## *RELATIVELY SPEAKING....*

BBC 1 TV's challenge in 1995 - to launch a brand new prime-time game show featuring the technology of Virtual Reality - was taken up by Kershaw Production Associates of Birmingham and Stag Presentations of Manchester. The two organisations were commissioned to make the programme - called *Relatively Speaking* - at the Pebble Mill Studios in March, 1996 for transmission in April and May. Following a series of trial shows, it was decided that the show should be hosted by Gordon Burns, star of another TV programme, *The Krypton Factor* and, more recently, leading news presenter on BBC 1's *North West Tonight*.

Relatively Speaking was a show about families, each competing to demonstrate their verbal communication skills in a variety of challenges involving detailed description and precise instruction. The final challenge placed one family member in an immersive virtual environment and provided the remainder of the team with a partially accurate map of the area. By constantly exchanging information, the immersed player had to find his or her way to a pre-specified point, seize an object or find sets of clues and escape within a set time.

Virtual Presence was chosen to develop the scenarios for the final challenge, in close consultation with Kershaw and Stag and the show's production and design teams. The overall concept was based on a maze environment, which itself formed part of an Egyptian pyramid, space station or lunar base. A series of pilot programmes were made at Pebble Mill in 1995, filmed in front of a live audience and distributed to groups of individuals across the UK, who were retained by the BBC for the purpose of assessing proposals for new TV programmes. In addition, the Virtual Presence team developed bespoke computer code to allow the maze models to be "explored" and interacted with in real time, implementing a simple form of collision detection, so that contestants could not cheat by placing their heads through walls and ceilings!

In order to allow one family member to immerse themselves in the virtual maze, whilst allowing the remaining family to view the final contestant's position, a unique merger of two British VR products was developed and featured **live** in the Pebble Mill studio. In essence, the system revolved around tracking the position of the immersed contestant and feeding this information in real time from a graphics "supercomputer" to a PC in order to generate and update a plan view of the maze for subsequent video display to the contestant's family.
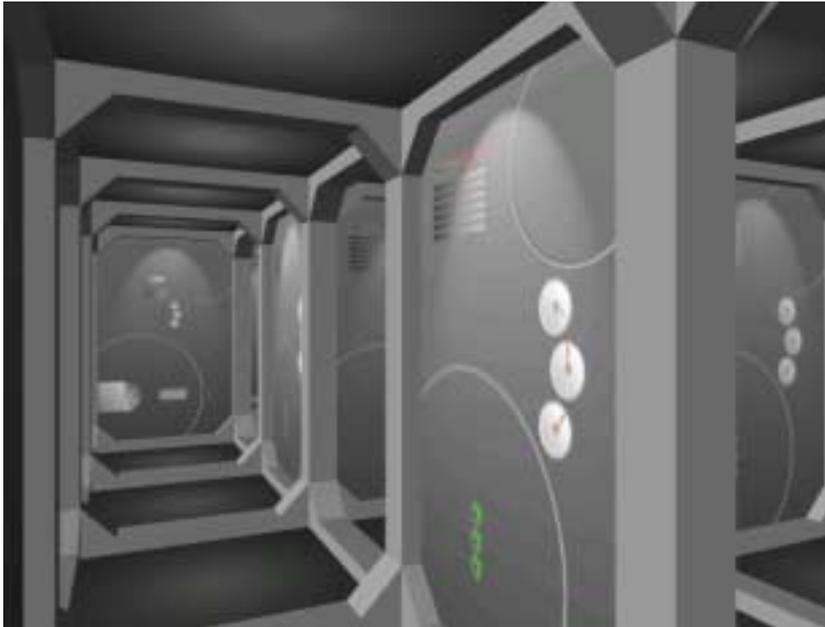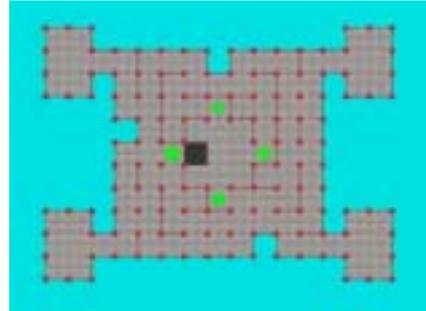
In the pilot sessions, the task of the family was to help guide their immersed relative through the maze, with the aim of reaching two out of four locked safes, located in the corners of the maze itself. Whilst following instructions from the main family body, the immersed contestant had to negotiate obstructions, such as rotating doors which remained open only for a 5-second period. On other occasions, the contestant would come across "secret doors" - invisible to the rest of the family - which might or might not speed his or her progress towards the safes. Advice was sought from the family as to whether using these doors was an appropriate move.

On reaching the safe, the contestant was required to search for and describe two symbols. By pressing the appropriate buttons on their console, the family "unlocked" the safe. Reaching out and opening the safe door, the contestant could then view their prize. The final task demanded that the contestant returned to the centre of the maze to unlock the main safe. If this was achieved within the overall timescale of 4 minutes, the family won a trip to the Epcot Centre in the States (replaced by a holiday for 12 in the Cotswolds for the actual series!). A similar maze formula was developed for the scheduled series, but with the new scenarios, the family communication aspect was emphasised - the focus of the game was not so much on reaching the centre of the maze...the difficulty was getting out again...without being "crushed" by falling Egyptian stones or "incinerated" by a force field.

- **Source CAD Data (maze models): MEDIT**
- **CAD-VR Conversion Code: Virtual Presence Limited Proprietary**
- **Integration/Run-Time: DIVISION *dVISE/dVS* (SG *Onyx*); Superscape VRT**
- **Interaction/Display: Immersion, networked with Desktop and Video Projection. Special Family Choice Selection Buttons.**
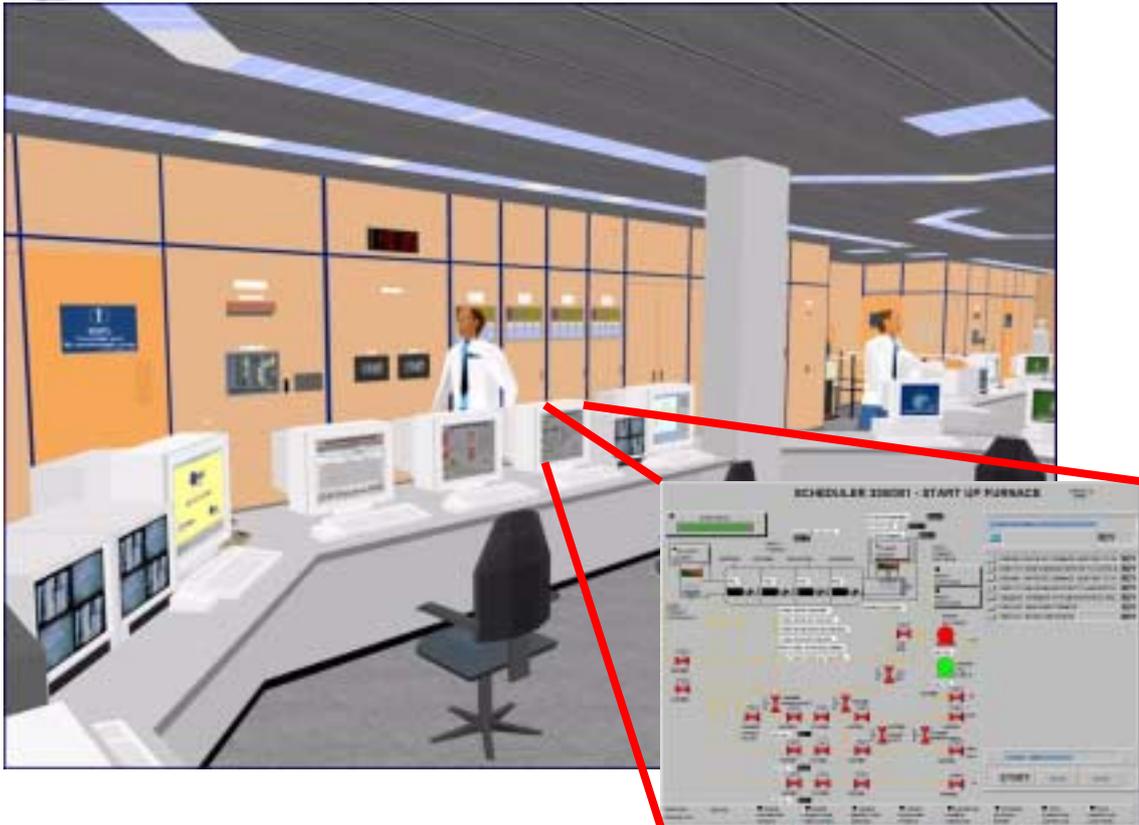
BNFL SMP Central Control Room

One of the first VR projects sponsored by British Nuclear Fuels plc in 1993 focused on the prototyping of the Central Control Room (CCR), for the planned Sellafield Mixed Oxide Plant (SMP). Virtual Presence's approach to modelling the virtual CCR not only ensured that the "first-pass" model was a reasonably faithful representation of the early design concept, but that subsequent changes and design upgrades could be carried out quickly and cheaply.

Using plans and console drawings provided by the BNFL SMP Team, the main geometric layout of the virtual CCR was first "constructed" using a proprietary VR package, at that time hosted on a Pentium P-90 PC. Photorealism was introduced by using digitised images from an existing control room with similar ceiling, wall and floor finishes, control and alarm panels, computer screens, TV displays, warning signs, and so on (THORP). Once the initial modelling effort had been completed, attention turned to how best to allow BNFL representatives to experience the virtual CCR. The use of immersive technologies - head-mounted displays, gloves, and so on - was considered inappropriate, due to the requirement for presentation of quality 3D graphics to a team of SMP managers, designers and engineers from different disciplines. To overcome these problems, use was made of Virtual Presence's early stereoscopic projection facility. Wearing polarising spectacles, visiting representatives of the SMP Team were able to move around the early version of the CCR model in 3D and quickly assess preliminary proposals for workstation layout and other features, such as lines of sight across the control room, panel mountings and light fitting distribution. Furthermore, by lowering the apparent viewpoint on the projection display (a single computer entry achieved this), it was possible to simulate the view of 5th and 95th percentile seated operators at one of the workstations.

This approach to displaying the virtual CCR proved to be highly successful. One encouraging result of the demonstrations was that the virtual CCR helped to remove the technical and language "barriers" so often found when engineers, designers, ergonomists and managerial personnel from the same company come together for project reviews. The real-time virtual

"walk-through" enabled the visiting specialists to interact effectively with each other, discussing future modifications and their impact on the overall CCR concept.

Many of the BNFL representatives involved agreed that full immersion would be desirable in the future, once headset and glove technologies had matured to a level where the immersive experience meant that users actually felt present in the CCR. An important feature of Phase 2 of the SMP project involved an evaluation of contemporary VR technologies for assisting ergonomists to assess the design of proposed hardware elements of the CCR. A breakthrough came when it was demonstrated that an early proposal to equip the CCR with ceiling-hung monitors (see picture above) might well cause operator neck fatigue over time but could also compromise the timely detection of warning display and enunciator outputs. Interestingly, these assessments *were* based on the use of immersive VR technologies, placing operators within the control room and undertaking experimental trials. As a result of this phase of work, not only were BNFL ergonomists able to change the proposed design to improve working and safety conditions, it also convinced BNFL to procure their own in-house PC-based VR system (with a basic immersion capability). Since this time, BNFL personnel (at Risley in particular) have themselves been undertaking development and assessment work for other company divisions, not to mention other nuclear power organisations in the UK.

Another project developed the CCR model to a stage whereby it could be used for operational training. Not only did this require the introduction of high-quality visual display unit screen formats (allowing the user to "power-up" the SMP furnace), it also demanded the "presence" of virtual mannequins with whom the VR user can interact. Virtual log books are available for recording activities and any control input made by the user is realistically reflected in related displays located throughout the control room.

- **Source CAD Data: Superscape VRT Object/World/Texture Editors/MEDIT**
- **MEDIT/VRT-dVISE Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: Division *dVISE/dVS*; Superscape VRT; Silicon Graphics *Onyx and InfiniteReality Engine***
- **Interaction/Display: Immersion/Desktop/Stereo Projection**

Where Science Never Sleeps...
THE BNFL SELLAFIELD
VISITORS' CENTRE TV ADVERTISEMENT

On 3 July, 1995, during the television advertisement break at around 21:20 on the UK's *Channel 4*, a shepherd was seen to don a Virtual Reality (VR) headset and "fly" for a brief 4-second period across a virtual representation of fields in Cumbria, in the North of England, in search of a lost virtual lamb. This and similar imaginative sequences were filmed in support of a commercial advertising British Nuclear Fuel's refurbished Sellafield Visitors' Centre. The real-time VR sequence was produced by Virtual Presence, under contract to BNFL. In the absence of suitable digital terrain data, the geometric, or polygon-based, model of Wast Water in Cumbria (covering some 15 square kilometres) was produced mainly by hand, using a graphical modelling package and ported into a commercial VR operating system for the real-time fly-over sequence (hosted originally on a Silicon Graphics *RealityEngine*[2], or *Onyx* graphics computer).

Having built the area and lamb models, the next stage of the project involved improving the visual quality, by introducing *photorealism*. To do this, it was necessary to obtain photographs of such features as grass, stone walls, granite outcrops, trees, lambswool, and so on, some having been taken from a helicopter survey of the area. These photographs were then digitised, using a flat bed scanner, and electronic edits were carried out on a personal computer, using a proprietary digital image editor. In the case of acquiring appropriate tree images, the trees were digitally "cut" from the background scenery and further enhanced, prior to *texture mapping* onto the surfaces within virtual land model. Although the filmed sequences showing the shepherd donning a VR

headset in a field, the actual "fly-over" sequence was filmed at the Virtual Presence's premises in Manchester. The headset "used" by the shepherd was actually a prop, built by the TV production company to look like a hybrid design of other commercial VR products. The final TV images were filmed directly from the Silicon Graphics *Onyx* monitor using a broadcast quality TV camera, whilst a member of the Virtual Presence Team controlled the action using real VR equipment. For information, the actual equipment used to achieve the final VR fly-over included an original Virtual Research Flight Helmet, a Polhemus Fastrak head/hand tracking system, and a simple hand controller. As well as the high-resolution screen-based imagery used by the TV crew, composite video signals were relayed to the head-mounted display at the same time, so

that what the crew filmed was, in effect, a 2D representation of the 3D images seen in the Virtual Presence team member's headset.

A final comment about the virtual lamb. Some 2500 polygons were used by a BNFL CAD engineer to produce a graphical lamb model which, suitably textured, would look reasonably convincing. This contrasts with the 6000 or so polygons used by the VR applications developer which made up the *entire* area covering Wast Water and the surrounding terrain!

- **Modelling/Database: MEDIT, 3D Studio (Lake District textures from ground and helicopter photography)**
- **MEDIT/3DS-VR Conversion Code: Virtual Presence Proprietary**
- **Integration/Run-Time: DIVISION *dVISE/dVS* (SG *Onyx*)**
- **Interaction/Display: Immersion, Desktop**

Cooperative Wholesale Society (CWS)

Founded in 1844, the Cooperative Wholesale Society (CWS) is a major UK business with activities in banking and insurance, retail of food and non-food products and travel. The company also has a substantial manufacturing base. For many years the Cooperative Movement has been viewed as innovative, boasting a number of technology firsts in banking and retailing.

The design of supermarkets and the planning of spaces within them are time consuming and costly processes. Every product on display within a supermarket is there to be purchased. The positioning, volume, lighting and advertising of each and every product is designed to achieve maximum sales potential. It is still the case today that the standard method of product layout visualisation is the planogram. At best, planograms are two-dimensional photographic images. At worst, they are two-dimensional drawings showing coloured boxes. For the CWS in 1992, VR was seen as a major innovation in the visualisation of shelf layouts, allowing marketing specialists to interact with space planners, product buyers and supermarket managers in a way never before imagined.

Therefore, the original focus of the VR work sponsored by the CWS was to allow the visualisation of supermarket shelf layouts and to allow marketing personnel to interact with space planners, product buyers and supermarket managers. A further aim was to investigate the integration of VR, as an intuitive user interface, with electronic point-of-sale systems, electronic shelf-edge pricing, customer tracking systems and intelligent packaging.

At the outset of the work, this scope was changed slightly in order to use VR for a slightly different purpose, that of ergonomics and "context" prototyping of a new design of checkout for the CWS chain of *Late Shops*. Initial geometry build and parent-child hierarchy definition activities were carried out using a proprietary PC-based VR system. In close consultation with the CWS Point of Sale Manager, successive refinements to the model were made until the style,

size and layout details were acceptable. The virtual checkout was then converted, ready for visualisation using a high-end graphics "supercomputer". The model enabled the company to experiment with new checkout designs - looking at issues such as store security and potential salesperson/customer interaction problems when handling bags full of products. The virtual *Late Shop* even appeared on *Off Your Trolley*, a BBC TV series hosted by Lloyd Grossman, screened in September and October of 1995!

Later, on the basis of the close working relationship between Virtual Presence and the CWS Point of Sale Manager, the PC-based component of the Virtual *Late Shop* exercise was modified to become more of a retail design tool. Called *Mercator*, the system provided the CWS representatives with a portable (laptop-hosted) VR store design demonstrator. Simulating a multi-windowed environment, *Mercator* gave users the ability to navigate a CWS store, place simple product representations on shelves and move store furniture - checkouts, gondolas, refrigeration units, even individual shelf groupings - around using dedicated keys. It was this simple demonstration which led two years later to the development of the *Concept$_{VR}$* virtual space planning system for Sainsbury's[1].

Following the successful presentation of a video record of the virtual design activities to CWS Directors, further work took place on the original goal of the CWS project. Automatic links between the knowledge-based software of a leading space planning system (**Intactix**) and VR run-time systems were demonstrated, allowing structurally correct graphical supermarkets to be constructed automatically for preliminary spatial evaluations. The software was designed to access databases containing geometric and textural information based on internationally standardised *universal product codes* (UPC). Whilst each brand on sale had a unique texture (generated from digitised images or pattern catalogues), around 20 base geometries were thought sufficient to describe every product available. The retail industry actually recognises a much smaller number (cube, bottle, roll, pyramid, bag, etc.) for the purposes of space filling. These geometric constraints actually ease the porting of large numbers of products (rather than large product *geometries*) between different platforms and software architectures, promoting subsequent enhancements for real-time interactive walk-throughs, such as detail management, object replacement, and so on.

- **Source CAD Data: Superscape VRT Object/World/Texture Editors**
- **VRT-dVISE Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: Division *dVISE/dVS*; Superscape VRT; Sense8 WorldToolKit; Silicon Graphics *Onyx and InfiniteReality Engine***
- **Interaction/Display: Immersion/Desktop/Video Projection**

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[1] **See also Applications Sheet No. Retail/Apps/JS.98.1**

Crime Conquest

Regular media reports of day-to-day problems faced by young schoolchildren suggest that there may be significant potential for Virtual Reality to assist in alerting youngsters to some of the more disturbing aspects of today's society. In October of 1996, the Greater Manchester Police Authority (GMP) was considering spending a considerable amount of money on furnishing either (a) a large articulated lorry or (b) a regional centre in order to present video demonstrations of such events as cashpoint muggings, separated infants, burglaries, accidents and so on to primary and secondary school children. The budget allocated was **exclusive** of the actual hardware required to run the demonstrations. Concern was expressed within GMP that the video-based solutions being considered could become quickly dated, were not sufficiently "high-tech" or interactive to capture the attention of schoolchildren and, in the case of the regional centre idea, would have serious impact on school timetables, transport costs and the like. They had not initially considered VR, due to a perception of very high costs. However, on visiting Virtual Presence they discovered that it would be possible to develop a range of crime scenarios using a cost-effective PC-based solution, ready for widespread distribution to local schools.

Crime Conquest VR, then, is a PC-based VR "societal trainer", distributed to up to 300 schools in the Greater Manchester area during the Autumn of 1998. Co-funded by GMP, Virtual Presence, The Shrievalty Trust and BNFL, the trainer exploits VR by allowing schoolchildren to "enter the bodies" of different virtual participants: their decisions at crime scenes involving people and property dictate what happens next. The system has been designed for presentation to children of 11 years and older (Key Stage 3+), in keeping with some of the aims of the IT components of the National Curriculum.

Crime Conquest VR

Schoolchildren will be able to take on different roles to experience a range of crimes involving people and property, all of which take place within a virtual reality city. As witnesses, they will have to be observant; when playing the role of police officers, they will have to make fair and just decisions; as themselves, they will have to be vigilant and forward-thinking. VR enables the children to "enter the bodies" of these different virtual participants - their decisions at the scene of the crime dictate what happens next.

The result of a 12-month collaborative project involving the Greater Manchester Police, Virtual Presence Limited, the Shrievalty Trust and British Nuclear Fuels plc. *Crime Conquest VR* has been designed for presentation to children of 11 years and older (Key Stage 3+), to fulfil a societal training role in keeping with the aims of the IT components of the National Curriculum. Just some of the scenarios include:

Trouble with youths... Is this group of teenagers just a collection of innocent bystanders? Are they causing a nuisance or even exchanging drugs? The activities of youths throughout the virtual city have to assessed and dealt with carefully.

Joyriding... A stolen BMW has crashed and a member of the public has been seriously injured. Your attempts to telephone for assistance are thwarted because of a vandalised 'phone kiosk... Fortunately a police officer is nearby, but will you come forward and volunteer information on the fleeing driver?

Identikit... Having seen the driver of the stolen vehicle, you are escorted to the VR city police station where you sit in front of a virtual computer to take part in a realistic identikit procedure. How close will your match be?

Safe as houses... You are going out for the evening, but have to make your home - both inside and outside - secure before 'phoning for a taxi. How many items will you leave not dealt with?

Personal Safety... Having spent an enjoyable evening at the local night club, you find that you have to walk home alone. Which route will you take? What potential threats to your safety might you encounter on the way? Will you use the subway, walk through a dark park area, or accept a lift from a stranger?...

Human Factors / Ergonomics

Virtual Presence's commitment to excellence in the field of Virtual Reality is not just restricted to the provision of software development effort or the supply of turn-key VR systems. The successful introduction of as unique technology as VR into an industrial or commercial setting demands a heightened awareness of the characteristics and limitations of the human individuals and teams who will ultimately be required to use the system.

Human factors (traditionally *ergonomics* in the UK) is the study of the working relationship between the human and his or her working environment. Having evolved from classic studies of the effects of fatigue on human perception and vigilance during the Second World War, human factors is, today, a mature field of endeavour. Its contribution to the well-being of human workers is increasing in importance as complex systems move more and more towards computer automation and support.

In the field of Virtual Reality, the rôle to be played by human factors cannot be underestimated. There exists today a myriad of possible information display and data input solutions to any one VR application. The requirements for implementing VR, be it immersive or based on single/multiple desktop displays, 2D/3D/spherical/volumetric projection devices (including CAVEs), can only be specified once a complete understanding of the human's task has been formulated. Virtual Presence offers a **complete** service in this respect.

HF/Apps/Ergo.98.1

In the defence and aerospace arena, Virtual Presence is aware of, and frequently applies the results of important initiatives such as MANPRINT and the contents of existing human factors standards, such as NASA-STD-3000, MIL-STD 1472D, DEFSTAN 00-25 and ISO 13407, *Human-Centred Design Processes for Interactive Systems*.

The company possesses staff qualified to postgraduate level in ergonomics, with national and European (CREE) accreditation. Also, Virtual Presence maintains a comprehensive ergonomics library and frequently commissions bodies such as Birmingham University's Ergonomics Information Analysis Centre and the Crew System Ergonomics Analysis Center (Wright Patterson Air Force Base) for specialist R&D searches. Capabilities (which are not exclusive to the domain of Virtual Reality) include:

- Human operator task analyses - *in situ*, video-based, or specialist debrief,

- Feasibility studies – defining the needs of the potential users of VR in a given applications setting,

- Review and recommendation studies (past projects have been conducted for the nuclear industry, food processing organisations, the Defence Research Agencies at Chertsey and Portsdown, medical companies, retail research bodies and supermarket chains),

- Special equipment design/evaluation studies (past projects have included "flying" hand controllers, tactile/force feedback systems for general and medical applications, head-slaved stereoscopic camera units, special-purpose VR retail "trolley" interfaces, eye tracking systems),

- Workplace design – anthropometric and biomechanic aspects (real *and* virtual),

- Health & Safety aspects of Virtual Reality (See also Applications Sheet No. HF/Apps/Ergo.98.3),

- Design and execution of special VR trials and human factors experimentation (based on real *and* virtual environments),

- Application and analysis of perceptual-motor and cognitive tests (pre- and post-experimentation),

- Questionnaire design and user surveys.

FERMEC BACKHOE / LOADER
DESIGN, ERGONOMICS & MARKETING

In the mid-19th Century, Canadian-born Daniel Massey was responsible for starting what was to become a legendary business in the development of agricultural equipment. From his early venture into the design of basic farm implements to a merger at the end of that century with competitor Alanson Harris, Massey had set in motion a chain of events that was to bring together some of the great names in mobile earth-moving technologies. In 1951, Massey Harris acquired the business of inventor Harry Ferguson who had earlier invented the famous *Little Grey Fergie* tractor. The business that was to emerge and prosper – Massey Ferguson – needs no introduction at all. FERMEC, the company's present trading name (www.fermec.com), resulted after a management buy-out from the parent company – the Varity Corporation – in October, 1992, securing the organisation's future and its international base in Manchester, UK. Today, FERMEC is a wholly owned subsidiary of the Terex Corporation (www.terex.com), a global player in the manufacture of lifting, earth-moving and light construction equipment.

Looking for new technologies to complement the company's forward-looking plans for enhanced product engineering (which already include laser cutting, welding and forming technologies, integrated assembly lines and computerised product quality control), FERMEC did not have to look far for a natural partnership with two leading names in the virtual prototyping arena – PTC, specifically with its Division MockUp2000i^2 product (www.ptc.com) and PTC's strategic partner Virtual Presence UK. Virtual Presence has long been a user and reseller of the Division product range and was even responsible for funding the first ever commercial Division VR computing system, *Vision*, in 1990.

FERMEC is a user of Computervision's CADDS5X tool, so the source data for their backhoe/loaders were already in a format suitable for conversion and manipulation to produce

a quality real-time interactive simulation of the vehicle and backhoe mechanics. Indeed, the modular approach adopted by FERMEC in the design of vehicles and attachments makes the company's products an ideal "target" for implementation in VR. The interior 3D cabin detail was not available at the time this project was performed. Consequently, Virtual Presence's 3D modelling team – working closely with FERMEC engineers – produced a detailed visualisation of the driver/operator's workstation, again suitably structured for supporting real-time interaction and control of the backhoe. The mechanical components of the virtual backhoe system have been structured within the DIVISION 2000 software to take account of the kinematics of the overall system. Actuation of the cabin joysticks (initially using proprietary electromagnetic body tracking equipment) results in realistic motions and limit constraints of the links and joints. The operator of the virtual backhoe visualises the operations by donning a head-mounted stereoscopic display and is free to look around the cabin as he might during an actual excavation or earth-moving operation.


Integrating the immersive VR technologies with the physical seating and joystick control facilities used in the backhoe loader adds yet another level of fidelity for the design and marketing specialists of FERMEC. This arrangement helps potential customers to gain a more realistic "hands-on" experience of handling the backhoe without even having to approach a real backhoe/loader or excavator.

FERMEC has already experienced the benefit of virtual prototyping, not just as a tool for backhoe design or the assessment of cabin ergonomics, but also in direct marketing. On a recent nationwide tour, visitors to the FERMEC mobile engineering exhibition were attracted to the company's exhibition stand as a result of the first "outing" of Virtual Presence's simulation. They were able to witness FERMEC's innovative design approach first hand. This resulted in 6 purchase orders for backhoe systems – without any real equipment even being present!
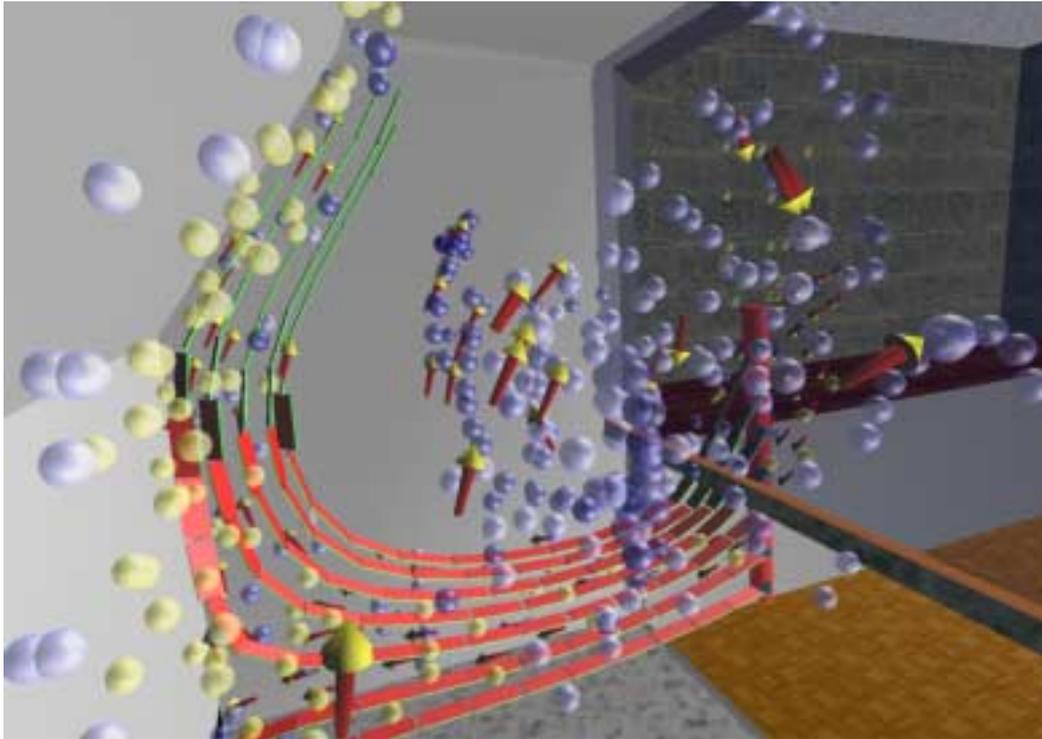
## Computational Fluid Dynamics - Health & Safety Executive

In 1996, Virtual Presence undertook a project on behalf of the UK Health & Safety Executive (HSE) to evaluate Virtual Reality (VR) as a means of highlighting potentially hazardous working procedures to industrial plant personnel. The final demonstrator focused on the potentially harmful build-up of vapours in a confined petrochemical vessel, released by the chiseling action of an unprotected, unharnessed worker. An important aim of the work was to generate a first-level *visual* simulation of the spread of the vapour which, in reality, was invisible. Operators were "exposed" to the threat using immersive VR technologies. An early part of this first project involved an investigation into what was achievable using current **PC**-based technology. Using a proprietary VR toolkit, vapour molecules were displayed in
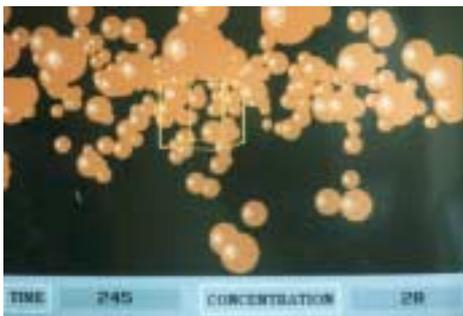
the form of simple spheres, and a wireframe cube denoted which portion of the 3D simulation was being sampled for vapour densities. The user could "fly" the sampling cube (using keyboard inputs) through the rising vapour in order to measure the changing concentration where required. At the bottom of the screen were two data panels which displayed elapsed time (in seconds) and an arbitrary figure denoting vapour concentration within the boundaries of the wireframe cube.

This simulation demonstrated considerable potential for utilising the increasing graphics capabilities of PC-based platforms in any future occupational health/hygiene work for the HSE, especially in the visual display of information (generated by established simulation outputs) not normally visible to the human user. The goal of visualising computational fluid dynamics (CFD) databases using PC VR tools and techniques was reflected in the outcome of a 1998 project conducted for the Health and Safety Laboratory (HSL), based in Sheffield.

The project took the form of a feasibility study to assess the appropriateness of VR technologies in visualising and interacting with CFD databases. The "target" virtual environment for study was a simple chemistry laboratory with a conventional fume cupboard. The goal of the work was to use VR to generate source particles in real time and visualise airflows in the vicinity of the cupboard's sash handle. The CFD package providing the 3D source data was CFX-F3D, designed by AEA (Atomic Energy Authority) Technology's CFD Service Facility in Harwell.
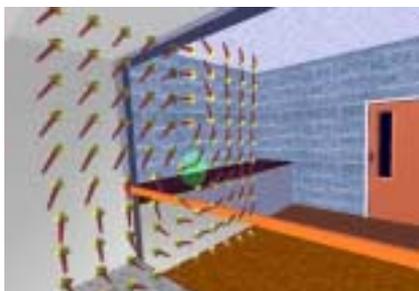
The 3D CFD data were analysed to establish the optimum method of extracting the information needed to produce a dynamic VR simulation. The software developed by Virtual Presence stores the information in the same block/cell structure as provided in the output from CFX and has hard-coded functions which allow it to read in any other CFD data produced by CFX. Once the data are stored, special cell-to-cell "occupation history" techniques are used to avoid searching every cell in the laboratory (some 90,000 cells in total in this instance).

The project concluded successfully with a demonstration of the results of the CFX database-VR system integration work, using a variety of VR display and interaction technologies. Immersive (headset-based), desktop, desktop plus field sequential stereo glasses and projection display facilities were used for this demonstration, giving users the ability to experience and experiment with a variety of dynamic particle representations – single and multiple streamers, lattices of textured spheres and 3D arrow fields.
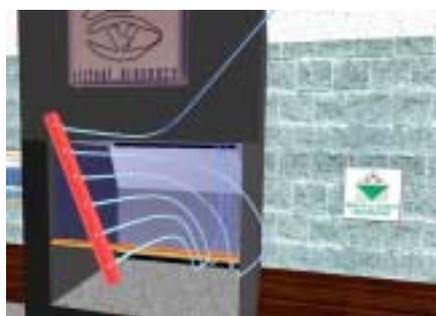
Whilst a graphics "supercomputer" was used during part of the study, the main demonstration took place using a Windows NT machine, achieving display frame rates of the order of 20 frames per second or greater for 300 non-textured particles. For comparison, running the VR simulation on a Pentium 266 (a system costing 100 times less than that of the supercomputer and one-fifth that of the NT machine), it was possible to track and display the movements of 300 non-textured particles at over 10 frames per second.

- **Source data (CFD): AEA Technology's CFX-F3D**
- **Main modelling package: MEDIT**
- **Data and geometry conversion software: Virtual Presence Proprietary**
- **VR run-time package: Sense8 WorldToolKit**
- **Development and run-time hardware: Silicon Graphics *InfiniteReality* Engine; Intergraph TDZ 2000 VX25GT (64Mb texture memory); Pentium II-266 with 32Mbytes of RAM and a Permedia II graphics accelerator**
- **Interaction and display systems: <u>Immersion</u> – Virtual Research VR4, Polhemus Fastrak, Virtual Presence hand controller; <u>Large-screen projection</u> – Electrohome 9500LC *Marquee*; <u>Stereo desktop</u> – Stereographics CrystalEyes**

Haptic Feedback

The term "haptic" refers to all human perceptions relating to touch and force. Touch or "tactile" feedback is mediated by sensors within the human skin; force feedback is dominated by the action of special sensors embedded within muscles and tendons ("kinaesthesis"). Virtual Presence has been active in haptic feedback research, development and product distribution since the very early 1990s.

Teletact (1990 - 1992)

The *Teletact* Glove was originally designed to complement any glove-based input device in a Virtual Reality or telepresence system. The Teletact concept first originated in November of 1989, when Virtual Presence's present Northern team was part of the UK's National Advanced Robotics Research Centre in Salford. Co-developed with Airmuscle Ltd of Cranfield, the first prototype glove, employing small air pockets was produced in September of 1990, and appeared on the *Tomorrow's World* TV Programme later that year. This prototype glove was of an analogue design, supplying up to 13lb psi of air pressure per pocket. A second glove was produced as a pre-market system, and although it was built to more rugged standards, its proportional control system was considerably simpler in design (based on digital technology), permitting rapid inflation and deflation of the pockets.

A more sophisticated glove - *Teletact II* - was specified in May of 1991. This device featured a greater density of air pockets, 30 in all, with two pressure ranges. The majority of the pockets (29) were limited to 15lb psi. However, a new palmar force feedback pad was specified, receiving a maximum pressure of 30lb psi. A vacuum system was also specified to increase the step response of the glove whilst deflating.

Teletact *Commander* (1990)

The Teletact *Commander* Development Project was also instigated at the National Advanced Robotics Research Centre when it was realised that proprietary data input gloves were, at the time, both expensive and significantly deficient as interactive devices in a number of important respects:


- Unreliable gesture recognition which in use proved very fatiguing and frustrating (often making "fly-throughs" of the virtual world and grasping of virtual objects impossible),
- Re-calibration of gloves was necessary every time they were donned and doffed (or even after lengthy periods of wear, once the hand had been sweating considerably),
- The fragile nature of gloves (ie. the fibre optic flexion, extension and abduction sensors), and the lengthy repair times from the USA.

To overcome some of these problems, a simple multifunction hand controller or "grip" was designed which, together with Polhemus or Ascension tracking sensors, provided a comfortable and reliable means of interacting with virtual environments. Three Teletact-like air pockets were also integrated to provide simple tactile cues when the user touched a virtual object. These pockets were controlled either by compressor or by a single solenoid-actuated piston. With 5 small buttons and a toggle switch, ergonomically located for finger and thumb actuation, naïve users were found to adapt to the grip within 2 minutes. It was concluded that a well-designed handgrip could be as intuitive to use as a glove, costing a fraction of the price.

Early Medical Haptic Feedback Demonstrator (1994)

One of the results from a 2-year Virtual Reality medical project sponsored by the British Department of Health and Wolfson Foundation was a haptic feedback "proof-of-concept" demonstrator, developed by a mature postgraduate student of Manchester Metropolitan University (now a member of the Virtual Presence team) in just 12 weeks. The general mechanical layout of the 3-degree-of-freedom (plus grasp) system was based on three, mutually orthogonal actuator rods, connected using self-aligning rod-end bearings, to the tip of the artificial instrument, the stem of which is allowed to slide through a pivot.
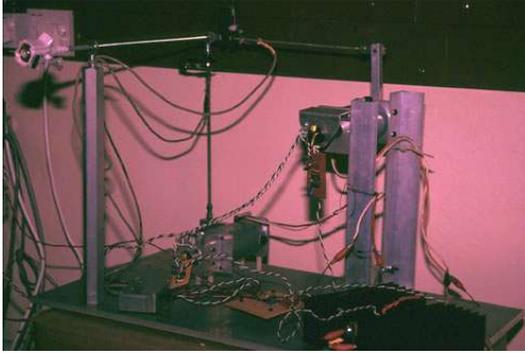
By providing the appropriate force to each of the rods, any required force could be applied to the tip. The rod forces were supplied via cranks fitted to servomotor shafts. The cranks were 10cm long and their movement restricted to 60° giving a 10cm cube as the useable volume. Each motor shaft was fitted with a rotary position sensor and the actuator rods were fitted with force sensors close to instrument tip.

The software developed delivered force, first and second derivatives of force with respect to distance, mass, and damping factors. An initial investigation into this approach, using a simple demonstration with PCs only, showed considerable promise. The system was further enhanced by demonstrating dynamic effects, including "pulsation", elastic grasp and tear. Early responses from practising surgeons (and representatives from other VR application areas) were very favourable, one Senior Registrar even likening the pulsating sensation to "touching the aorta".

Defence Research Agency (DERA) Tactile Feedback Control Panel Demonstrator (1995)

The *TactGlove*, developed for the Defence Research, was a stand-alone tactile feedback glove demonstrator, consisting of a 3-digit sensory glove assembly (thumb, index and middle finger), equipped with PZT (lead zirconate titanate) piezo "sounders" to provide variable frequency tactile input. The glove was built to Virtual Presence's specifications by the Electronic & Electrical Engineering Department of the University of Salford. A purpose-built interface card allowed the glove to be driven from (at the time) a standard 486 or (later) Pentium PCs. For the purposes of demonstration, the visual interface - a simple VR control panel - was developed using Superscape Limited's Virtual Reality Toolkit (VRT), Version 4.00. Users could view the virtual control panel using either a standard monitor, or a set of Virtual I-O *i-Glasses* (stereo or biocular modes). Mounting a Polhemus Fastrak sensor on the *TactGlove* enabled the user to control the apparent 3D position of a schematic "hand" (in effect a three-dimensional tri-cylinder cursor). On making contact between the "hand" and one of three virtual controls (a rotary knob, push-button and toggle switch), the appropriate "collision" signal was transmitted to the glove sensors, either singly or in combination. Actuating the control produced a perceptible change in the frequency of stimulation, higher or lower than the initial collision frequency. Thus, as the rotary knob was rotated counter-clockwise and clockwise, the frequency of

stimulation decreased and increased. As the push-button and toggle switch reached their break-out force, the piezo frequencies increased gradually, followed by a step decrease to indicate actuation.

### The *PHANToM* Haptic Interface (Present Day)

Sensable Technologies Inc's *PHANToM* haptic feedback system is, today, part of Virtual Presence's ever-expanding product distribution portfolio and the company is involved in numerous projects, providing implementation advice and consultancy to ensure that the PHANToM is applied to those aspects of a task that warrant force and tactile feedback.

The *PHANToM* allows users to interact with virtual objects and environments using visual *and* haptic cues. By grasping a small stylus, or by inserting their fingers into a thimble or holding a stylus, each supported by a linked system of joints and counterbalanced arm members, users can input three-dimensional (up to 6-degrees-of-freedom) position data into the host computer (Windows NT or Unix environments). Small servomotors deliver the sensations of touch and force from the virtual environment back to the user via the same linked members. For more sophisticated applications, multiple thimbles may be used simultaneously.

### *PHANToM* Usage in Aerospace Maintenance Training
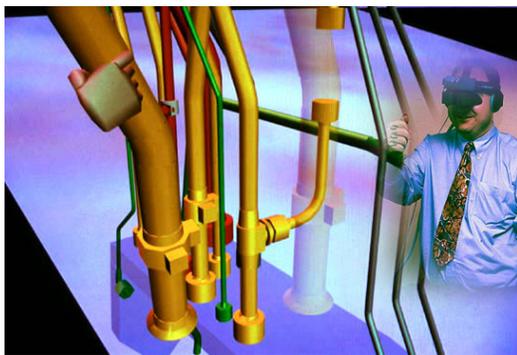
The use of VR to streamline design and training processes in the aerospace industry is not new. However, the absence of a credible haptic feedback mechanism had forced developers such as Virtual Presence, in its collaboration with Rolls-Royce, to use other sensory cues to indicate collision detection between pipes, tools, limbs and so on (eg. visual 3D "ghosting") within a cluttered working volume.

As with other engineering applications of VR, it is only recently, that the aerospace industry has revisited VR to assess its suitability for 21st Century projects and products. The European Initiative **ENHANCE** (ENHanced AeroNautical Concurrent Engineering) brings together the main European civilian aeronautical companies and seeks to strengthen cooperation within the European aeronautical industry by developing common working methods which govern the European aeronautical field, defining appropriate standards and supporting concurrent engineering research. One project within *ENHANCE* concerns an advanced VR maintenance demonstrator which links a virtual mannequin with PTC's DIVISION MockUp virtual prototyping

software with Sensable Technologies' *PHANToM* haptic feedback system. Based on a 3D model of a conceptual future large civil airliner, the VR demonstration involves controlling the mannequin during aircraft preparation and safety procedures, and in gaining access to retracted main landing gear for the purposes of wheel clearance testing.

Certain key interaction events throughout the demonstration are executed using the *PHANToM* device. In order to define these stages clearly, and to identify those procedures and events warranting the application of haptic feedback, a context-specific task analysis was carried out, as recommended in the 1999 International Standard **ISO 13407** (*Human-Centred Design Processes for Interactive Systems*).
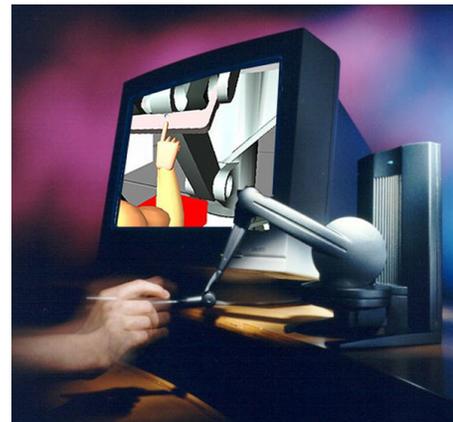
PHANToM Usage in Medical Simulation Training

As well as the early UK Advanced Robotics Research Centre "keyhole" surgery haptic feedback attempts, there have been, and still are projects with significant haptic technology components. One of these forms part a European Union Framework V Project called *IERAPSI*, an Integrated Environment for Rehearsal and Planning of Surgical Interventions. An early *IERAPSI* work package relates to the human-centred definition of surgical procedures (again based on ISO 13407), specifically focusing on surgical activities underpinning mastoidectomy, cochlear implantation and acoustic neuroma resection. The surgical procedures definition and task analyses were conducted by Virtual Presence in collaboration with the ENT department of Manchester's Royal Infirmary. These exercises resulted in the selection of the *PHANToM* Desktop/1.5A for haptic and vibratory stimuli when simulating the use of pneumatic drill (through cortex and petrous bone) and a second device - a *PHANToM* Desktop - for irrigation and suction.
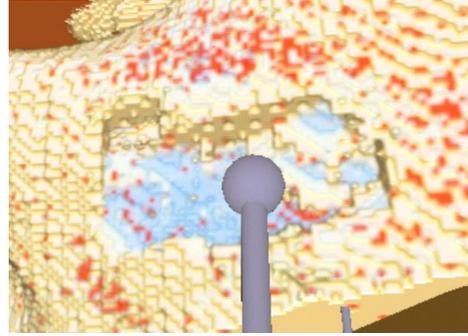
PHANToM Usage in Mine Clearance Training

Virtual Presence (Paris) has developed an immersive VR land mine detection training system for the French Army, using the *PHANToM* as the primary interaction device.

The system presents the trainee with a basic representation of the ground area to be investigated and, using a standard issue military probe attached to the *PHANToM*, he is required to locate potential mines by gently inserting a virtual representation of the probe into the "ground".
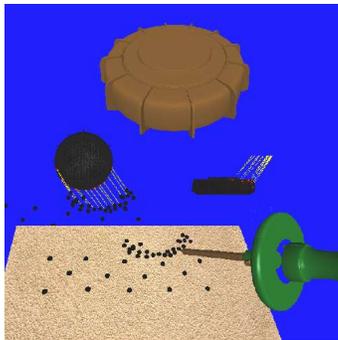
Once a definite contact has been made, the trainee must continue probing until a recognisable pattern of penetrations has been made. In addition to the visual and haptic features of this trainer, a pattern recognition system is available which matches the trainee's penetrations with known land mine geometries. Once a pattern match has been made, a schematic of the most likely mine configuration is displayed.
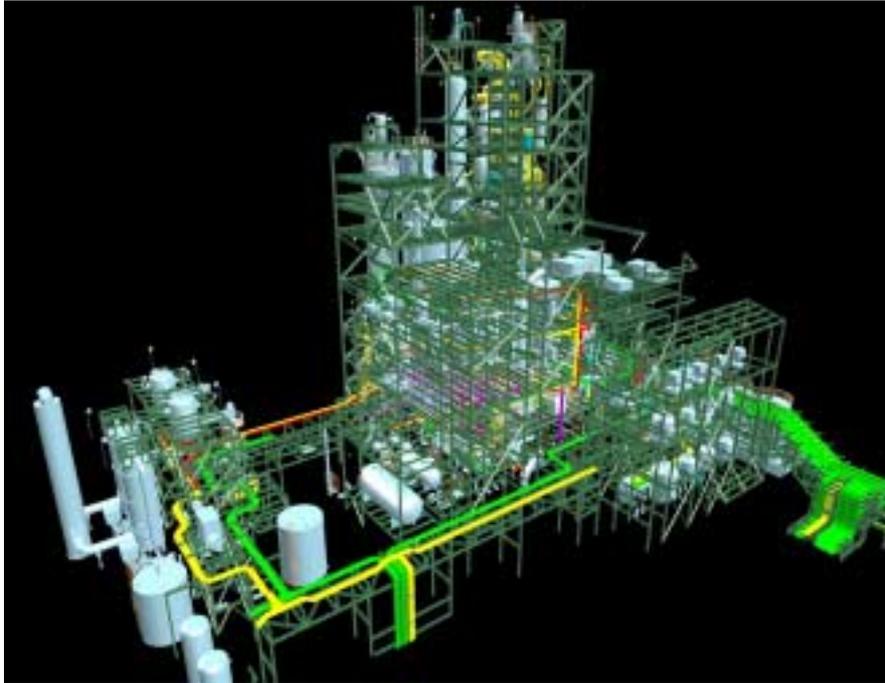
ICI/Fluor Daniel Petrochemical Plants

Virtual Presence Limited has been active in the demonstration of VR technologies for petrochemical plant applications since 1993. The first project in this area, which was carried out on behalf of ICI and their plant design contractors Fluor Daniel Ltd., involved production of a detailed VR model of 2 selected bays of the Middle Distillate HDS Portion of ICI's SulFerox Plant design. Both companies were interested in a commercial assessment of VR, not only as a complimentary technology to CAD and a means of replacing costly scale plant models (see HDS model, picture right), but also as a mechanism for improving working practices and reducing plant design and total life cycle costs.

During the course of the Project, CAD models of the HDS components were supplied to Virtual Presence to be converted and "reassembled" into a VR model, capable of being displayed and interacted with by means of "desktop" workstations, 2D/3Dprojection displays, and fully immersive VR systems. Rather than simply produce "another VR fly-through", requirements were placed upon Virtual Presence by ICI and FDL to demonstrate the functional nature of VR. To this end, and following a number of brainstorming sessions within and between each organisation, a shortlist of 6 "mini demonstrators" were specified for the final project review, listed overleaf.

- **Instant Change**, whereby the virtual model could be modified efficiently during run-time by moving objects, re-sizing, altering valve locations, and so on.
- **Operator Training**, displaying plant walkways, manways, vessel interiors, vessel shut-down and access procedures. Indeed, a subsequent project for the UK Health & Safety Executive addressed these very issues[1].
- **"Touch and Tell"** Tagging, whereby objects in the virtual environment could be interrogated simply by touching the object with the virtual hand or cursor. Once touched, data such as item name, main plant item number, manufacturer, and so on would appear in a separate window.
- **Line and System Tracing**, highlighting (through simple touch and tell action, as above) a line or system route, so that its path can be traced through the plant.
- **Constructability**, demonstrating, by means of a virtual crane system, the power of VR as a tool for aiding constructors' and contractors' decisions in, for instance, judging the accessibility of a given area or volume during major vessel installations.
- **Internals Installation and Removal**, allowing maintenance technicians to visualise and rehearse work before entering the real vessel, for example.

The only information missing from the CAD libraries was that pertaining to the plant pipework. A short development project was undertaken by Virtual Presence resulting in software which, based on the input (from hard-copy) of isometric node and bend data, generated virtual pipework *automatically*, complete with valves, lagging diameters and other plant features. Once the virtual pipe runs were constructed, they were located in their correct spatial position in and around the HDS plant steelwork.

Since these early studies, Fluor Daniel and Virtual Presence have collaborated on the development of a VR prototype of a Kodak processing plant, complete with moving machinery and virtual mannequins (picture below, right). At ICI's 1996 annual conference in Keele, the (then) largest VR petrochemical plant construction in the world (based on an existing plant in Teesside) was demonstrated. The converted PDS model, running in real-time on a Silicon Graphics InfiniteReality Engine, using both immersive and projection technologies, boasted the graphical equivalent of 200km of electrical cables, 21km of pipework, 2000 tonnes of steelwork and 1300 items of equipment (pumps, vessels, valves, etc.). At the 1997 conference, a shared immersive (headset-based) VR demonstration was staged, showing how two Fluor Daniel engineers could work together in the same virtual environment and cooperate in the disassembly and maintenance of a complex pump mechanism.

- **Source CAD Data: AutoCAD (HDS), PDS, PDMS, MEDIT**
- **Conversion Code: Virtual Presence Limited Proprietary**
- **Integration/Run-Time: DIVISION *dVISE/dVS* (Intergraph TDZ series; SG *Onyx/InfiniteReality Engine*)**
- **Interaction/Display: Immersion (Single User, Shared)/Desktop/Stereo Projection)**

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[1] **See also Applications Sheet No. Eng/Apps/HSE.98.1**

Interior Visualisations

Closely supported by VP Group, a small Manchester Airport-based company has taken the initiative to investigate and market the potential offered by VR, particularly in the assessment of new corporate styles for seat fabrics and cabin furnishings (carpets and curtains, headrest covers, even luggage bin trims and general finishes). A single aircraft cabin was initially modelled to high visual detail prior to the application of very high quality textures, scanned from material samples provided by some of the participating airlines - Britannia, easyJet, Airtours, Air 2000. More recent work has involved the use of VR to model the interior of customised executive jets, enabling their purchasers to make design changes and decisions prior to the expensive process of fitting out the real cabin.

The modelling and texture application quality has to be of a very high quality, both for real-time performance and visual impact - viewers need to be able to look very closely at the fabric design (including the weave), so pixellation of the textures when very close must be kept to a minimum. Similarly, image degradation must be kept low if the aircraft cabin is displayed to groups of designers and evaluators using video projection techniques. Seat, carpet and curtain textures can be changed instantly, by a single key entry, enabling users to evaluate different design concepts quickly and cheaply, avoiding the need for potentially wasteful physical prototypes. An interesting and unpredicted use of the technology has been in the sale of designs and fabrics no longer required by an airline company, as was the case in 1996 when,

left with many hundreds of metres of unwanted material following one company's bankruptcy, they used VR to market the material and design to others.

Another interesting story involved a senior member from an airline who was less than satisfied with the results of his venture into VR prototyping. Claiming that VR technologies had *not* delivered a true representation of his team's new design, he went ahead and commissioned the refit of an aircraft with the proposed material. However, when senior company executives were introduced to the real-world prototype, exactly the same criticisms were voiced as were evident in earlier VR presentations to other company representatives. The actual design concept was at fault! VR had not visually transformed the supplied material data in any way. In fact VR had represented the result in a very realistic manner which, had that fact been accepted, would have saved the company many thousands of pounds!

VP Group has also provided clients in the nautical market with visualisations of new interior concepts for vessels, including early designs for the first class passenger areas onboard the GEC *CAT* catamaran.

Virtual Lowry

"He painted Salford's smoky tops
On cardboard boxes from the shops,
And parts of Ancoats where I used to play..."

From the record *Matchstalk Men and Matchstalk Cats and Dogs*, by Brian & Michael (Pye 7N 476035). The record first entered the
UK charts on 25 February, 1978 and reached the "Number One" spot on 8 April that same year, holding the position for 19 weeks.

L.S. Lowry (1887-1976) was a renowned Salford and Manchester artist, perhaps best remembered for his stylised portrayal of everyday people in everyday life. In 1994, a major project was launched by Salford City Council to commemorate the artist through the integration of art, technology and education within a complex to be constructed on Salford Quays by the year 2000 - the **Lowry Centre**. To emphasise the integration of these fields of endeavour, Virtual Presence was contracted to develop and stage a VR demonstration for the benefit of visiting Executives from the Millennium. The contract, which was awarded on 23 June, 1995 was completed, on schedule, only **12 working days later** - 10 July, 1995, the day of the Commission Executives' visit! Later, it was acknowledged that the VR component of Salford's bid was instrumental in securing the £127 million of grants for the Centre.

The successful demonstration was based on the concept of a solitary gallery, located at the centre of a virtual "computer network", with electrical circuit tracks extending out from the gallery perimeter as far as the eye could see. Three Millennium Commission Executives wore Virtual I-O *i-Glasses* for passive viewing of the activities of an immersed gallery "guide", equipped with a VR4 headset, Polhemus Fastrak head/hand tracking system and hand controller. The virtual gallery was furnished with a range of Lowry paintings and other artefacts, including an antique Victorian-style chair, marble glass-top tables and a glass-fronted book cabinet (all glass with environment mapping), a Venus de Milo, futuristic loungers hovering in one corner, and a human bust sporting a virtual pair of *i-Glasses*, mirroring the head movements of the immersed guide.

Her/Apps/Lowry.98.1

Leaving the gallery, the guide then "flew" the visiting Executives into one of Lowry's paintings - *Coming From The Mill* (1930). The 2D painting immediately transformed into a 3D world, portraying the stark style of perspective with which Lowry endowed his industrial and street works of art. Texturing of the buildings, streets and sky was achieved by scanning and digitising high quality prints of Lowry masterpieces, ensuring that the process did not lose the brush stroke

qualities of the artwork. Lowry characters - the famous "matchstick" or "matchstalk" people - were then animated, again using digital pre-processing of Lowry prints, but this time separating and moving the characters' legs to achieve a simple 3-frame textured animation sequence. Groups of moving people were achieved by mapping these textures onto billboards, slowly moving them across the virtual scene. As well as being based on *Coming From The Mill*, the virtual Lowry world comprised a number of scenes from many of his pictures, including *A Landmark* (1936), *Level-Crossing* (1946), *The Funeral Party* (1953), *Man Lying on a Wall* (1957), *The Sea* (1963).

- **Modelling/Database (Gallery and Street): MEDIT**
- **MEDIT-*dVISE* Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: DIVISION *dVISE/dVS* (SG *Onyx*)**
- **Photo Textures/Animation: L.S. Lowry Pictures; Copyright: Salford City Council (reproduced and processed for VR model with permission)**
- **Interaction/Display: Immersion (gallery "guide"), Partial Immersion (gallery observers)**

Close-Range Weapons Simulation Facility
HMS Collingwood

With the closure of the coastal firing range at HMS Cambridge near Plymouth in March 2001, 20 and 30mm naval weapons students are being trained today using a special simulation facility at HMS Collingwood near Portsmouth. Using state-of-the-art Virtual Reality techniques, including the latest in head-mounted display (HMD) technology, weapons students are now able to undertake realistic firing exercises, engaging targets as if located on an actual Royal Navy vessel. The simulators were commissioned by NRTA and developed by Virtual Presence Ltd over a period of just 6 months.
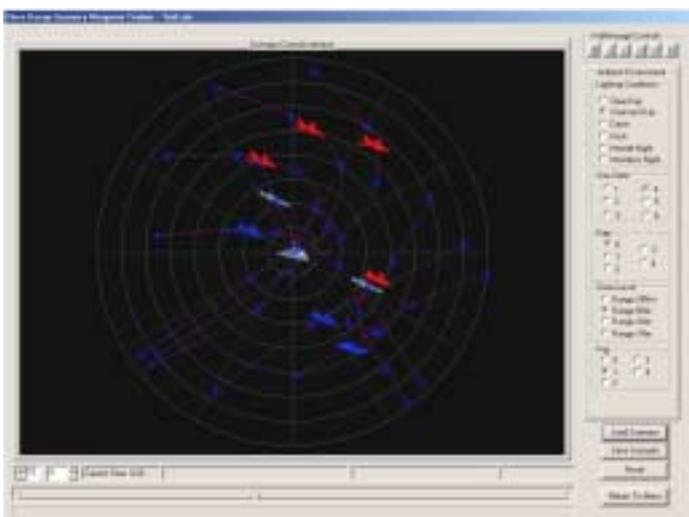
By means of a specially designed computer interface, weapons instructors can design and save a variety of training scenarios by using simple mouse and keyboard inputs. A wide range of hostile platforms (aircraft, surface vessels and missiles) can be programmed to approach the student's "own ship" from different bearings and ranges, and at different heights and speeds. Friendly and neutral aircraft or vessels can also be introduced into each scenario. Once the instructor has introduced a

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particular threat it is then possible to program its future route or profile by inserting one or more waypoints. Each waypoint can be associated with a change in direction, height or speed, thereby endowing the platforms with realistic behaviours. Quite complex scenarios can be generated in this fashion, with aircraft and ships even releasing missiles at certain points during their pre-programmed profiles.

During the training exercises themselves, these pre-programmed behaviours are displayed via HMDs to the student 20/30mm weapon aimers and, for simple tracking training, via a video projector to students manning a general-purpose machine gun (GPMG). The view through the aimer's HMD is that of a virtual weapon emplacement on the starboard side of their "own ship". The environment in which the scenario takes place can itself be programmed to include sea states from zero (calm) to 6, mist and fog levels, time of day and rain effects. In addition to the weapon aimer's position, 2 trainee Weapon Directors Visual (WDVs) stand on a purpose-built Gunner Director's Platform (GDP) within the HMS Collingwood simulator facility. The WDVs are also equipped with HMDs, each having been modified by the addition of a small switch. Pressing the switch magnifies the view available to the WDV, thereby simulating the use of binoculars. Calling out and acting on instructions, the WDV and weapons aimers interact to engage incoming targets. On firing the virtual 20/30mm weapon, realistic barrel motions can be seen, together with smoke and tracer effects. Successfully destroyed aircraft explode and fall to the sea. Sound effects have also been provided, including weapons discharge and an ambient, background naval vessel noise. Once a scenario has been run as a training exercise, it can be replayed by the instructors for debrief purposes.

Another component of the training system, located in a separate facility at HMS Collingwood relates to the observation and reporting of fall-of-shot, in this case for the ranging of larger calibre weapons (eg. the 4.5", Mk. 8 gun). Here, the virtual world images are fed into a special pair of virtual binoculars, mounted in place of the optical unit of a Director Aimer Sight (DAS). The instructor can test the student's splash-spotting skills by interactively selecting an impact point for a virtual projectile in the available DAS field of view. As well as seascape scenarios, the DAS students can also be presented with a landmass, consisting of static trees, building and vehicle targets. The weapons and DAS simulators are fully DIS compatible. This development could, for example, allow one or more of the simulators to fulfill a defensive role on a virtual ship taking part in a synthetic warfare exercise, irrespective of whether the vessel was hosted on a different simulator within HMS Collingwood, elsewhere in the UK, or even further abroad. In January, 2002, the CRWS team at Collingwood fired their one millionth virtual round, an event that was highlighted not only by the presentation of a trophy, but by a recognition on the part of all concerned that, had this been real ammunition, the cost to the RN would have been well in excess of £25 million!
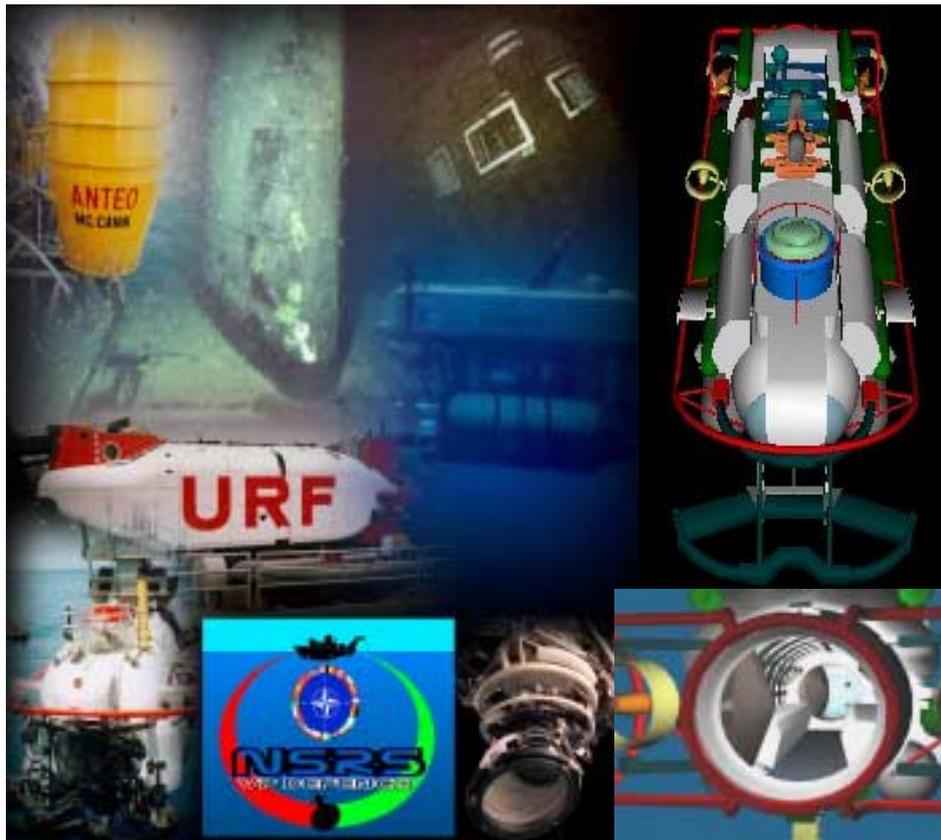
SUBMARINE RESCUE
SYNTHETIC ENVIRONMENTS TRAINING

In 2001, VP Defence completed a Human Factors and Training Needs Analysis Scoping Study under subcontract to WS Atkins, who had been commissioned to conduct the overall Project Definition Study for the NATO Submarine Rescue System (NSRS), reporting to the Integrated Project Team

(IPT) of the same name within the UK Ministry of Defence. VP's involvement with WS Atkins came about not only as a result of the company's pioneering work in delivering virtual or synthetic training systems to the defence arena, but also due to the fact that members of the company had participated in the UK's *Bondi* Initiative (1979 to 1983), an R&D programme designed to evaluate emerging technologies suitable for replacing humans from subsea oil and gas exploration environments. Whilst at BAe, one of today's VP personnel took part in trials undertaken in 1982 at the Fort William/Loch Linnhe diving facility in Scotland, which

involved two ROVs (including an early *Scorpio* system) and the British Oceanics *LR2*, the 3-person, single-atmosphere, predecessor of the *LR5*, operated today by RUMIC as part of the UK Submarine rescue System (UKSRS).

At the time of publishing the PD Study, the NSRS concept had not been defined to the extent that it will take the form of a manned rescue vehicle (SRV), a single/limited crew remotely operated rescue vehicle (RORV) or, as is presently the case, an SRV with remotely operated vehicle (ROV) support. Consequently, VP's TNA scoping report was written to cover 3 alternative system options. These were (a) manned submersible only (SRV), (b) manned submersible with remotely operated submersible support (SRV + ROV) and remotely operated submersible with single/limited number support crew *in situ* (RORV). The VP report concluded that a good proportion of the basic engineering and support tasks associated with a future rescue submersible system can be trained in a

cost effective way by exposing trainees to actual equipment in a dry (dockside/storage facility), using actual equipment. However, there were a number of critical tasks that could not be effectively trained in this manner, such as submersible dive and navigation procedures under a range of subsea and bottom conditions, DISSUB inspection and debris clearance and manipulator/special tool handling. Consequently an affordable (PC-based) virtual environment simulation facility was suggested that would (a) re-use simulation software already commissioned by the MoD/RN (eg. the seascape, weather modules and 3D naval objects used for the close-range gunnery trainer at HMS Collingwood and the virtual *Trafalgar* Class submarine constructed for FOSM), and (b) deliver the following key training elements:

- Variable sea states at launch
- Variable strength subsea currents with fixed or changing bearings
- Variable degrees of water turbidity
- Variable DISSUB bottom angles
- Pre-set DISSUB external lighting arrangements
- SRS external manipulator functions
- Water jet cleaning of silt on deck
- Emergency Life Support Stores (ELSS) "pod posting"
- Attachment of Distressed Submarine Depressurisation System (DSDS) hose
- Variable SRS subsystems reliability (thrusters, lights, etc.)
- Simulated evacuation procedures using synthetic mannequins

The final point listed above is of particular interest, given parallel efforts internationally in the use of synthetic environment training technologies for various aspects of submarine training (eg. VESUB, Submarine Qualification, "Dry" (SMQ(D)) for the British *Astute* SSNs). VP's report concluded that training policy should ensure, where possible, the integration of future development effort to ensure that both DISSUB rescuers *and* evacuees will benefit from the existence of a submarine/submarine rescue simulator.

Since this study was completed VP has conducted its own in-house effort to prove the feasibility of the company's NSRS training concept. Using open standard, license-free software, together with 3D objects archived in an ISO-standard format (including a 3D model of the *LR5* submersible supplied by RUMIC), a variety of mini-demonstrators have been developed, including visualising the evacuation path from a submarine forward escape compartment through the TUP skirt, into the *LR5* SRS interior.

VP Defence is now looking to partner with the successful prime contractor for the NSRS system and would welcome further enquiries from organisations interested in including a cost effective synthetic environment training system and/or a recognised award-winning human factors capability within their proposals. VP Defence also welcomes general enquiries for company papers and publications that describe recent successes in the application of PC-based virtual environments to defence applications.
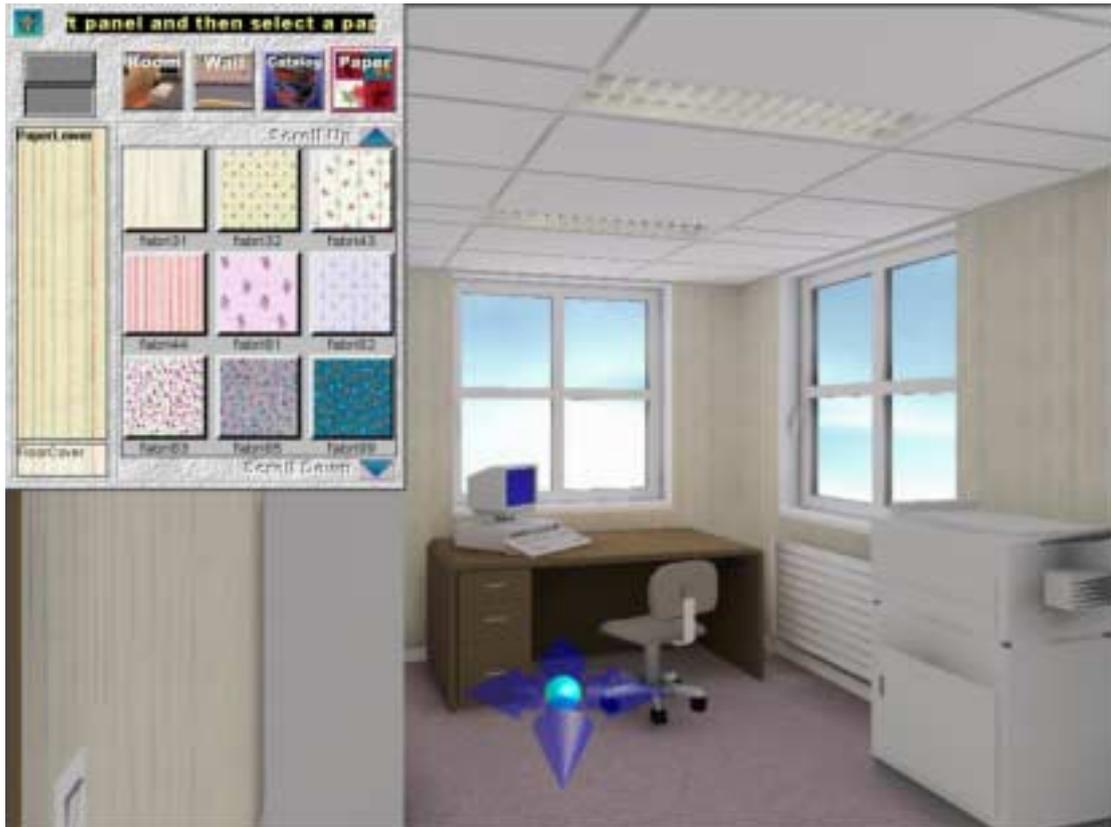
Paperspace

Paperspace is an interactive room decoration system, the result of an 8-month project sponsored by Virtual Presence, Imperial Décor International (the export division of the Imperial Home Décor Group (UK) Limited), Peak Productions, based in Worcestershire and Sunray Wallcoverings - a major wallpaper client of Imperial - based in Hong Kong. Apart from the obvious marketing benefits, the main commercial impetus for ***Paperspace*** relates to helping sales outlets to avoid the expense of leasing large retail floor spaces in places like China. In many respects, the application has similar commercial goals to the Virtual Reality kitchen design system demonstrated by Japan's Matsushita in the early 1990s. However, limited retail spaces are not just a problem faced by vendors in Continental Asia and the Far East. It should be noted that many - if not all - of the large European "DIY" outlets are themselves unable to offer sales space for *every* wallpaper product offered by the likes of Imperial.

An initial selection of computer-generated rooms, both domestic (eg. lounge, bedroom) and commercial (eg. reception, office) were modelled using proprietary packages. In order to improve the visual realism of these models, each was processed using a *radiosity* program designed to simulate lighting effects by rendering room surfaces according to a physical model of how artificial and ambient light is reflected and absorbed in that room.

When users first interact with the ***Paperspace*** system using a touchscreen display, integrated within Imperial's *Gallery* class of merchandise display unit, they are

presented with a visual "drop-down" menu that allows them to select the virtual room closest to that they wish to decorate in real life. They are then led carefully through a series of design steps, beginning with preferred wall style – plain, wall plus ceiling border, wall plus ceiling border plus dado rail, and so on. Once a wall style has been chosen, the user is prompted to select one of many virtual (CD-hosted) wallpaper "catalogues". On selecting a catalogue, samples are displayed within the drop-down menu, as is a simple schematic showing the selected wall style.

The user is then free to experiment with applying a variety of wallpapers and borders. They are also given a facility to choose a floor finish close to that in their own real setting. At all stages of the design process, the user can "explore" their virtual room simply by moving the mouse cursor over one of the forward-backward / left-right movement icons available in the centre of the screen.

Paperspace has been written under Open GL and runs on an Intergraph TDZ 425 workstation with V25GT graphics card. *Paperspace* was launched in Marbella in early June 1998, with additional roll-outs planned, including the USA (Imperial Wallcoverings in Cleveland), Russia, the Ukraine and China.


- **Source CAD Data for Room Models: MEDIT, 3D Studio**
- **Radiosity Package: Lightscape**
- **Integration/Run-Time: Open GL**
- **Interaction/Display: Windows NT Desktop with Philips IntelliTouch Touchscreen**
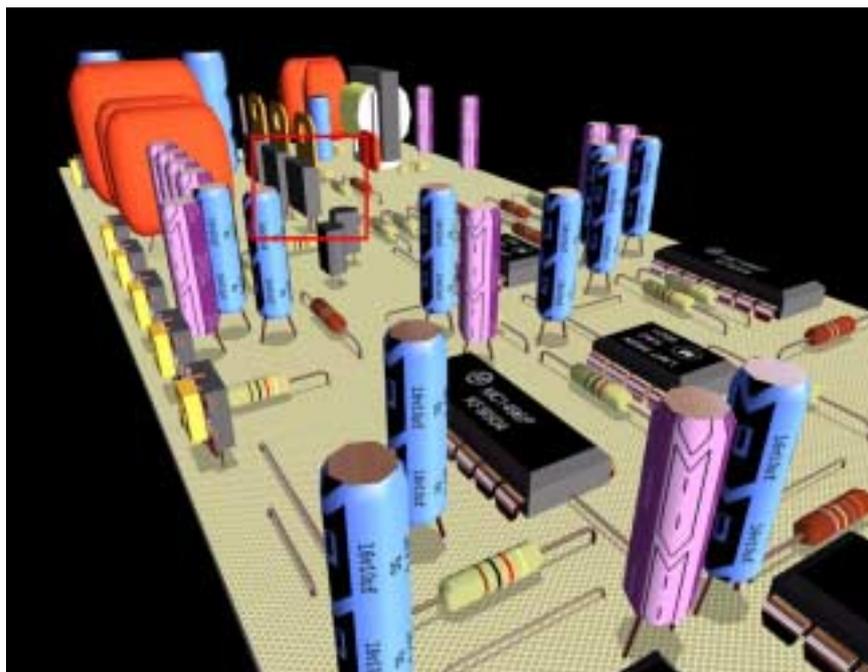
Philips Semiconductor (TrenchMOS) Miniaturisation Project

Philips has been evaluating Virtual Reality for some time, but the challenge made to Virtual Presence by their Stockport-based semiconductor factory late in 1996 was to use VR to "miniaturise" employees so that they could experience the microscopic nature of the semiconductors they were employed to manufacture.
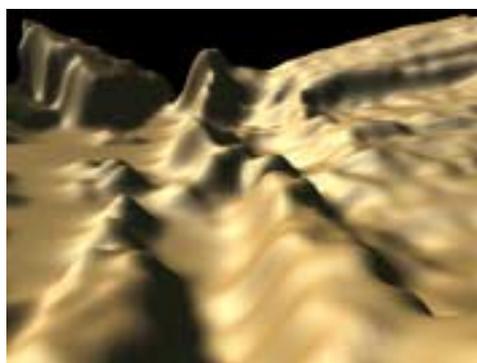
Using VR to visualise objects at micro-/ nano-scales is not a new idea. As long ago as 1992, Virtual Presence was using VR to visualise the output of a scanning tunnelling microscope (STM), effectively giving surface engineers the means to witness - and *measure* - atomic changes brought about by chemical and radioactive processes. The data produced by the STM are ideal for conversion into a VR model, which is typically made up of hundreds of individual polygons or "facets". Instantaneous records from the location of a mechanical "boom" supporting the microscope's probe provide x and z coordinates of each surface point during the scan. Data relating to the y coordinates (surface relief) are obtained from tiny boom deflections which occur as the system attempts to maintain a fixed current between the probe tip and the sample surface.

It may be of interest to note that a similar conversion process was employed for the 1996 *Virtual Stonehenge* project - converting the many thousands of surface data points collated during an earlier photogrammetric survey of each of the 80 stones[1]. Unfortunately, no such scanned data existed at the outset of the Philips project. Consequently, the entire demonstration had to be constructed by hand, using drawings and electron microscope photographs.

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[1] **See Applications Sheet No. Her/Apps/EH.98.1**

The demonstration starts when the VR user dons a head-mounted display equipped with a small electromagnetic tracking sensor which relays position and orientation information to the host computer, updating the images in the headset as the user's head turns. Once in the headset, the user finds himself in a simple office environment. The user is also provided with a handgrip which is used to control his movements around the office. On a desk in front of the user is a printed circuit board, lying next to a PC.
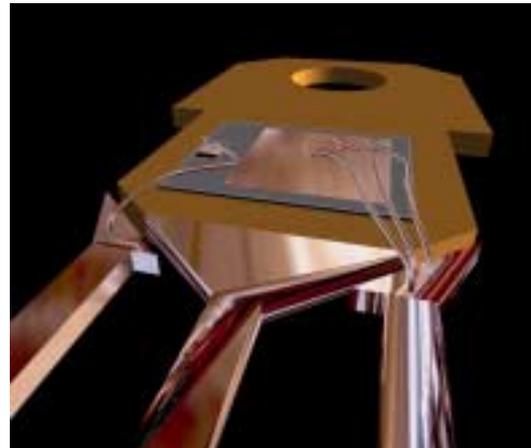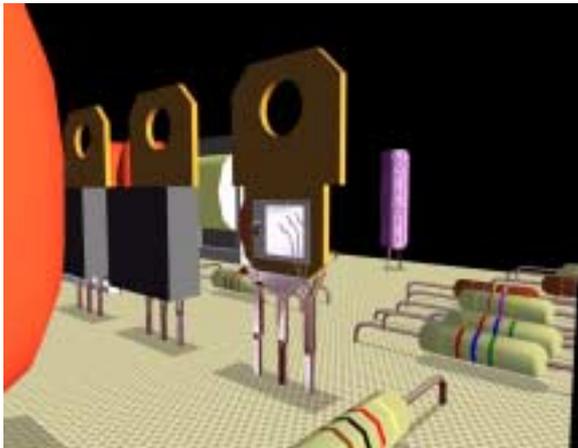
As the VR user approaches the desk, he is "shrunk" to a height of around 1cm and is then free to move amongst the resistors, capacitors, microprocessors and the TrenchMOS semiconductors themselves. On approaching one of the semiconductors, the plastic cap automatically lifts off, exposing the TrenchMOS itself. The user is then shrunk again, this time to a height of around 1mm, and can move around the very reflective surface of the chip.

The final shrinkage takes the user to a height of some 20-30 microns, and, as smooth aluminium substrate is removed, the regular hexagonal patterns of the chip surface are exposed, extending as far as the eye can see.

- **Source Data: Photographic/Electron Microscope Images/MEDIT**
- **MEDIT-VR Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: Division *dVISE/dVS* (Silicon Graphics *InfiniteReality Engine*)**
- **Interaction/Display: Immersion/Desktop**

RAF Helicopter Voice Marshalling
Virtual Environments Trainer

The past 2 years have witnessed a steady increase in the number of search and rescue missions flown by RAF helicopter crews. To quote but one example, in 2000, the Anglesey (NW Wales)-based Search and Rescue Training Unit (SARTU) of the Defence Helicopter Flying School (DHFS) at RAF Valley had carried out 231 rescue missions, ranging from injured mountaineers and air crash survivors to the airlifting of ferry passengers and the transfer of road traffic accident victims to hospital. As of the end of 2001 the total stood at over 200.

Central to the success of these missions is the role played by the helicopter voice marshalling aircrew. Working out of the open rear doors of the RAF's *Griffin* HT1 (Bell 412) helicopters, voice-marshalling aircrew verbally relay important flight commands to the pilot in order to guarantee the accuracy and safety of the aircraft's approach to a landing site or target object. Looking across the spectrum of RAF activities, voice marshalling plays a vital role, not only in search and rescue missions, but in the delivery of military and survival resources to remote areas, often confined by natural features such as forests and mountains.

Training aircrew on the ground to support RAF helicopter pilots to fly into increasingly hazardous and confined environments is becoming more and more difficult. To improve upon the current situation, in November of 2001 the RAF commissioned VP Defence to develop a VR Voice Marshalling simulator in order to foster improved training techniques and to minimise the need for costly "remedial" training, both on the ground and in the air. The project began by conducting a human factors and training needs analysis, performed with the support of RAF subject matter experts from the Central Flying School (CFS) and DHFS. These analyses involved ground exercises and flight trials at RAF Shawbury and Valley and set out to define:

- the primary Voice Marshalling task elements (open-field, open-sea and confined area approaches),
- features of the *Griffin* demanding graphical reproduction (in particular those items mounted on or around the door, skid and outer skin used to generate parallax cues with external environmental features), and
- the specification of the sources of (predominantly monocular) visual cues, utilised during reconnaissance and final approach (for both land and sea operations).

The results of these trials were collated into a single user requirements document that became the baseline reference for the "construction" of the virtual world. The simulator development period was limited by the in-service training needs of the RAF and took place between November, 2001 and February, 2002. In brief, the main elements of the delivered simulators include:

VM Student's workstation. A simple wooden framework representing part of the rear door area of the *Griffin* helicopter has been constructed to provide a suitable minimum metallic framework for the immersive VR equipment (ie. the Polhemus *Fastrak* tracking system for the Kaiser *ProView* XL-50 head-mounted display) and to provide aircrew students with safe and representative handholds, together with a robust attachment point for a standard RAF harness;
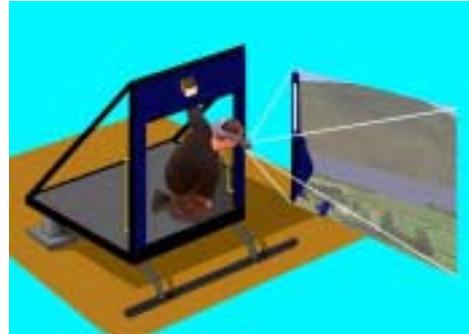
VM Trainer's workstation. A single Pentium IV PC (Windows 2000) with dual graphics cards drives both the real-time rendering engine for the VM student (duplicating the student's HMD view on one of two trainer displays) and the *scenario control interface* used by the trainer to set up, run and replay/debrief scenarios;

Virtual landscape scenarios. In order to facilitate subsequent transfer of training assessments, it was decided to construct a virtual landscape representative of the RAF Shawbury site. Digital terrain elevation data and aerial photographs were used to generate the base topography, with the airfield occupying some 3km by 4km (at high fidelity) and the surrounding environment out to 10km by 10 km represented at a lower resolution. Target objects, from military trucks to barrels

can be positioned within the virtual landscape by the VM trainer. Other landscape features, such as copses, dead trees, small lakes and ponds, electricity/radar pylons, hangars and other man-made features are included to ensure sufficient visual details to support a range of VM activities;

Virtual seascape scenarios. The majority of the effort necessary for delivering a virtual seascape had already been expended, courtesy of a previous project designed to deliver immersive VR trainers for Royal Navy close-range weapons systems. Target objects, from survival dinghies to a motor launch can be positioned within the virtual seascape by the VM trainer. Sea states 1 through 6 are available and, for both the sea and land environments, variable levels of fog and precipitation can be selected, together with and time of day effects.

The in-service date for this simulator is scheduled for March 2002, after which a short study will be conducted to review the process of how well the VR system has been integrated with existing training techniques and to appraise the success (or otherwise) of its adoption by trainers and students alike. Another early goal, to be conducted with SMEs from the RAF, is to carry out an investigation of the transfer of training from the simulator setting to the real-world environment.

REALITYCheck

In 1992, Virtual Presence became the first company to design virtual stores and demonstrate the potential for using VR to prototype and evaluate products in a simulated retail setting. Subsequent efforts for such leading household names as Lever, Nestlé and Procter & Gamble have resulted in a high quality concept-to-market service. When this technology was married to the consumer research capabilities of the specialist company MRSL, the result was *REALITYCheck*, a technique which allows cost effective analyses of shoppers' behaviours and responses in simulated retail environments.

In *REALITYCheck*, virtual shoppers are equipped with VR headsets and interactive hand controllers. Shoppers navigate their way around a computer-generated store pushing a virtual trolley. As in real life, they can browse, pick up products, scrutinise packaging and check prices, removing items from their trolley and replacing products back on shelves as required.

The feasibility of the *REALITYCheck* concept was tested by 27 volunteer subjects in the Spring of 1998 (7 males, 20 females; mean age 39 years, standard deviation 14 years, age range 18 to 67). Representatives of a market research organisation recruited members of the general public in the Sale area for the trials. The final subject pool consisted of individuals with backgrounds as diverse as college student, nurse, PA, regional sales manager for a perfume company and school dinners assistant.

Later, on arriving at the Virtual Presence premises, subjects were briefed on the nature of the trial and were asked to complete a comprehensive questionnaire, covering such topics as computer familiarity, awareness of Virtual Reality, current state of health, and so on. The *REALITYCheck* moderators were also briefed on the health and safety aspects of immersive

Virtual Reality[1], thereby protecting the well being of subjects both during and immediately following the virtual shopping trial.

Subjects were allowed a short period of time to train on the immersive VR system and then indulged in a 5-10 minute "shopping expedition", concentrating their purchasing behaviours on a soap powder category (based on the Lever category layout for the Safeways chain of supermarket). Video records were made of each trial and subjects were invited to record their own verbal comments during playback.

The feasibility study proved to be a considerable success. One of the significant results was that, during the actual immersive trials and the subsequent video playback sessions, none of the subjects recorded comments which related to the fact that they were "in VR" - wearing a headset, experiencing fatigue problems or interaction problems with the hand controller, and so on. All comments were focused on the subject's actual shopping behaviour - why they were looking for one brand or packaging type over another, how they normally located their product of choice in a real supermarket, and so on.

Further interesting results were forthcoming from the questionnaire analysis. For example, many more subjects than expected were familiar with the concept of VR (24 out of 27). Furthermore, in response to the question "If, in the future, a Virtual Reality shopping system similar to this was commercially available - in the same way as one can rent satellite or cable services today - would you consider renting and using one at home?", 21 out of the 27 of the respondents stated yes. The only common adverse symptoms reported with the immersive VR set-up, as recorded using the Simulator Sickness component of the questionnaire, were slight headache, eyestrain and focusing difficulties.

REALITYCheck will be deployed in different ways. Least radically, it will be used to augment current video-based research, where volunteer shoppers in a real supermarket setting are equipped with eye tracking equipment to monitor their visual search and gaze behaviours. Another research method involves tracking shoppers through a supermarket using in-store security cameras or a concealed trolley camera. A more imaginative use of the *REALITYCheck* system would be to test the shoppers' suggestions after they have been filmed and questioned. Virtual environments, unlike real settings, take seconds to alter, so the time and cost benefits of this approach when compared with traditional methodologies are enormous.

- **Source CAD Data: MEDIT (Product models developed for Lever Brothers; category shelf *in situ* within original Cooperative Wholesale Society VR supermarket)**
- **CAD-VR Conversion Code: Virtual Presence Limited Proprietary**
- **Integration/Run-Time: DIVISION *dVISE/dVS* (SG *InfiniteReality Engine*)**
- **Interaction/Display: Immersion (V8 Headset, Polhemus Fastrak and Virtual Presence Hand Controller)**

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[1] See also Applications Sheet No. HF/Apps/Ergo.98.3
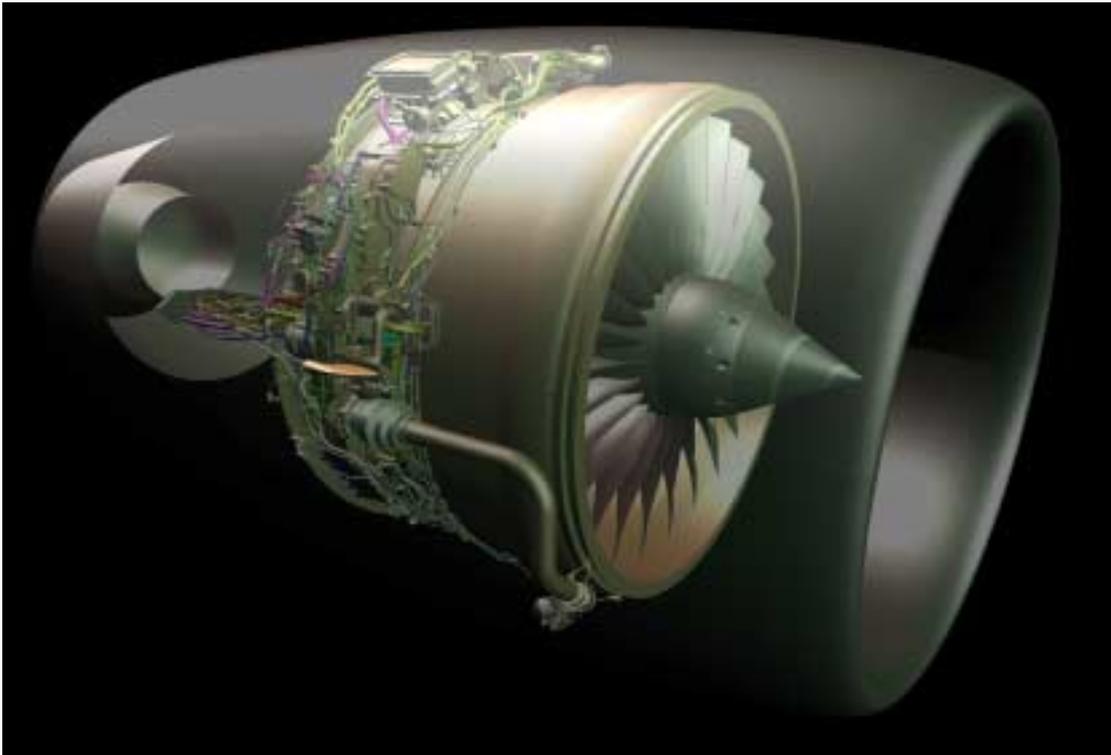
Rolls-Royce Trent 800 Aero Engine

On 19 January, 1993, the BBC's *9 O'Clock News* featured a short item on Virtual Reality. Part of the feature showed a member of Virtual Presence's staff exploring a very simple VR model of a jet engine, using an early VPL *EyePhone* head-mounted display (HMD) and joystick-like hand controller.

Ten months earlier, Virtual Presence and Rolls-Royce had conducted a short feasibility study to evaluate the rôle of VR in the future business of aero engine design, maintenance evaluation and advanced training. At the outset, the project focused commercially on how VR technologies and design practices might be used to replace costly 1:1-scale engine mock-ups, known as Physical Pre-Assemblies (PPAs). Another important issue raised early in this study was that of **preserving technological investment**. Rolls-Royce would not even consider "adopting" VR if it meant their significant investment in computer-aided design (CAD) facilities would be compromised. If VR could be shown working effectively alongside conventional CAD workstations and practices – delivering an intuitive real-time interface for the purposes of reviewing engine designs and maintenance training (something CAD could not provide) – then the probability of commercial acceptance of the technology would be improved.

A basic but robust CAD-to-VR conversion was first demonstrated in 1992, the result of which can be seen in the smaller of the two pictures above. This early step into a British engineering application of VR was made possible by a unique parallel processing (transputer-based) computer called *Vision*, the first commercial prototype developed by Division Limited under contract to Virtual Presence.
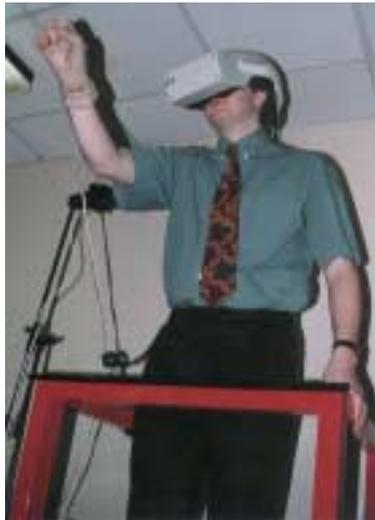
After becoming a founder member of Virtual Presence's *VRS* Initiative and collaborating closely with VSEL and Rolls-Royce & Associates[1], improvements to the functionality and visual quality of the model were rapidly made. By the Spring of 1994, the virtual Trent 800 model had reached a stage whereby usability trials could be carried out. Trial participants, wearing an early Virtual Research *Flight Helmet* HMD and *Cyber*Glove hand input devices, were located within a simple wooden framework. On donning the HMD, they could view the framework reproduced graphically in the form of a virtual "cherry picker". By interacting with a simple virtual control panel, this set-up created the illusion that participants could move around the virtual Trent engine as if on a gantry or crane.

Simple virtual tools were implemented which allowed the users to release bolt and bracket fittings. On registering a "collision" or "clash" between tool and bolt, a simple animation sequence was generated whereby the bolts automatically unscrewed, leaving the pipe geometry unconstrained. A unique collision pre-processor was developed which vastly reduced the computational power required for clash detection. With haptic feedback technologies in a very rudimentary state of development[2], it was not possible in 1994 to provide a realistic physical restriction of the movement of hand/arm when pipes were in collision. Consequently a visual solution was developed which involved the instantaneous display of a "ghost" pipe image whenever a collision state with a neighbouring pipe was registered. The system prohibited subsequent manipulations of the grasped pipe by forcing it to "spring" out of the user's hand and return to its last legally recorded position, merging with the ghost image.
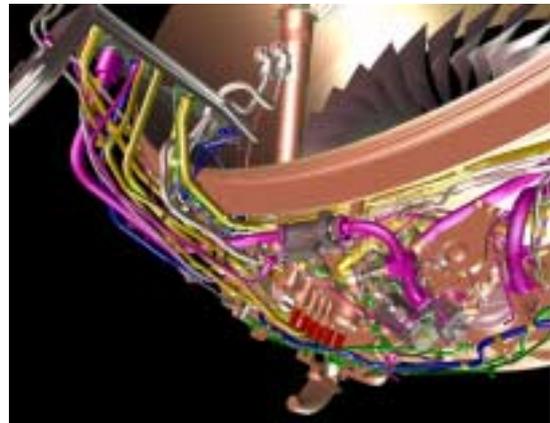
Throughout the early collaboration with Rolls-Royce, the involvement of individuals from the home company (who might one day be the users of an engineering VR system) was considered of paramount importance. To this end, company directors, shop floor workers, CAD ("Digital Pre-Assembly") engineers and trades unionists were all involved in the trials and postgraduate support for usability evaluation was sought from the Ergonomics Unit of University College, London. The comments and criticisms from the trials participants were invaluable. All were carefully noted and many have since been used to generate documents supporting (for example) best practice "design-for-VR" advice[3], or Immersive VR Health & Safety guidelines[4].

- **Source CAD Data: Computervision CADDS4/5X; PVS; Optegra**
- **Unique Geometries: Superscape VRT (Phase I, to 1994)**
- **Collision Detection Functionality: Sense8 *WorldToolKit* (Phase I, to 1994)**
- **CADDS-VR Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: Division *dVISE/dVS* (Silicon Graphics *Onyx and InfiniteReality Engine*)**
- **Interaction/Display: Immersion/Desktop/Stereo Projection**

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[1] See Applications Sheet No. Eng/Apps/VSEL.98.1
[2] See Applications Sheet No. Hap/Apps/98.1
[3] See Stone, R.J., & Angus, J., "Virtual Maintenance"; *Aerospace*; May, 1995; pp.17-21.
[4] See Applications Sheet No. HF/Apps/Ergo.98.3

Sainsbury's Supermarkets

In 1993, VR technologies were taken to their very limits when one of the UK's major food retailers, Sainsbury's, produced a requirement for the largest virtual supermarket ever demonstrated. When Phase 1 was completed 10 months later, the virtual store interior and exterior received unprecedented press coverage, amounting to well over one million pounds sterling in equivalent advertising terms. More important, however, was the fact that Sainsbury's original requirement focused on a practical and commercial evaluation of VR as a method of revolutionising the company's store planning and design procedures. Sainsbury's normal practice involved the building of full-scale physical mock-ups of store areas, fixtures and fittings. Sometimes this required real store spaces to be cordoned off for design reviews and evaluation trials, often involving senior personnel. VR, therefore, appeared to Sainsbury's to offer a potentially attractive solution to what was becoming an extremely costly design-and-review process.

As with an earlier exercise for the Cooperative Wholesale Society[1], plans and drawings of the store in Regent Road, Salford were provided by Sainsbury's, which, together with on-site measurements, enabled the interior and exterior geometric layouts of the store to be constructed using proprietary PC and Unix workstation VR packages. A comprehensive library of relevant 35mm pictures were taken both of the inside and outside of the Salford store, and a range of Sainsbury's product packages were also acquired for subsequent scanning and texture mapping. In the immersive VR trials using the final supermarket model, it was possible to change gondola heights and aisle widths by means of a simple virtual rod. By grasping the rod and moving it up

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[1] **See also Applications Sheet No. Retail/Apps/CWS.98.1**

or down, the shelf heights of a group of local gondolas would change. Grasping a tag on the side of the rod and moving it up or down caused the aisle widths to increase or decrease. Changing the entire Salford store back wall design was achieved by the user triggering a simple animated sequence which lowered the wall into the ground and replaced it with a new design concept from another British store. After implementing changes, Sainsbury's representatives were free to explore store internals, and by "inserting" their virtual hand into any of the products on display and by depressing a button on their hand controller, a three-dimensional product was acquired. Releasing the same button caused the product to vanish from view, and to reappear automatically at one of the checkouts.

The success of this first phase of work, together with historical PC-based toolkit efforts expended for the CWS (reference footnote on front page), prompted Sainsbury's to issue a further challenge - to develop a VR toolkit which demonstrated the image quality approaching that of the first virtual Sainsbury's store and possessed the design functionality of earlier PC demonstrations. The result, after nearly two years of development and testing, is *Concept$_{VR}$*, a VR space planning system which exists not on an expensive graphics supercomputer requiring trained specialists, but on an accelerated Windows NT PC (Intergraph) using in-house planning and design personnel. During development, not only was the *Concept* system modified to accept new 3D store component models, designed by other departments of, or suppliers to Sainsbury's (based on exported VRML geometries), it was also equipped with a comprehensive suite of tools to manage product images, lighting, floor, wall and ceiling textures, and real-time store measurements (using a virtual "tape measure").

Another development, enabling store planners to provide a rapid means of presenting their latest store concepts to other departments and suppliers, was the provision of a "virtual panoramic camera system". The virtual camera takes a series of "photographs" at various predefined "nodes" throughout the VR store to produce images which can be "zipped" together to form 360° panoramas. Delivery of the panoramas on CD or via the Internet is reasonably straightforward, permitting access to new store concepts by individuals and organisations with lower specification PCs. The end user is free to "jump" between nodes and visualise areas of the virtual store which are presented at a high level of visual quality.

- **Source CAD Data: MEDIT, Superscape VRT (Phase 1), VRML2 (*Concept$_{VR}$*)**
- **CAD-VR Conversion Code: Virtual Presence proprietary**
- **Integration/Run-Time: Superscape VRT, Division *dVISE/dVS* (Phase 1: Silicon Graphics *Onyx*); Sense8 WorldToolKit (*Concept$_{VR}$*)**
- **Panoramic VR: QuickTime VR (Apple), or Surround Video (Black Diamond)**
- **Interaction/Display: Immersion/Desktop/Video Projection**

SUBMARINE QUALIFICATION (SMQ) TRAINING

As already witnessed in the military aerospace domain, the use of simulation in the design and management of naval vessels and in the training of their personnel is delivering significant benefits and cost savings for minimal initial outlay. Based on similar experiences in delivering the Avionics Training Facility for the RAF's F3 *Tornado* aircraft, and resulting from over a decade of work with British submarine developers and users (including the Royal Navy's Flag Officer Submarines, FOSM), VP Defence has developed a "mixed media" solution, called *VOCS*^{TM} (Vessel Orientation & Critical Systems), capable of delivering effective classroom familiarisation training for submariners. *VOCS* is a human-centred methodology that results in the delivery of meaningful training and design content – hosted on commercial, off-the-shelf (COTS) PCs and based on available source data, including 2D/3D drawings, 2D/3D CAD, photogrammetry and interactive photographic, video and hypertext material.

Although the original project for FOSM was based on the early training and vessel familiarisation needs for submariners destined to serve on the UK's fleet of *Trafalgar* Class (SSN) boats (such as HMS *Trenchant* shown above), the results of the project are equally relevant to other national and international submarine classes, such as the *Vanguard* SSBN vessels, and future platforms such as *Astute*. The original RN requirements for SMQ system related to the initial provision of a PC-based trainer that would enable students to become familiar with the layout of the target class of boat, including decks, compartments, key items of equipment, main service routes (eg. high-pressure air), safety equipment and so on. *The Safe Submariner* concept is central to VP's *VOCS* methodology. Furthermore, the system is required to preserve the RN's investment over a long period, by demonstrating features that support:

- Simple upgrading (to account for boat-to-boat differences, refit planning, special system upgrades/equipment additions)

- Fidelity upgrading (as technology and resources permit)
- Database links (with existing and planned interactive electronic training material)
- Diver training (eg. hull inspection)
- In-service training (extension of the model for operational and contingency planning)
- Navigation (including channel and "blind" pilotage) and Officer of the Watch/Deck training (as with the US Virtual Environment Submarine, or *VESUB* programme, using immersive VR technologies to simulate bridge/fin OOD location)
- Dockside deck and incident procedures
- Special and safety-critical incident rehearsal (eg. casualty airlift, distressed submarine – *DISSUB* – evacuation (see below and separate applications sheet))
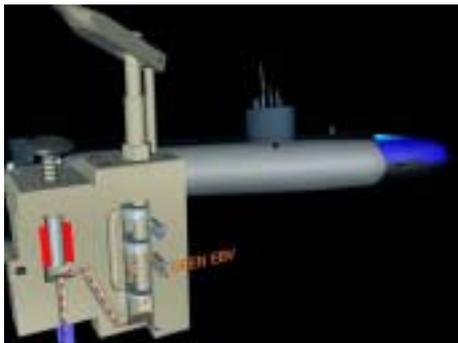
An SMQ exercise demonstrator has been developed by VP Defence that requires the student to describe, locate and actuate the emergency blow control valve (EBCV), within the forward escape compartment of a *Trafalgar* class submarine. Students can explore the virtual compartment on predefined paths. At any point, they are free to turn, look around and interact with "active" scene items. On entering the virtual forward escape compartment, the student is confronted with visually recognisable 3D features – lockers, fire equipment, consoles, ladders, large-bore piping, and unique components These 3D objects can be modelled using data sourced from CAD, photogrammetry, scale models, even simple illustrations and photographs. Where additional detail and realism is required, panoramic (360°) images fade in and out on demand, their location in space closely matching their 3D counterparts. "Hot spots" within the panoramas are linked to additional 3D objects, containing recognisable models of important and safety-critical equipment (such as the ECBV) or digitised text/video extracts from existing training and informational sources (including IETMs). In the case of the 3D objects, once the hot spot has been interrogated (single mouse click), the object appears, complete with textured features and labels (relevant to its identification and operation). The student is then able to initiate any animated or interactive features (including sound effects) to demonstrate procedures and processes (eg. solenoid actuation, HP air transfer to main ballast tanks). In the case where the operation of safety equipment originates from elsewhere in the submarine (eg. operations compartment), warning displays are also presented.

With regard to the issue of evacuating a disabled submarine, VP Defence was also a member of the NATO Submarine Rescue System (NSRS) PD Study team, addressing the high-level training requirements for future manned or unmanned rescue vehicle solutions and ensuring commonality of training (where appropriate) between NSRS and SMQ. Since that project was completed, a *VOCS* demonstrator has been completed, showing the ease with which an existing 3D model of the UK Submarine Rescue System (kindly provided by RUMIC Ltd, operators of the LR5 submersible) can be integrated with the current SMQ demonstrator of the *Trafalgar* Class submarine.

English Heritage: *Virtual Stonehenge*
"...the largest and most challenging PC-based heritage reconstruction carried out to date"

Virtual Heritage Conference & Exhibition, December 1996

In 1995, English Heritage completed the most intensive survey of the Stonehenge area ever undertaken, generating a large database of information. It is the nature of databases that, whilst they contain much information that is significant or useful, this information is difficult to differentiate. English Heritage saw VR as a possible solution to their problem. The brief to Virtual Presence was to produce a high quality and accurate record of the stones and their environs in their present state. Whilst not designed to replace the real experience, the visualisation was to be detailed enough to allow people to "walk" amongst the stones and inspect the different textures in 3D - something the general public is no longer allowed to do.
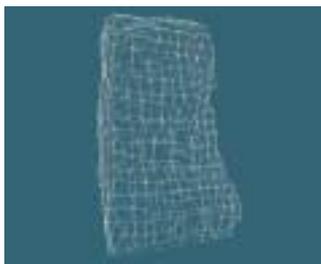
During the initial project review stage, Intel Corporation (UK) approached English Heritage with an offer to co-sponsor the Project, through their Community Liaison Programme. In conjunction with Intergraph (UK), Intel selected the Pentium Pro-based TDZ/GLZ Workstation series, on which the model was to be developed and finally demonstrated. Before the team could begin the time-consuming process of inputting all the information from English Heritage's digital survey into Sense8's VR package, WorldToolKit, a surface representation of each stone was manually built up from point data extrapolated from hundreds of stereo photographs. Around 60,000 points made up each of the 80 or so surveyed stones. This figure had to be reduced to allow real-time rendering to take place on the target Intergraph platforms. A painstaking manual process gradually "decimated" these point data. The result was 10 separate models of each stone, the level of detail on each chosen to correspond to a variety of end user viewing distances - the further away, the lower the level of detail. At run-time the software selects the 5 most appropriate levels of detail, based on the characteristics of the computer being used.

Her/Apps/EH.98.1

One from each of a stereo pair of photographs was then digitised, processed and texture mapped onto the geometry of the relevant stone. Even small surface features such as cracks, lichens and fungi are clearly visible. The full version of the Stonehenge model requires 80 Mb of texture RAM. Lower resolution versions (26 Mb and 8 Mb have, however, been produced). Stonehenge's virtual landscape was created from digital topographic information derived from aerial photography and boasts all the features contained within the real area - barrows, ditches, roads, the Avenue and the current Visitors' Centre. In geometric terms, the entire model contained 50,000 polygons - 40,000 of these described the stones and immediate terrain, the remaining 10,000 occupying the more distant terrain (area: 2.5 x 2.5 kilometres). Other historical features - ditches, banks and the like have been geometrically exaggerated, otherwise they would not be visible to the user when at normal eye height in the virtual world. It took four developers six months to complete the Project. Virtual Stonehenge was launched at the London Planetarium on June 20, 1996, a few hours before the actual Summer Solstice. Following a description of the Solstice by the renowned astronomer and celebrity Patrick Moore, English Heritage's Chairman, Sir Jocelyn Stevens, donned a VR headset and set off to explore Virtual Stonehenge, pausing to view the night-time sky (see below), the real-time sunrise (see below) and to remove all 20th Century, man-made artefacts, returning the site to a near-"virgin" condition, as is planned for the year 2000.

Astronomical Mapping. The basic source data for the star positions were originally downloaded from the Internet using Right Ascension and Declination for stars with a greater Apparent Visual Magnitude than 3.55. This form was chosen, as it was not practical to represent the stars according to their "real world" positions (in this case the virtual world would have had a bounding box measured in light years!). Right Ascension is measured in hours (24) and had to be converted to degrees, and Declination was measured in degrees (-90° to $+90^o$). These can be thought of as the longitude and latitude lines that span the Earth. The star positions were then projected onto a sphere surrounding the Stonehenge model from the celestial equator (ie. centre of the earth). Once the stars were spherically projected, they were scaled according to their Apparent Visual Magnitude. The position of Stonehenge from the centre of the Earth then had to be taken into consideration as the "star sphere" was being projected from the celestial equator. This involved shifting the whole star sphere and then spinning the sphere around an axis close to the North Star.

Sunrise Effect. Various methods of achieving a real-time sunrise effect were discussed. It was decided that a method based on using smooth shaded ellipses would take full advantage of the Intergraph hardware and Sense8's WorldToolKit. For the sunrise effect to work, there were two objects primarily interacting with each other - the hemisphere surrounding Stonehenge (the sky) and a "virtual" sun. The sun had various parameters which could be set. The actual sun object can be thought of as a number of bands of differing circumference (each representing a different fixed colour) centred around a point. If one imagines a point travelling from the centre of the bands to the outside, the colour of the point would then gradually change. If the distance between bands is increased and the point is travelling at the same speed, then the perceived change in colour be would less obvious. This is useful when one wishes to fade gradually from night to day over a long period, and for the extreme effects when the fade changes from red to yellow over very short distances. The interpolation between the different colour bands was computed and stored in a colour look-up table to optimise execution time. Each point in the hemisphere (sky dome) was individually coloured according to its distance from the sun. This was achieved through interaction between the sun object and the sky dome. The virtual sun was initially placed at its furthest band distance from the dome and then gradually moved inwards. This created the essence of the sunrise effect. To enhance the effect of a genuine sunrise further, the spheres (bands) were changed to ellipses, thus recreating the atmospheric refraction that is seen on Earth. Through the use of an ASCII text file, the developers were then allowed to experiment with various parameters for each band (eg. the number of band, the colour, individual radii, the number of colour interpolations and the three dimensional elliptical shape used). By using this method it meant the demonstration takes advantage of Gouraud shading, thereby using a minimum amount of texture memory and keeping run-time efficiency at an optimum level.

RAF *Tornado* F3 Avionics Training Facility

The *Tornado* ADV, or Air Defence Variant, later designated F3 by the RAF, entered service in 1985 and, following the announcement of a comprehensive weapons, radar and avionics upgrade in 1996, is today the UK's principal air defence aircraft, pending the introduction of the Eurofighter or *Typhoon*. To support such operational rôles as air defence and long-range interception, the testing and maintenance of electrical, mechanical and computerised systems onboard the aircraft must conform to exceptionally high standards. Consequently, avionics maintenance training is intensive and the technical expertise of qualified RAF ground crew is second to none. However, as with many other applications in the military sector, gaining access to appropriate hardware for maintenance training, be it a complete aircraft or even individual functional components (Line Replaceable Units, or LRUs), can never be completely guaranteed, given the demanding defence and policing duties performed by RAF *Tornado* squadrons across Europe and further abroad.

Overcoming these problems by employing Virtual Reality technologies in the classroom was the focus of a project undertaken by VP Defence under contract to Alenia Marconi Systems. On the basis of VP Defence's track record in aerospace maintenance projects and experience

in defence human factors, the company was subcontracted to develop the avionics training simulator for the *Tornado* Maintenance School (TMS) at RAF Marham, using proven VR modelling techniques and open systems run-time software. The system is hosted on a high-specification Windows NT system and, uniquely, features 3 screens per workstation, each displaying different working views of the aircraft, avionics bays, LRUs and/or virtual test equipment. 10 such workstations were produced, fully networked, allowing a **minimum** of 8 students to be trained and supervised by 2 instructors in basic and advanced *Tornado* F3 avionics maintenance routines, with collaboration between students supported over the local area network as necessary.

As well as the virtual aircraft shell itself (around which students are free to move), all moving surfaces are present (removable and hinged panels, flight control surfaces and radome), as are internal and external aircraft systems connector points. Full cockpit detail and functionality has also been delivered, for both the pilot and navigator positions. To produce this level of visual and interactive fidelity, 5 of VP's developers spent an entire week creating digital still and video footage, plus some 1300 film images of an F3 *Tornado*. The images were also used in conjunction with 3D drawings, again constructed by the VP team (in the absence of any CAD data) to construct a faithful VR representation of the aircraft shell. Over 450 LRUs feature in the simulation, located in equipment bays around the aircraft and as control and display units within the cockpit. Once the TMS trainers have programmed individual faults or sequences of faults, the students can explore the aircraft, opening hinged panels and selecting LRUs for removal, inspection and test using any of around 50 additional virtual test sets. Every control input made by the trainee results in a realistic and accurate change of state within the virtual *Tornado*, be it the movement of external flight surfaces, down to the illumination of individual LRU/test indicators.

In contrast to previous hardware and CBT-based training facilities at TMS (the main facility based on physical cockpit mock-ups costing over £UK 14 million), ATF has, since its operational debut in 1999, reduced training time from 13 to 9 weeks and downtime – time in which the waiting students do nothing – from 3 to zero weeks. The TMS Marham trainers believe the course could be shortened even further, but are reluctant to do so, choosing instead to increase course content and promote retention through "consolidation breaks" and extra-mural self-pace refresh trials). Feedback from the Marham trainers suggests that, in contrast to previous courses, ATF students "grasp the concept" (ie. gain enhanced spatial and procedural knowledge) up to 40% faster than achieved by previous non-ATF students. The modified *Tornado* F2 rig, as used by the GR4 course students, is still considered to be important, in order to deliver health and safety training associated with lifting procedures for some of the heavier LRUs, for example. Of particular interest is the cost of the ATF facility. In total this amounted to just over **one-tenth** of the cost of previous non-VR set-ups!

Tornado GR4/AGTR	*Tornado* F3 ATF
13 (GR4) and 11 (AGTR) week course	9 week course (+ 40% uptake improvement)
3 weeks downtime (zero activity)	0 weeks downtime
10 major faults; observe all, hands-on possibly 2	50 major faults; hands-on all
£UK14 million	£UK1.5 million

For further information, contact Prof. Bob Stone (Scientific Director, VP Group) on (+44) (0)161 969 1155; e-mail: r.stone@vrsolns.co.uk.

Department of Trade & Industry:
The UK VR Forum

The work and track record of Virtual Presence in the Virtual Reality arena has often been cited by regional and national government bodies as an example of the UK's strong applied capabilities in information technology. Indeed, the company featured in the Government's third White Paper on Competitiveness, "Creating the Enterprise Centre of Europe"[1]. In the same year the White Paper was published, the Manchester division of Virtual Presence was commissioned by the Communications & Information Industries Directorate of the UK's Department of Trade & Industry (DTI) to compile a comprehensive report on the international VR market. The Study paid particular attention to the UK's national, technical, academic, applications and commercial status, and to the country's international standing. Part of the underlying research set out to determine whether there was a need for government support in order to preserve the country's envied, yet deserved lead in a technology which some countries, notably the USA and Japan, consider to be of strategic international importance, or whether the UK has, through commercial, collaborative and academic initiatives, already developed VR to a level where the technology and applications are self-sustaining.

A Public Summary document, outlining the findings of the Study, was published by Virtual Presence in October of 1996[2, 3]. The report concluded by emphasising that the UK's strengths and opportunities in VR originated not from academic initiatives, nor from dissipated European collaborative projects, but from the efforts of innovative, committed and enthusiastic British small-to-medium sized companies ("SMEs"). Yet those same strengths and opportunities had

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[1] **CWP III,** *Becoming World Class,* **p.165; 13 June, 1996.**
[2] **Stone, R.J., "A Study of the Virtual Reality Market", Public Summary Document (Ref. URN 96/994), prepared for the Department of Trade & Industry (Communications & Information Industries Directorate); October, 1996.**
[3] **Virtual Presence's Study Team included the Manchester Business School and** *VR News.*

become responsible for fostering a fragile market - selling a *vision* had not been enough. Numerous potential commercial and industrial users of VR were "holding back" on investment because of a lack of understanding as to what the technology could achieve, or indeed *was* achieving within the real world, as opposed to within the impressive environments offered by VR showrooms, academic laboratories or demonstration centres.

Unfortunately, this "holding back" was identified as creating a further fragile commercial situation, in that pioneer producers in VR had to incur a substantial "educational" cost in selling to inexperienced buyers - this was highlighted as a potentially important case of market failure. The recommendations made by Virtual Presence to the DTI were designed to address ways in which:

- the UK's world lead in VR could be preserved,
- the uptake of VR nationally could be accelerated, and
- the British VR commercial (and academic) situation could be strengthened in order to preserve the country's unique rôle in a field of endeavour which has been developing rapidly within Europe only since 1990.

Virtual Presence recommended that a **cross-industry** forum should be established, underpinned by the Government and demonstrating strong leadership by industry. The result of this recommendation, the *UK-VR Forum*, became a reality in 1997, and has since been increasing its activities through the dissemination of case study material, staging workshops in such areas as heritage and manufacturing and forming a dedicated Web site with links to all key UK players. Virtual Presence plays a strong rôle in the direction of the Forum, not only in the overall Steering Group, but in the supporting activities of a number of Action Groups as well.

The UK VR FORUM
[www.ukvrforum.org.uk]

A body of representation of Virtual Reality practitioners and users in the UK whose main aims are:

- **to promote national and international business opportunities through a coordinated campaign of awareness,**

- **to present itself as a body of competence in the field of VR, acting as a focal point for independent advice and guidance,**

- **to foster consistent technical and commercial excellence through the coordination of research, development and educational programmes, and**

- **to provide advice and guidance in the exploitation of the results of such programmes throughout the VR industry.**
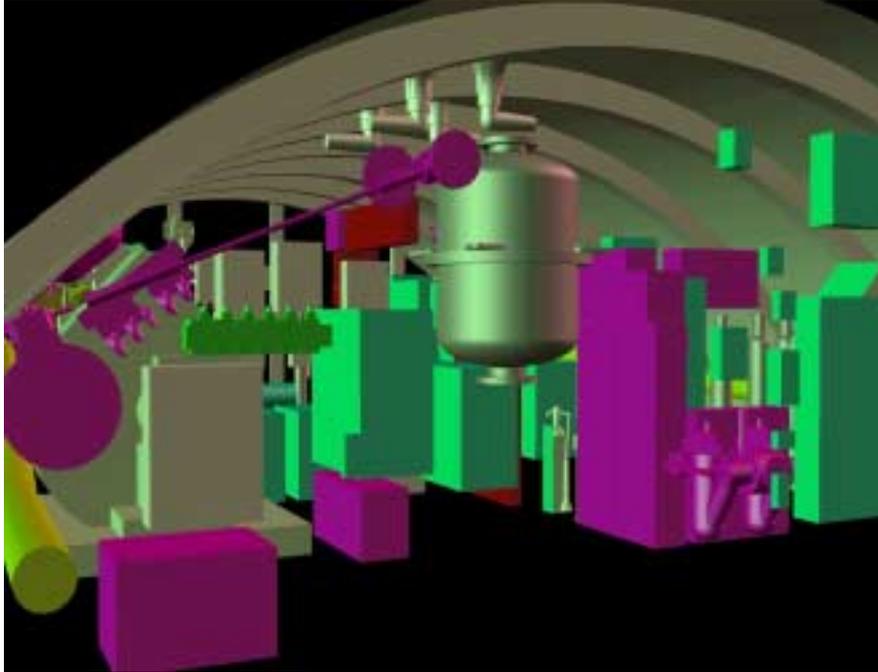
GEC Marine (VSEL) – Rolls-Royce & Associates
Virtual Submarines

Working collaboratively with Rolls-Royce and Rolls-Royce & Associates, Vickers Shipbuilding & Engineering Limited (VSEL, now part of GEC Marine) began their venture into Virtual Reality in 1993 with the ambitious goal of modelling complete submarine environments.

As with Rolls-Royce's[1] original interest in VR - the replacement of expensive physical prototypes - VSEL's focus was quite similar, but on a much larger scale in both size and investment terms. VSEL saw the eradication of physical models in the life cycle of a submarine not only bringing major commercial benefits to the company's design, evaluation and concurrent engineering activities, but also enhancing the project review, evaluation and training requirements of the Royal Navy and Ministry of Defence. At VSEL in Barrow-In-Furness, an impressive one-fifth scale model of a Trident Nuclear Submarine is housed within an enormous facility. Model human figures ("Action Men") are used for

basic ergonomics evaluations. The financial and manpower resource required to build and maintain models of this complexity over the **entire life** of, say, the *Trafalgar* or *Vanguard* classes of submarine is huge, not to mention the insurance implications of protecting such a facility.

From the outset, VSEL - like Rolls-Royce - specified a firm requirement for immersive and projection VR technologies. Another common denominator was the investment by both VSEL and Rolls-Royce in the Computervision computer-aided design (CAD) product range. An agreement was reached between Rolls-Royce and VSEL that work in support of the first immersion/interaction demonstration would focus on the Trent 800 model (see Footnote 1). Once that had been demonstrated, it would be accepted that the same interactive features and engineering database interrogation qualities could be transferred to the virtual submarine domain.

GEC Marine's new Virtual Reality Development Centre represents a major commitment on the part of the company to the technological and commercial benefits of VR. Working alongside the Company's

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[1] **See Applications Sheet No. Eng/Apps/RR.98.1**

established CAD facility and equipped with sophisticated computing, immersion and 3D projection facilities, the GEC Marine VR Centre is now fully operational. As well as mainstream work in the development of future submarines, such as the *Astute* class, the facility is being actively exploited by the company, its clients and contractors - with consultative support from Virtual Presence - in a wide range of land and sea vehicle projects, including future-concept aircraft carriers and commercial ferries, such as the GEC *Cat*.

Also in the submarine domain, Rolls-Royce & Associates' initial requirement was for a multi-window information display system which could demonstrate the potential of VR in the radiation safety training of naval personnel and defence health physicists. The final system took the form of a 3-window simulation, based on actual radiation measures provided by RR&A. One window allowed the user to navigate around any of the three decks of a submarine's nuclear reactor compartment. Another provided a plan view of current position. The third

window displayed instantaneous and cumulative radiation doses, together with the elapsed time and the user's current *x*, *y* and *z* deck location;
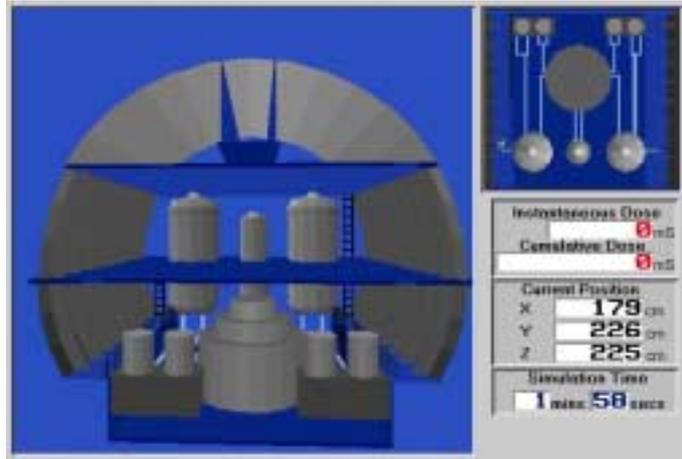
Both VSEL and RR&A, like Rolls-Royce, are committed to the integration of human factors knowledge, not just in the application of VR technologies, but in the day-to-day shop-floor use of the systems as well. Virtual Presence's collaboration with all three organisations has been invaluable in the preparation of standard practice and guideline documents[2]. Postgraduate student research into human factors and usability issues of immersive VR (carried out in collaboration with University College, London and funded by Virtual Presence, VSEL, Rolls-Royce, RR&A and BNFL) has been under way since 1995, with the project being selected as one of the first three exemplary Faraday North West *Master* projects that same year.

- **Source CAD Data (GEC/VSEL): Computervision CADDS4/5X; PVS; Optegra**
- **Conversion Code: Virtual Presence Limited Proprietary**
- **Integration/Run-Time (GEC/VSEL): DIVISION *dVISE/dVS* (SG *Onyx/InfiniteReality Engine*)**
- **Integration/Run-Time (RR&A): Superscape VRT**
- **Interaction/Display: Immersion/Desktop/Stereo Projection**

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[2] See also Applications Sheet No. HF/Apps/Ergo.98.3