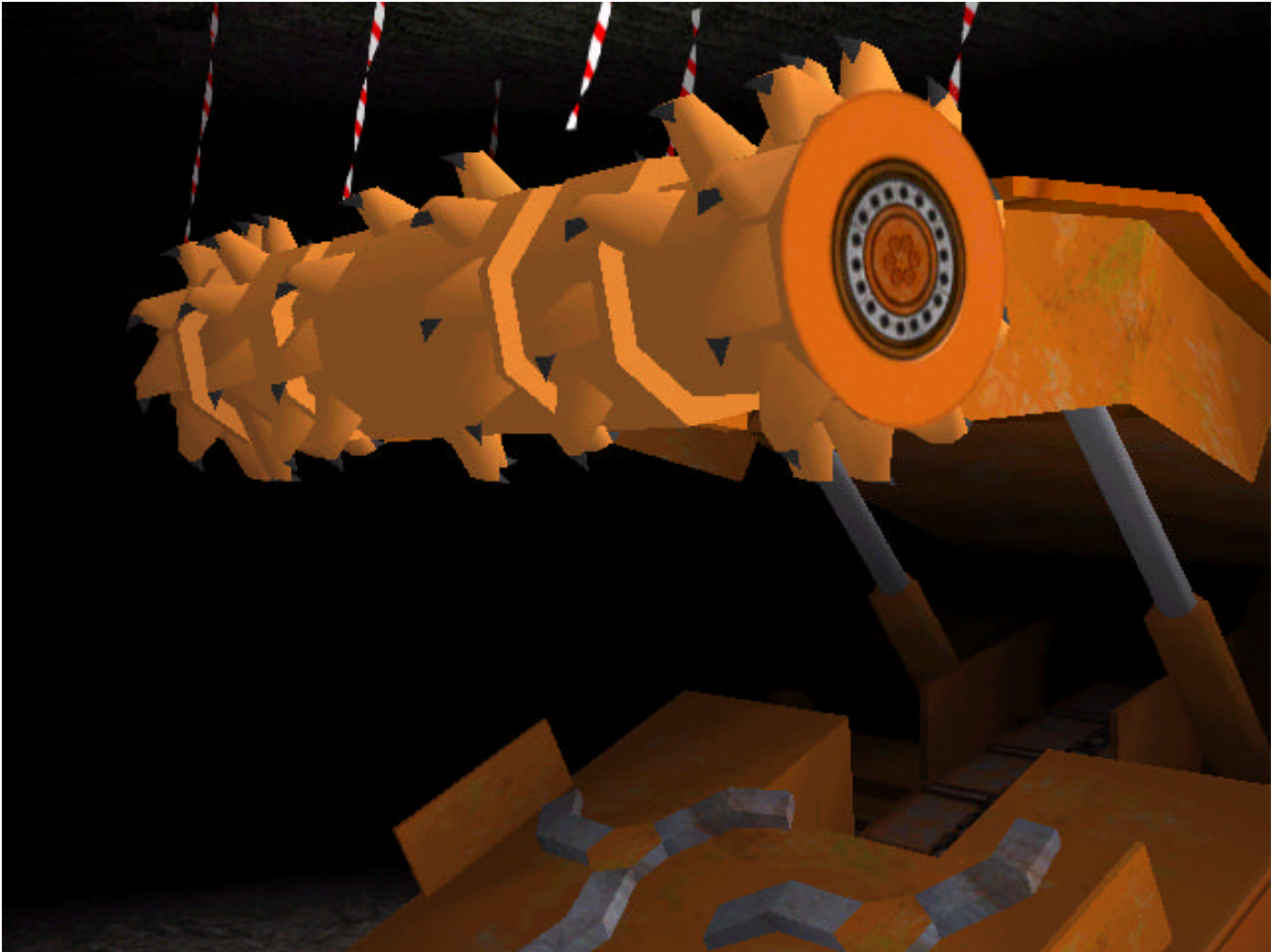


5DT VR COAL



Virtual Reality Continuous Miner Training Simulator

5DT
Fifth Dimension Technologies

www.5dt.com

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1.0 System Description

1.1 System Overview

The 5DT Virtual Reality Continuous Miner Training Simulator [VR Coal hereafter] teaches the Continuous Miner [CM] trainee how to control a CM in such a way as to **increase productivity while maintaining a high safety standard**. The trainee controls the CM in a virtual coal (or potash) mine with controls that accurately resemble those of a real CM (remote control version). The trainee works through a series of training scenarios that vary in complexity from simplistic training scenarios to very complex and challenging scenarios. The trainee receives a complete training report at the end of each training session. The system may be used for the training of new operators or for evaluation and re-training of experienced operators. The training is performed in a **safe and controlled environment**.

1.2 System Description (please refer to Fig. 1)

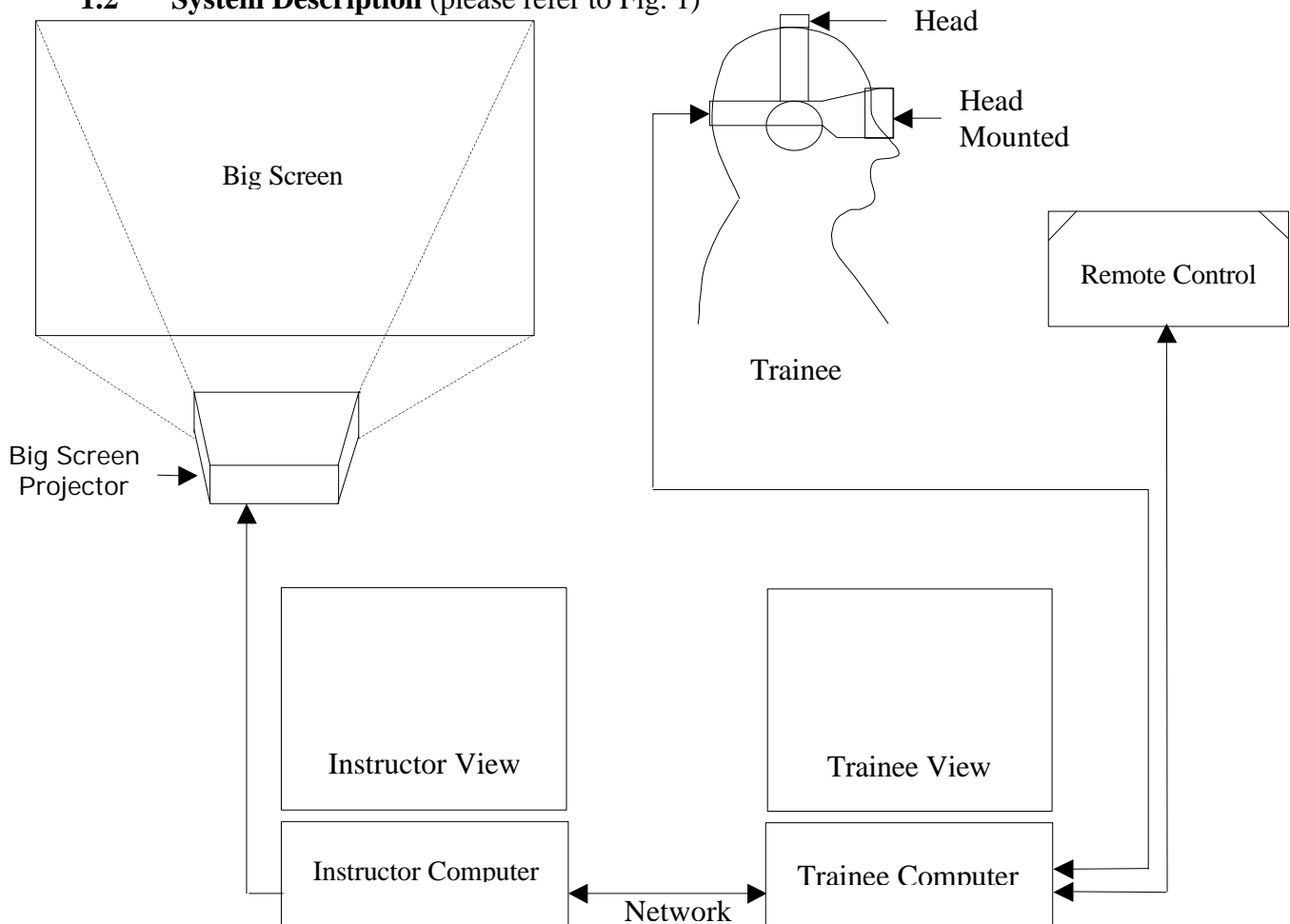


Figure 1 – System Block Diagram

The system consists of two computers that are networked together. The first computer is the **Instructor Computer**, which shows the virtual instructor on the monitor. This computer is also connected to a **Big Screen Projector**. The second computer is the **Trainee Computer**.

When an event occurs, or if the trainee performs a mistake, event messages and/or error messages will be superimposed on the instructor's view. These messages will not be visible to the trainee, yet will be visible on the **Big Screen** to benefit the rest of the class.

The trainee wears a **Head Mounted Display [HMD]** (please also refer to Image 1 on page 14). The HMD contains 2 miniature computer screens and 2 headphones. This enables the trainee to view the virtual mine, virtual Continuous Miner [CM] and virtual Shuttle Car [SC]; as well as hear different sounds created in the virtual environment.

A **Head Tracker** is fitted to the HMD. For example, when the trainee looks downward, the Head Tracker measures their head orientation and relays such positioning information to the trainee's computer. The computer then calculates the image that the trainee would have seen when looking downward in an actual coal mine. This image is displayed on the 2 miniature screens inside the HMD. The computer calculates new images approximately 30 times every second. The result is that the trainee is totally immersed in a virtual environment.

The trainee's view through the HMD is also displayed on the monitor of the trainee's computer (trainee view).

The trainee controls the virtual Continuous Miner [CM] with a **Remote Control Unit** that accurately resembles a real remote control unit (please also refer to Image 1 on page 14).

1.3 Background

This system was originally co-developed by **5DT (Fifth Dimension Technologies)** and **Sasol Coal**, one of the leading coal producers in South Africa.

Over the past 2 years more than 400 Continuous Miner [CM] operators have been trained, evaluated or re-trained with the system.

2.0 Applications

2.1 Training of new Continuous Miner [CM] operators

VR Coal allows the instructor to train new CM operators in a controlled and safe environment. A trainee's skills are developed systematically with the CM. The trainee may be exposed to very complex and/or life-threatening scenarios without risk of injury.

2.2 Evaluation and re-training of existing CM operators

VR Coal is ideal for the evaluation of qualified CM operators, since all actions performed by the operator are recorded. The skills of a qualified CM operator may be analyzed in detail, where re-training or corrective training may be applied to sub-optimal skill areas.

For example, a supervisor in an operational coal mine may find faults in a particular operator's performance, and can then schedule corrective simulator training for the operator.

2.3 Research and Development

VR Coal may be used to try new procedures in a virtual realm first, before validating these procedures in reality. VR Coal is an ideal tool for the development and implementation of best practices.

2.4 Familiarization and Introduction tool

It is often the case that a majority of coal mine personnel have not experienced any time underground. This can lead to an unsatisfactory understanding of the coal mining process, which can result in sub-optimal mine management and administration. VR Coal is ideal to expose administrators and managers to the *cutting edge of their industry*.

2.5 Marketing and PR

VR Coal could be used to show visitors what it is like to work in a coal mine, without exposing them to the real environment.

3.0 Benefits

3.1 Highly reduced loss of CM production time during training

It is unnecessary to interrupt actual production to perform basic skills training with VR Coal.

It is important to note that 5DT (Fifth Dimension Technologies) does not propose that Virtual Reality [VR] training replaces reality-based training in totality:

"Virtual Reality is not intended to replace reality-based training. It is a powerful medium intended to supplement and enhance reality-based training."

3.2 Shorter CM operator training periods

VR Coal has been designed to minimize the training cycle while maintaining a very high standard in terms of skills development and safety awareness. The pre-simulation module teaches the user how to optimally control the controls of the CM. The trainee is then exposed to several training scenarios, ranging from simple to complicated scenarios. The system continuously evaluates the trainee so weaknesses in performance are quickly identified.

"With VR Coal, the focus is on Smarter Production, not just Increased Production."

3.3 Enhanced CM operator skills development

With VR Coal, trainees may be exposed to a wide variety of conditions and environments, some which may be life threatening in actuality. A trainee can be prepared for much more than average/normal conditions.

VR Coal can exactly measure trainee performance, which can lead to an enhanced skills development.

3.4 Improved application of best practices

VR Coal enables a mining group to evaluate and optimize their best practices. Once these have been identified and established, VR Coal may be used during workplace implementation.

3.5 Increase in annual average tonnage per CM

The annual tonnage per continuous miner may be increased significantly with the use of VR Coal. An initial user¹ reported an average annual increase from 478kT to 604kT per CM. This reflects a *26% increase*.

3.6 Reduction of dust

The fundamental training strategy behind VR Coal is not simply for increased production, but improved quality of the total production process. Dust reduction is one of the many benefits reaped with the use of VR Coal. The reduction in dust leads to better working conditions, better visibility and a safer working environment (e.g. a lower combustion risk). An initial user¹ reduced dust from 15mg/m³ to 5.4mg/m³, a **64% reduction**.

3.7 Reduced contamination

VR Coal's focus on the quality of production (smarter production versus simply increased production), also contributes to reduced contamination. Whenever an operator cuts into the virtual roof or floor, it is reported by the system. The contamination of an initial user¹ was reduced from 4.1% to 2.3%, a total **reduction of 44%**.

3.8 Reduction of fine coal

An initial user¹ reduced their fine coal² from 31% to 28.2% while using VR Coal.

3.9 Increased safety awareness

A trainee is able to experience the results of their actions with VR Coal. The system continuously evaluates the safety performance of an operator.

1. **Sasol Coal** has been using VR Coal for the past two years. During the same period, a *Renewal Project* was implemented. One of the objectives of the Renewal Project was to standardize operational practices, and VR Coal was one of the instruments used to reach their desired goal. (It is important to note that the obtained benefits listed above cannot be subscribed only to the use of VR Coal. The benefits were the *combined result* of the use of *VR Coal in conjunction with the Renewal Project*.)
2. Sasol Coal's main client, Sasol Synthetic Fuels, specified that the supplied coal particles/chunks were required to be between 6mm (.24") and 60mm (2.36") in diameter for their processes. Within this context, fine coal is therefore considered to consist of particles less than 6mm in diameter.

4.0 Product Features

4.1 Realistic Visuals (Please refer to the Image Overview in section 11.0)

The VR Coal virtual world and objects ***look like the real thing***.

4.1.1 Continuous Miner [CM]

A fully functional computer generated CM has been created. All the relevant parts move, pivot, and/or rotate correctly.

4.1.2 Shuttle Car [SC]

A computer graphics SC with lens-flared headlights and a moving conveyor belt, supplements the CM.

4.1.3 Mine (Image 7, page 17)

The mine itself has a very realistic feel with cutting marks on the walls (vertical marks on the forward faces and circular marks on the sidewalls), realistic roof and floor textures, roof bolt streamers, and shiny slip sections.

4.1.4 Cable handler (Image 9, page 18)

When the CM is trammed backwards, a virtual cable handler ensures that the cable is not in danger.

4.1.5 Instructor and surprise visitor

The trainee can see the virtual instructor. Additionally, a surprise visitor may be programmed to transgress the area in which the trainee is in control of.

4.1.6 Special effects

The purpose of special effects is to make the simulation as realistic as possible. A few examples are:

- a. Sparks, when cutting into the roof (Image 8, page 17).
- b. Roof bolt streamers that move in accordance with the ventilation system (Image 7, page 17). The streamers cease to move when there is a ventilation system failure.
- c. Coal, that falls down when cut from the face.

4.2 Realistic Sounds

The VR Coal virtual environment *sounds like the real thing*.

Every action in the virtual world corresponds to the correct relevant sound. During VR Coal's development, sound recordings were conducted underground and have been mixed together to produce a very realistic auditory experience.

4.3 Realistic Dynamic Models

VR Coal objects *behave like the real thing*.

The CM and SC in VR Coal responds correctly to control inputs. When CM malfunction events are triggered, the CM responds correctly to the control inputs.

Other examples of realistic modeling are:

- a. Reduced cutting speed when cutting into rock rather than coal.
- b. Increased cutting speed when cutting into burnt (devolatilized) coal.
- c. Change in the density of the coal when it is cut (1m³ of coal in the coal face [in situ] corresponds to 1.5m³ of coal once it has been cut).

Complete trainee immersion is achieved because the VR Coal virtual environment looks real, sounds real, and responds like reality. Trainees may get so involved in the environment that they start to perceive it as reality.

4.4 Pre-Simulation Training Module (Image 2, page 14)

Before a trainee can operate the CM in the virtual world, they first need to know the associated terminology; as well as how to control the CM with the remote control unit. The pre-simulation module serves to prepare the trainee to operate the CM. The pre-simulation module can be performed on a separate computer.

4.5 Realistic Control Interface (Image 1, page 14)

The remote control unit used in VR Coal accurately resembles the real remote control of the corresponding reality-based CM. *It looks, feels, and weighs the same as the real remote control unit.*

4.6 Mine Section Editor (Image 3, page 15)

The purpose of this editor is to allow the instructor to create, edit and save different virtual mine sections. Editing is done on a plan view (top view) with assistance of two side-section views. The mine section editor consists of several modules:

4.6.1 Volumetric Pixel [voxel] editor

The virtual mine is constructed with volumetric pixels [voxels] of approximately 250mm x 250mm x 250mm (10" x 10" x 10"). The instructor/administrator may edit the mine to determine exactly where the following will appear:

- a. Air (tunnels)
- b. Rock
- c. Soft coal
- d. Hard coal

The relative hardness and density of the above voxels are also variable. The instructor may lay down realistic strata, e.g. a thick coal seam with a thin layer of rock at a specific height within the seam.

4.6.2 Floor and ceiling editor

The instructor may edit the floor and ceiling (roof) heights. These heights are normally chosen to reflect the dimensions of the mine where the trainee will be working after training.

4.6.3 Cracks and slips

The instructor may position cracks and slips (step-shifted strata) with the mine section editor.

4.6.4 Placement of roof bolts (and other objects)

Roof bolts and other objects may be placed with the editor. In the immersed 3-D view, roof bolts may be recognized by the red-and-white plastic streamers hanging from it (Image 7, page 17).

4.7 Scenario Editor (Image 4, page 15) (Image 5, page 16)

A scenario is a sequence of events. To create a training scenario, the following steps must be followed:

- A mine must be created {Section 4.6 above}
- The starting position of participating entities (e.g. CM and SC) must be defined {Section 4.7.1 below}
- Time Dependent events must be defined {Section 4.9 below}

4.7.1 Placement of entities

The scenario editor allows for the placement (starting points) of the following entities within the virtual mine section:

- a. Trainee (position/orientation)
- b. Instructor (position/orientation)
- c. CM (position/orientation)
- d. SC (position/orientation)
- e. Laser (origin/direction)

4.7.2 Events

The scenario editor allows the instructor/administrator to insert, edit or delete events. A detailed list of possible events is shown in Section 4.9.

4.8 Default Training Scenarios

A range of default training scenarios exists. The objective is to arrange these scenarios in order of difficulty so that the trainee can develop his skills systematically.

4.8.1 2-D versus 3-D Scenarios

Some scenarios are presented in 2-D (plan view) (Image 6, page 16) while others require 3-D operation (as viewed with the Head Mounted Display). The 2-D scenarios are normally presented first, so that the trainee can get the global picture, before proceeding with the 3-D scenario.

4.8.2 Tramming Scenarios

The following default tramming scenarios have been created:

- a. Tramming forward [sidewall on left of machine] {3-D scenario}
 - b. Tramming forward [sidewall on right of machine] {3-D}
 - c. Tramming backward [sidewall on left of machine] {3-D}
 - d. Tramming backward [sidewall on right of machine] {3-D}
 - e. Tramming around corner [forward, clockwise] {3-D}
 - f. Tramming around corner [forward, counter-clockwise] {3-D}
 - g. Tramming around corner [backward, clockwise] {3-D}
 - h. Tramming around corner [backward, counter-clockwise] {3-D}
 - i. Aligning with the coal face {3-D}
- Alignment with the coal face is important because it sets the stage for successful cutting.

4.8.3 Cutting Scenarios

The following default cutting scenarios have been created:

- a. Cutting cycle {3-D scenario}
- b. Filling a shuttle car {3-D}
- c. Cutting the floor {3-D}
- d. Sweeping the floor {3-D}
- e. Cutting the roof {3-D}
- f. Cutting a split (left to right) {2-D scenario}
- g. Cutting a split (left to right) {3-D}
- h. Cutting a split (right to left) {2-D}
- i. Cutting a split (right to left) {3-D}
- j. Pillar split (left to right) {2-D}
- k. Pillar split (right to left) {2-D}
- l. Pillar extraction (left to right) {2-D}
- m. Pillar extraction (right to left) {2-D}
- n. Cutting a cross-cut (left to right) {2-D}
- o. Cutting a cross-cut (right to left) {2-D}

4.8.4 Advanced Scenarios

A few examples of default advanced scenarios are:

- a. Roof falls {3-D}
- b. Surprise visitor {3-D}
- c. Cutting a rock lens {3-D}
- d. Ventilation system failure {3-D}

4.9 Events

There are two types of events that may be selected when compiling a training scenario; Time Dependent Events and Position Dependent Events.

When an event occurs, a specific reaction normally results, e.g. if the trainee cuts into the roof with the CM, sparks will appear. There will also be superimposed error messages on the trainee's computer monitor, e.g. "Cutting into roof". The system will then prompt the instructor to evaluate the reactions of the trainee by means of a question, e.g. "Cutter head lowered? Yes/No". The instructor will then have to key in "Y" for yes or "N" for no. The system logs the event as well as the operator reaction.

Time Dependant Events

With Time Dependent Events, the instructor can set the time at which the event will occur during the simulation.

The following Time Dependent Events may be selected:

4.9.1 CM power tripped

4.9.2 CM malfunction

The instructor may specify exactly what component of the CM malfunctioned, such as:

- a. Pump motor
- b. Flight chain / gathering arm
- c. Left cat track
- d. Right cat track
- e. Both cat tracks
- f. Cutter boom
- g. Cutter drum
- h. Lights
- i. Dust suppression system

4.9.3 CM retarded performance

4.9.4 Shuttle car motionless (indicative of non-alert SC driver)

4.9.5 Gas detected

4.9.6 Surprise visitor arrives

4.9.7 Roof/side-wall fail

4.9.8 Gathering arm blockage pending

4.9.9 Ventilation system failure

Position Dependent Events

Position Dependent Events are a function of the individual positions of the trainee, CM and SC within the mine, as well as their positions with respect to each other.

The following Position Dependent Events may be selected:

4.9.10 Cutting into floor

4.9.11 Cutting into roof

4.9.12 Cutting rock lens

4.9.13 Cutting soft coal

4.9.14 Overfill shuttle car (coal spillage)

4.9.15 Trainee walks without looking up

4.9.16 Trainee between CM and sidewall

4.9.17 Trainee between CM and SC

4.10 Training Log

The system logs all activities during a simulation. The mining operation report contains the *date, time, training scenario, mine, name of instructor, name of trainee, total coal mined* and a *list of events that occurred*. It also lists the response of the trainee to each event, as logged by the computer or instructor.

A typical mining operation report looks as follows:

00:05	Operator walking without looking up	
00:31	Cutting rock lens	
	Sump depth and shear speed adjusted?	Yes
	Sumped above/below lens?	Yes
	Tried to shear?	No
01:32	Operator walking without looking up	
01:45	Cutting into roof	
	Cutter head lowered?	Yes
02:30	Coal spillage behind CM	
	Retreated slowly after SC has left?	Yes
	Spillage cleared?	Yes
03:20	End of scenario	

4.11 Training Administration

The training administration module allows the instructor to do the following:

- a. Create new user (trainee) records
- b. Delete user records
- c. Edit user records
- d. Log operators and instructors on/off

4.12 Recording function

With this function all operator and instructor activities may be recorded and replayed at a later stage.

4.13 Modes

The simulator may be operated in one of two modes:

4.13.1 Stand-alone mode

4.13.2 Networked instructor/operator mode

The normal mode of operation is the networked mode, where both the instructor and operator computers are active. The simulation may however also be run on a single computer (stand-alone) mode. This mode is normally used for system demonstrations. It also offers a convenient back-up solution if one of the computers may fail.

5.0 Training

5DT will provide one week of on-site detail training for a core group of instructors when VR Coal is purchased. During this training the objective will be to "*Train the Instructors.*"

6.0 Warranty and support

The VR Coal system carries a full one-year on-site warranty (parts, labor, telephone, modem and e-mail support). On-site support personnel would be sent at 5DT's discretion in the event that a problem cannot be resolved by telephone, modem or e-mail support. Follow-up service contracts and/or upgrade plans may be negotiated.

7.0 Customization

The following may be customized:

7.1 Continuous Miner and Shuttle Car (computer graphics models and dynamic models)

7.2 Remote Control Unit

7.3 Cockpit controls

The basic VR Coal system was designed for Remote Control operation. 5DT is also capable of implementing systems that are controlled from a cockpit. In such a case, a cockpit that accurately resembles a real cockpit will be constructed. The control elements in the cockpit will then be instrumented and interfaced with the computer.

7.4 Company defined trainee responses to events

Different mining companies may want their trainees to respond differently to a specific event.

8.0 Technical Specifications

8.1 Hardware

a. Computers

2x Pentium III 700MHz computers (1 for instructor, one for trainee) with Geforce2 graphics accelerator cards.

b. Network interface

100Tx Ethernet

c. Head Mounted Display

5DT's HMD 800-35 (Full color 800x600 SVGA resolution, 35° Diagonal Field of View [FOV])

d. Head Tracking

Ascension's 3-D Bird orientation tracker

e. Remote control unit / Radio Unit

Manufactured by 5DT to mimic the control unit of the CM manufacturer. Please note that this unit is not intended for operational purposes (to control a real CM).

f. Big screen projector

InFocus DMD (1024x768 resolution, 1,200 ANSI lumens)

8.2 Software

- a. Operating system
Microsoft Windows 98SE
- b. Rendering engine
Microsoft Direct 3-D
- c. Software language
Microsoft Visual C++ 6.0
- d. Voxel Rendering
5DT's Dynamic Real Time Voxel Rendering [DRT-Vox]

9.0 Under Development at 5DT

The following systems are currently being investigated, or are currently under development at 5DT:

9.1 Virtual Reality Training Simulator for Roof Bolter [RB] operators

RB operators perform a very dangerous and important task. This simulator will focus on their safety as well as the roof bolting process.

9.2 Networking technology for simultaneous operation by the following entities:

- a. Continuous Miner [CM] trainee
- b. Shuttle Car [SC] trainee
- c. Roof Bolter [RB] trainee
- d. Instructor

The objective of this system would be to allow a CM trainee, a SC trainee and a RB trainee to simultaneously operate CM, SC and RB simulators that are networked together. These entities will then share the same virtual mine and work together as a team, as in reality.

9.3 Educational Computer Game for mine section supervisors

9.4 Open Cast (surface) Mining

- a. Dragline
- b. Dump Trucks and Loader(s)

10.0 About 5DT

5DT <Fifth Dimension Technologies> is a high technology company specializing in Virtual Reality [VR]. 5DT develops, produces, and distributes affordable VR hardware, software and related systems. 5DT also develops complete custom turnkey systems for all your VR needs.

For more information please contact:

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If a picture is worth a thousand words, a virtual reality experience is worth a million."

Virtual Reality is a technology that needs to be experienced.

We would therefore like to invite you to contact us to arrange for a demonstration of VR Coal.

11.0 Image Overview



Image 1 – Trainee Operator with Head Mounted Display and Remote Control Unit

The trainee wears a Head Mounted Display [HMD]. A Remote Control Unit that accurately resembles the real unit is used to control the virtual Continuous Miner [CM].

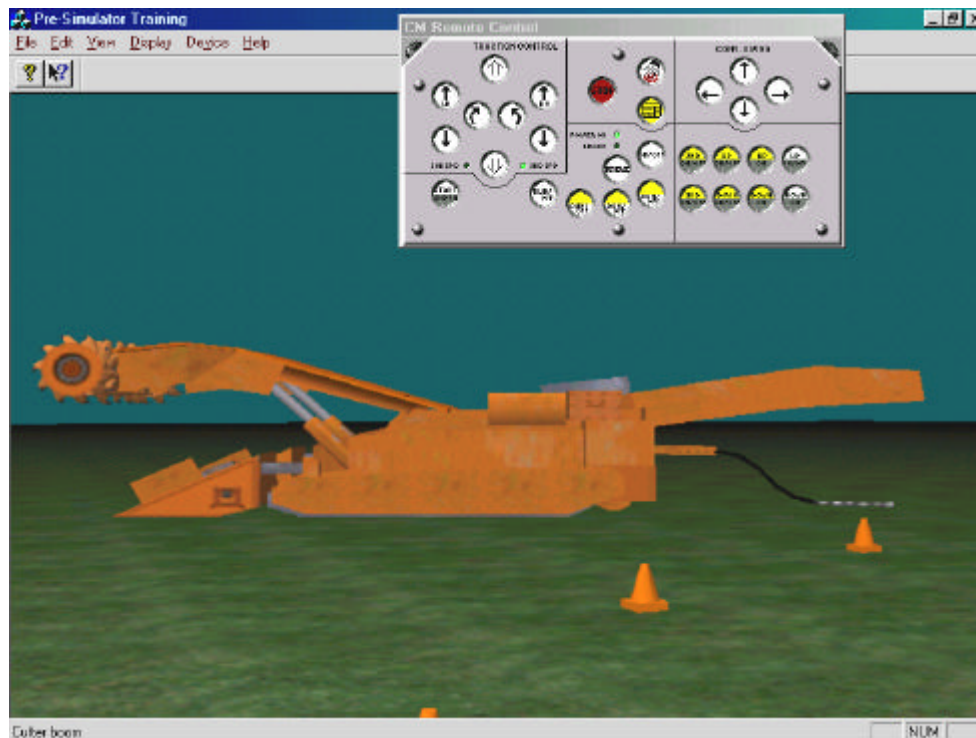


Image 2 – The Pre-simulation Module

The pre-simulation module teaches the trainee basic terminology and how to use the Remote Control Unit. A small remote control panel is superimposed on the image initially, but later it is removed.

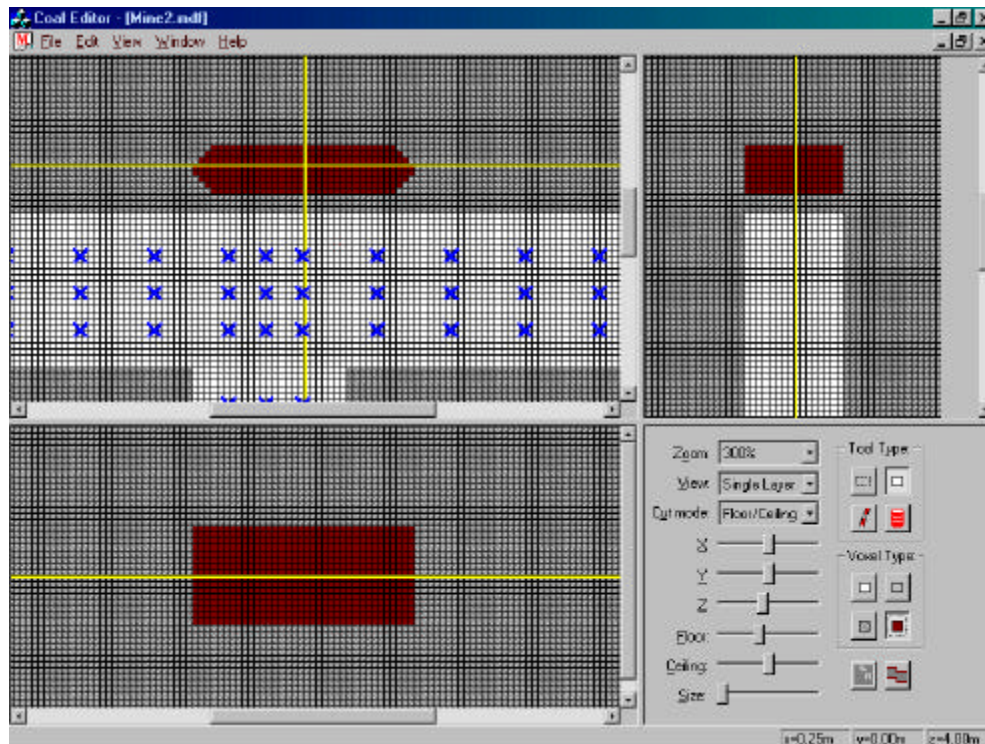


Image 3 – The Mine Section Editor

The mine section editor allows the instructor to create and/or edit a mine section that relates to mining conditions in their specific area. Rock lenses (red areas) and roof bolts (blue crosses) may be placed .

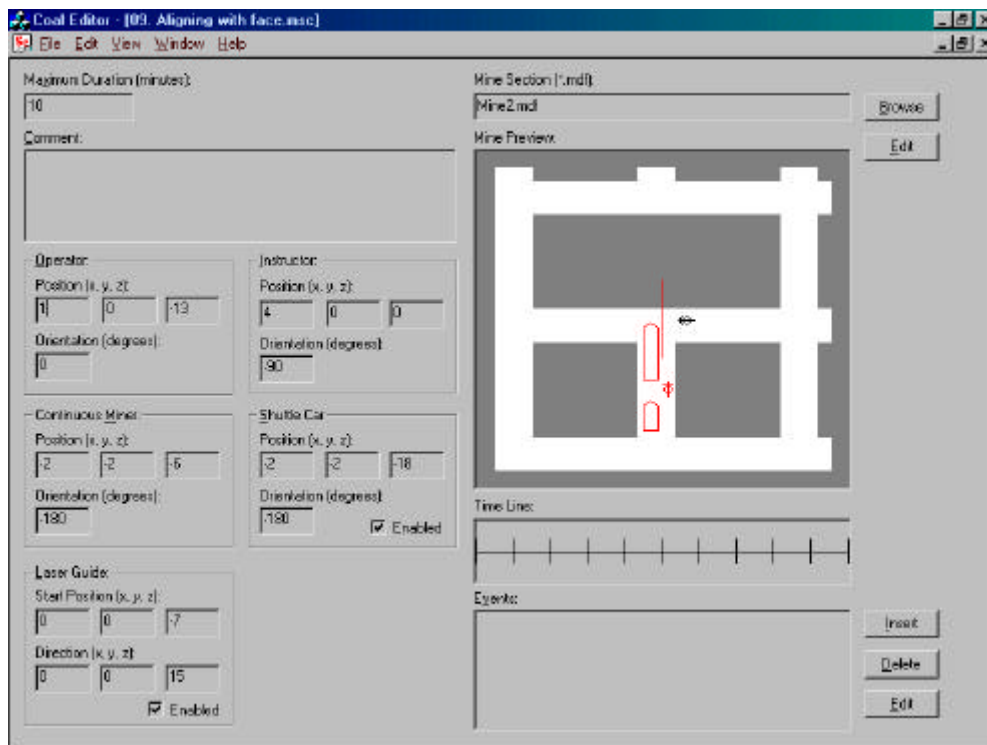


Image 4 – The Scenario Editor (1)

Once a mine section has been created (see image 3 above), the Scenario Editor is used to define the starting points (and orientations) of the continuous miner, shuttle car, instructor, operator and laser guide.

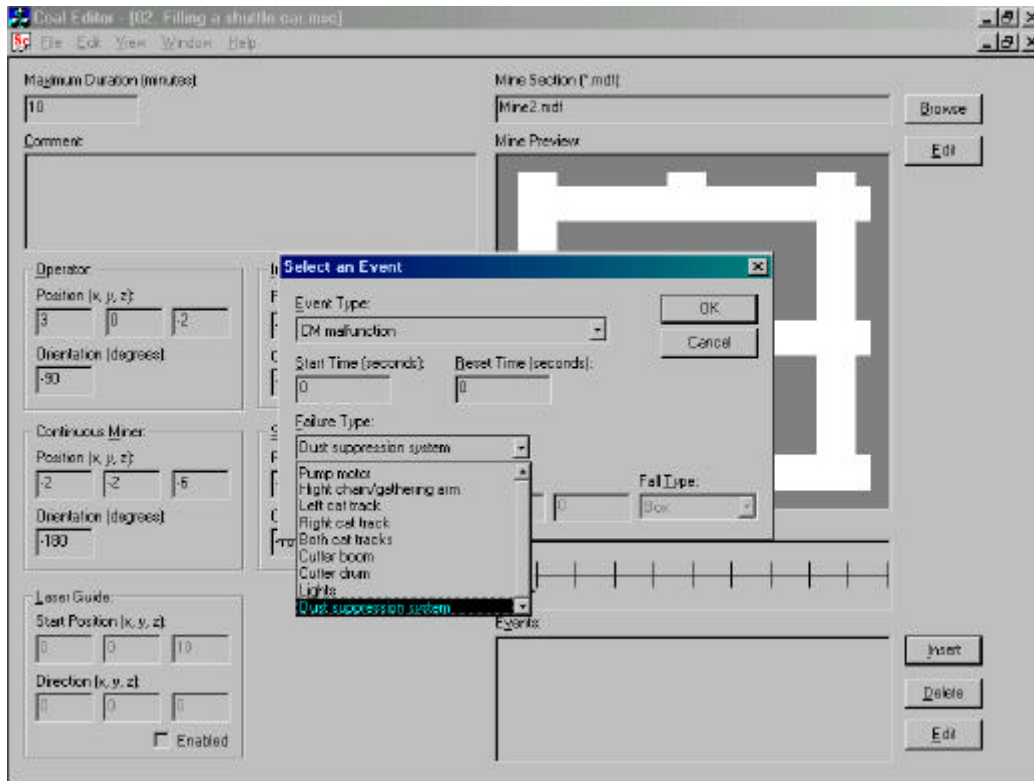


Image 5 – The Scenario Editor (2)

With the starting points of all the participating entities defined (see image 4 above), the instructor may now proceed to select time dependent events on the timeline editor.

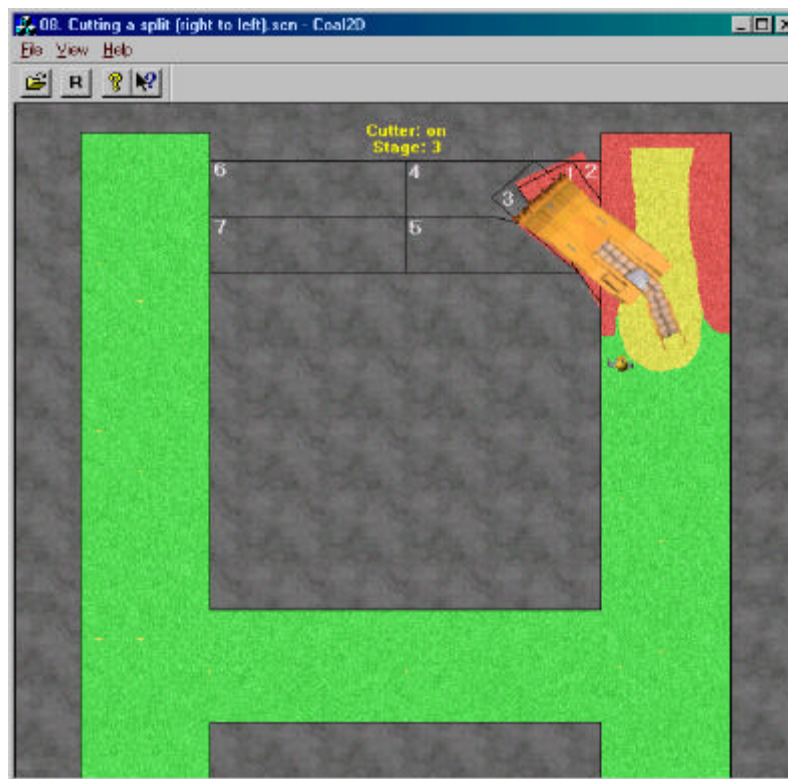


Image 6 – Cutting a Split (2-D)

Some training scenarios require training in 2-D first, before progressing to full 3-D scenarios. Once the trainee understands the relevant concepts from a plan-view perspective, it is time to experience fully immersed 3-D.

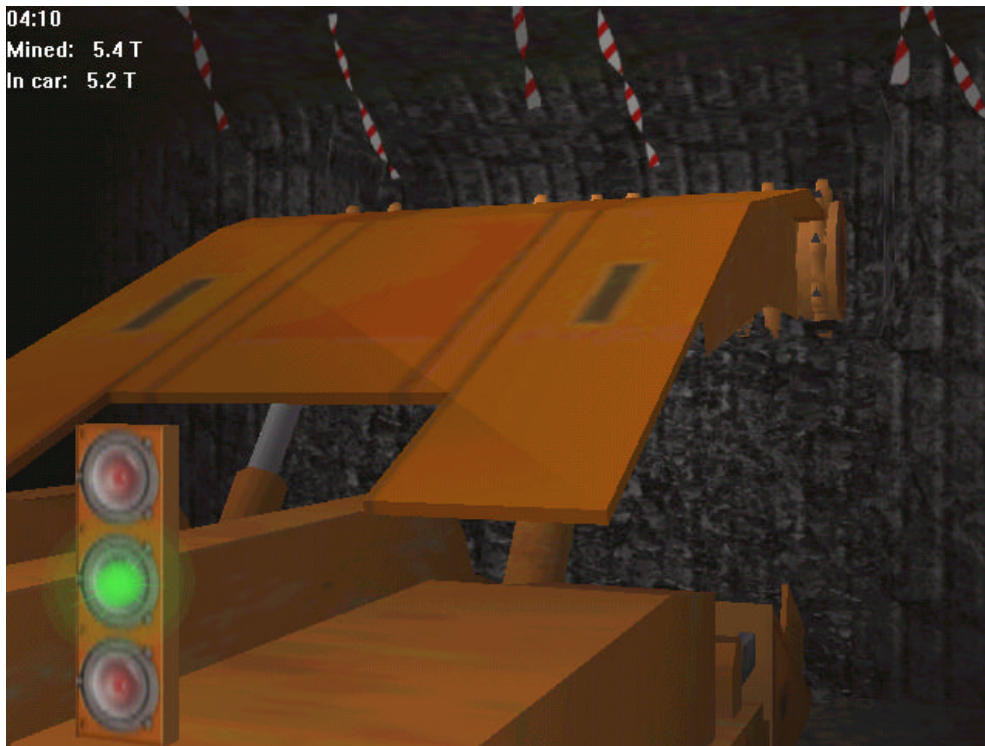


Image 7 – The Cutting Cycle

The Cutting Cycle is the foundation of Continuous Miner [CM] operation, and is considered a critical skill. Once the trainee has mastered the basics, a Shuttle Car [SC] is added, and the trainee is required to optimally fill a SC.



Image 8 – Cutting into the Roof

The trainee is taught how to use the level indication system (red and green lights) of the Continuous Miner [CM]. When these warnings are ignored, the CM will cut into the roof. Sparks and on-screen warnings will appear.



Image 9 – The Cable Handler

Whenever the Continuous Miner [CM] is trammed backwards, a virtual cable handler will ensure that the power cable is kept away from danger.



Image 10 – Overfilling the Shuttle Car

Overfilling of the Shuttle Car [SC] will cause spillage of coal. The trainee will see the coal spilling and hear the sound of spilling coal. A warning message will appear on the instructor's screen.