# Virtual reality and innovation potential.

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**Virtual reality (VR) is a technology that may have important implications for almost all industries and is starting to change the way products are manufactured. A new study examines how VR can help make businesses more innovative and emphasizes the need for several obstacles to be overcome if such potential is to be fulfilled. VR's potential for innovation, organisation and communication within companies is also explored.**

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This article examines how companies can harness virtual reality (VR) technology to help make themselves more innovative. VR has some unique characteristics which, taken together, can help companies to develop three features common to many innovative organisations: a capacity to experiment in depth; involvement of all in the innovation process; and an ability to capture ideas generated in the innovation process. However, some obstacles need to be overcome before VR fulfils this potential.

In Competing for the Future, Gary Hamel and C.K. Prahalad (1994, p103) describe virtual reality (VR) as, "a technology with profound implications for almost every industry". VR, they conclude, "is a powerful perceptual tool." Others have gone even further. Robert Voiers, the Founder Director of the EDS Detroit VR Center is quoted as saying: "Virtual Reality is beginning to change the way we engineer and manufacture our products. It's early days yet, but I believe we may be witnessing the start of a new industrial revolution." (VR News March 1998.) Although the market for VR technology is still in its infancy, a number of commentators have forecast a bright future (Bubley 1994, Herlsel and Jacobson 1994, MAPS 1995, Stone 1996, Thompson 1993). Nine of the fifteen Technology Foresight sector panels set up by the British Government highlighted VR as a technology with strong potential in their sectors: Communications; Construction, Defence and Aerospace; Health and Life-Sciences; IT and Electronics; Leisure and Learning; Manufacturing Production and Business Processes; Transport; and Financial Services.

What is covered by the term VR? As the next section shows, there is still some debate amongst practitioners about where the boundary should be drawn. VR shares some characteristics with computer-aided design (CAD) and with animation. However, the distinctive features of a VR model are that it is accessible, interactive, and operates in real-time:

* VR models are more accessible than CAD, whether viewed through headsets, on a large screen, or simply on a PC;

* they are interactive because the user can move about (and often modify) the virtual environment as he or she pleases; and

* as the user moves about the virtual environment, what he or she sees is updated in real-time.

Is VR really a tool for business? For a while, VR was seen essentially as a games technology, not really for the business user. That is no longer the case. While the market is still small, more and more companies are using VR, at least in an exploratory way: at least 21 out of the top 30 from the DTI World R&D Scoreboard. What benefits do they get from using VR? While few companies yet can point to precise measures of cost savings or other financial returns from VR investments, many point to important qualitative benefits from learning to use VR. In April the Institute of Electrical and Electronics Engineers (IEEE), one of the world's largest and most prestigious professional institutions, announced that there would be from 1999 an annual IEEE VR Conference (VR News April 1998).

As we shall see, VR is finding applications in many business-related tasks including training, simulation, prototyping, and data visualisation. The departments that most often pioneered the use of VR were R&D, production and design, but VR applications are spreading to many other parts of the organisation including board-level strategy, marketing and finance.

Much of the discussion about virtual technologies has centred around the following question: `Does the advent and implementation of these technologies mean that geographical distance is no longer a significant impediment to social and economic interaction?' This question and the debates stemming from it relate to a geographical sense of `virtual'. Can geographically distant partners interact as if they were virtually nextdoor to each other? If so, then this has implications for the globalisation of business and for the emergence of new geographically-dispersed organisational forms (`virtual

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organisations').

This paper focuses on a different question which addresses a relatively underdeveloped area within the VR debate: `Will VR technologies promote innovation by allowing the organisation to better explore possible future products and services?' This question relates to a visualising sense of `virtual'. It asks whether designers, consumers, policy-makers and others can interact more easily with possible future products, processes and services - virtually, as if they were here today. VR technologies that make it easier to visualise the future have implications for innovative activity: a given level of prototyping becomes cheaper; and more advanced (and realistic) prototyping becomes possible (Kalawsky 1993). It is natural then to ask whether VR will lead to more innovative activity, and if so, what form it will take and who will be doing it. These are the questions addressed in this paper.

This paper begins by defining VR. We then clarify what we mean by innovation potential and illustrate, with examples of current VR applications, how this potential may be enhanced. We then explore the ways in which VR may enhance innovation potential in the near future through improved data visualisation techniques and by facilitating more and better communication between various groups of interested parties.

The early discussion in the paper will seem very positive and may convey the impression that VR is unequivocally good for companies. In the final section we show that a number of obstacles and concerns have to be overcome before it will fulfil this potential.

What is VR?

Virtual reality is a collective term for those computing technologies which enable the user to interact in realtime with 3D computer-generated environments. The origins of VR can be traced back to the experiments of Ivan Sutherland in the early 1960s, when he developed the first head-mounted displays (Pimentel and Teixeira 1995). Modern VR systems vary considerably, both in terms of the range of technologies that they incorporate and in the variety of experiences that they convey to the user. For the purposes of this paper we are taking a broad definition of VR that ranges from "desktop" systems through to "fully immersive" systems.

Desktop technology involves the conventional human-computer interaction in which the computer-generated environment is viewed through a VDU screen; commands which enable the user to interact with that environment are usually entered using a keyboard or mouse interface. Most CAD systems have incorporated this type of interface and the supporting software that determines the designer's interaction with these computer models is now relatively mature.

Fully immersive systems on the other hand, describe a different kind of human-computer interaction altogether in which the user is either physically or metaphorically surrounded by the computer simulation. This may be achieved using a number of visual display technologies:

* Some systems utilise a headset or head-mounted display (HMD) that shuts out the user's awareness of the real world surroundings giving them the impression of being present within the computer-generated environment.

* Others include the CAVE (Cave Automatic Virtual Environment or Audio-Visual Experience) environment in which the user is situated in a cube with display screens on each side and wears shutter glasses that trick him or her into seeing 3D stereo worlds.

* The Immersive Workbench developed by Fakespace inc. and based on original work at the German National Computer Science and Mathematics Research Institute (GMD) is a device similar to a designer's drawing board which projects 3D representations for the user to manipulate.

* Wide-screen projection systems permit a group to experience virtual models in a theatre-style arrangement.

In many cases, tracking technology is used to sense the position and movement of the user within the artificial environment. In fully immersive systems, a range of peripheral devices are often used to relay appropriate visual, auditory and tactile cues to enable users to interact with their environment in a relatively intuitive fashion, conveying the sensation that they can manipulate and interact with computer-generated objects in much the same way as they would manipulate

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objects in the real world. Although the basic technology that underlies this form of interaction has been understood for many years, immersive systems have not as yet developed many universal standards or conventions to support their wider adoption outside the VR community.

Although fully-immersive VR is still the eventual goal of many developers, it is the less expensive partially-immersive desktop applications that are currently most prevalent. Even with these systems, it is only over the past ten years that researchers have been able to reproduce graphical images at anything like a sufficient rate to mimic movement in virtual worlds and it is really only in the last couple of years, with the widespread diffusion of powerful PCs, that this sort of technology has become available to a significant number of users. Anyone with a standard Pentium-based PC and a link to the Internet can now experience VR through a number of 3D browsers on the World Wide Web (WWW).

How do VR models differ from those generated by other means? Table 1 provides a summary. Physical prototypes offer the greatest degree of realism, but the marginal cost per prototype can be very high. The table describes these as prototypes with a low level of interactivity because it takes a long time to build a new prototype. Computer-aided design, by contrast, can achieve a high degree of interactivity, as models can be redrawn immediately and at low cost; but for the inexperienced eye a CAD model lacks realism and is often impenetrable. Animation offers high realism and changes to animations can be made at low marginal cost; but they are less interactive in the sense that the end user is taken through a pre-programmed "fly-through" and cannot explore the virtual environment as he or she wishes: changes to the animation can be made by the developer, and need not be especially expensive - but the point is that they are not made in realtime by the end-user. VR, by contrast, offers accessible and realistic images, the user can explore the virtual environment interactively, and changes can be made easily by the end user.

**Table 1**
**Characteristics of VR and Other Technologies**

| | Realism | Inter-activity | Marginal cost |
|---|---|---|---|
| Handmade physical prototype | Very high | Very low | Very high |
| Machine-made physical prototype | Very high | Low | High |
| Computer-aided design | Low | High | Low |
| Animation/ multimedia | High | Low | Low |
| Virtual reality | High | High | Low |

**Table 2**
**How Can VR Help the Innovative Organisation?**

| | | |
|---|---|---|
| Low marginal cost | [right arrow] | Capacity to experiment |
| Realism/accessibility | [right arrow] | Involving all |
| Interactivity | [right arrow] | Capturing ideas |

The table identifies the strong position of VR, but it would be wrong to deduce from this that VR dominates all these other prototyping technologies. Many will use VR to build early prototypes, but then use a physical prototype for the final stages, because the latter offers the highest degree of realism. Equally, VR does not replace CAD, because CAD offers a degree of precision in modelling that is not currently available in VR. From this perspective VR can be considered as a new means by which to display CAD data, thereby complementing rather than substituting existing technologies.

## Innovation Potential

We believe that innovative companies can exploit VR to extend their innovative potential by offering features that can help to extend some of those characteristics that are most important for the innovative company.

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While innovative companies come in many shapes and sizes (see Utterback 1994 for a good summary), they are usually good at the three particular activities:

* Capacity to experiment before committing to a design;

* Strong communication between different functions so involving all in the innovation process;

* Capturing ideas generated during the innovation process.

The essence of our argument is that the three special characteristics of VR identified in Table 1 above map onto these three activities. VR allows the user to generate many modifications to a prototype at low marginal cost, and these make it is easy to experiment before committing to a design. VR also offers realistic and accessible models, and this can help communication between different functions in the company. And third, as VR is interactive, ideas generated during the innovation process can be captured and incorporated into the VR model.

Capacity to experiment

VR enables greater experimentation with new products, services and processes prior to large-scale commitment. Those aspects of innovation that require detailed and repeated experimentation with different prototypes in different environments can be carried out much more quickly, cheaply, and in much greater depth using VR. Of course such experimentation is possible with other, existing technologies including CAD, but VR appears to offer even greater potential in this direction. This principle applies equally to innovative processes as well as innovative products. For example, one of the early uses of VR is in the planning of spaces such as production layouts, television studios, and the interior design of buildings and gardens. The user can `build' a representation of the space using a VR software package, and then experiment extensively with the layout until satisfied with it. This allows the user more scope to experiment in advance of committing to a design, and as such enhances innovation potential.

The BBC has used VR in this manner to develop prototype studio sets and explore the feasibility of new programme concepts. Because studio time is so very expensive, this can lead to significant cost savings. But beyond that, it can enable people to try out programme ideas that they would not be able to do otherwise (http://www. ukvrforum.org.uk/). The use of VR by John Deere, Boeing and McDonnell Douglas (see box) further illustrates the point. Because it is very expensive to produce physical prototypes of large equipment, VR models could reduce their costs and shorten design times.

Involving all

VR makes it easier to involve different groups of staff in the innovative process. Utterback (1994) argues that, if it is to succeed, the innovative spirit has to pervade all parts of the organisation: if innovation is compartmentalised, then it will be less successful, or may fail. One case study that addresses these issues is of a major car manufacturer that uses VR to model changes to parts of its production line. We were told of how a large number of potential users - from shopfloor workers to senior management - were taken through a virtual version of the production line in advance of its construction in order to check that they were satisfied with the layout (Swann et al 1997). Other companies have used VR to help demonstrate product innovations to customers. For example, DEK Printing Machines, the global market leader in the production of precision screen printing systems, used VR to enhance its sales process, and to demonstrate the innovative advantages of its products to customers (http://www. ukvrforum.org.uk/).

Related to this, VR can be used to improve the quality and quantity of the dialogue between different functions within the organisation, and with customers, suppliers and R&D networks outside the organisation. Given the cultural and functional diversity normally found within large firms in particular, and the associated multiplicity of different `languages', conventions, and norms, effective dialogue between different divisions and functions can be difficult. Some writers have commented on the tension between R&D and marketing as one of the more difficult areas of dialogue in the innovating organisation. Any technique or technology that facilitates such a dialogue may have an important role to play in extending the innovation potential of the organisation.

An example of this type of application is British Airways (BA) which has used VR to model passenger flow in airport

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terminal buildings. VR is used alongside existing simulation tools to make the results of its simulation models accessible to more people within the company. For BA, the main benefit of using VR "is to visualise what complex data looks like in real life ... the user can scan with his eye around the terminal ... understand the problems immediately." (VR News, March 1998.) Although the same information is available directly from the simulation model, BA found that the VR model was much quicker and easier to interpret.

One R&D manager in a major FMCG company gave another striking example of this. He indicated that a common frustration in developing prototypes using CAD is that some colleagues insist that these prototypes are incomprehensible. While someone in R&D could see a CAD representation of a new product design for what it was, this was not true of his marketing colleagues. With VR, the on-screen prototype can be accessible to all.

Capturing ideas

Because it can be used interactively, VR can be used to capture ideas generated during the innovation process. By taking employees through the virtual model, the car manufacturer mentioned above found that the process not only helped to avoid some potential mistakes but also created a sense of employee ownership of the space. VR provided a "suggestions box" where the suggestions could be implemented immediately.

Now, we look further ahead, to explore the ways in which VR technology may extend innovation potential in the near future. We focus on two generic applications: the use of VR for data visualisation and the use of VR to facilitate communication.

Data Visualisation

Building on the experiences of an ever-increasing number of computer users, mainstream software packages have been continually refined so that they are now considerably more intuitive to learn and use than the first generation of products. However, at the same time, the volume of information that we are required to process has been increasing (Toffler 1970, Handy 1994). Perhaps this is a reason for the so-called `productivity paradox': economic analyses to date suggest that IT investments have not, at least at a macro-level, contributed the productivity gains that might have been expected (see the 1995 special issue of the journal Economics of Innovation and New Technology for a fuller discussion).

VR technology can improve the way we handle information because of its capacity to increase information absorption by presenting it in a more intuitive fashion. One example of the use of VR in this context is in financial markets. Dealers are required to absorb and act upon large amounts of information in an extremely short timeframe. Performance is dependent on the ability to effectively monitor and comprehend share movements and related opportunities as they occur. At present, decisions on whether or not to invest are often made more on the basis of the dealer's experience and intuition than on any calculated scientific basis. The skill of the job lies in applying experience to a limited set of information. At present, dealers work from standard two-dimensional monitor displays. VR and three-dimensional visualisation offer the possibility of enabling dealers to absorb substantially more information at any one instant. Imagine that an icon in 3D space depicts each share. Share information can be plotted in this 3D space in such a way that shares with similar characteristics are placed close to one another. The distance in 3D space from some notional point can be used to indicate one characteristic of the shares, such as their value. Clever use of other characteristics such as colour, vibrational movement, or even sound could be used to indicate whether the dealer's attention should be drawn to some information about the performance of a particular share. For instance, if a share was being heavily traded then its icon could vibrate rapidly to draw the dealer's attention. In this fashion VR may enable dealers to comprehend and act upon more information more rapidly and thereby change the way in which they operate.

A leading application of this type is Metaphor Mixer[TM] developed by Maxus Systems International Inc. This is a portfolio management system used to integrate data from a variety of realtime sources. Paul Marshall of Maxus Systems International describes the application thus:

"In doing these kinds of trades, the way you beat your competitors is by having better software that signals movements in the market to you ... With virtual reality I can take a quantum leap in representing data. There are so many variables I can monitor, different attributes of different stocks, abnormal volume or occurrences, fundamental inefficiencies. The output of 45 different reports could be summed up in the behaviour of a polygon that changes color, blinks or spins, behaves in a

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pre-set way to instantly communicate with the manager what has happened to that security." (Pimentel and Teixeira 1995, p245.)

This principle could be applied to any situation where an individual has an interest in absorbing large amounts of information quickly. VR could thus bring substantial benefits in banking, market research, or document retrieval (Cugini et al 1996) and indeed in any form of research where the subject of interest is quantifiable.

VR is also being used to visualise objects from a perspective that would not be available to the human eye. Thus for example, Philips Semiconductors is using VR models to visualise the fine detail of components on a computer-printed circuit board.

Facilitating Communication

As we have stressed above, VR has the potential to promote easy comprehension and therefore to facilitate better communication across functional and professional boundaries. Modern product development projects are becoming ever more ambitious, and as a result they tend to involve a wider range of professionals. The difficulty facing many R&D managers is that different facets of the design and innovation process tend to be divorced from one another because it is difficult for any one person to have the technical knowledge to understand every aspect of the design of such complex artefacts. VR can alleviate this problem by enabling everyone involved to more clearly visualise the artefact on which they are working before anything is actually constructed. There are many problems associated with integrating complex systems, and often faults in the design of new products are perceived only after several stages of prototyping have been undertaken. If those initial stages of development could be completed in a virtual environment then the resulting costs of errors could be drastically reduced.

We saw some examples of this above in the context of a car manufacturer and an FMCG producer. Another example (introduced to us by the Advanced Interfaces Group at Manchester University) is an oil company developing a new oilrig. The benefits for engineers of being able to walk through a 3D representation of the plans of the rig may be substantial. VR could give them an additional spatial awareness, which it would be impossible to achieve by looking at traditional 2D plans. This may allow them to spot design problems where, for instance, some piping containing hazardous substances may stray too close to other piping to be safe. Many of the problems in designing and constructing such large-scale projects arise because of the difficulty of visualising information from traditional engineering drawings.

However, the potential of VR is much greater than this. By constructing virtual models of engineering projects, it becomes possible for anyone to understand what it will be like to walk around the object in question. In this way engineers can convey their ideas to any number of interested parties -- including people without the technical awareness and accumulated knowledge to understand technical drawings.

Returning to our example of the oilrig, imagine a situation in which the tugboat captain, whose job it is to tow the rig out to sea, is shown a VR representation of the rig. The captain may have little or no knowledge of engineering, and as such is unable to interpret schematic diagrams of the rig. A VR model may be sufficiently realistic for him to identify defects in the design of the rig that would prevent him from towing the rig out to sea. This capacity to involve lay users in the innovation process is an important feature of VR.

Finally, VR can be useful in any situation where costs arise from manipulating physical artefacts. An excellent example where this 3D visualisation can be useful to management is in the design and manipulation of production lines. In most manufacturing companies, if a manager decides to alter the production line in an effort to increase productivity, it will be necessary for the line to be shut down while it is re-arranged. This "down time" may be expensive -- especially if the company is unable to meet the current demand for its products (a likely trigger for the desire to increase output). Any changes that are made to the design of a production line bring with them a degree of uncertainty. The manager in question may realise only after the event that the new layout had practical problems in implementation, and may even prefer to revert to the original design. This sort of problem could have been eliminated if the manager had been able to air the ideas amongst the experienced staff who operate or manage the line. VR offers this possibility, as any number of people, in different geographical locations, can be shown a virtual design in advance of its implementation. In this way, VR becomes a more general-purpose management tool, which can allow a number of people to contribute to a particular managerial decision.

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Obstacles and Concerns

Thus far, this discussion has painted a fairly rosy picture of what VR can do. But if the technology really has all this potential, then why aren't all companies using it? One answer is that many companies have begun to explore applications of VR. Some, indeed, have started to invest on a larger scale, but the majority of investments to date have been small scale in nature.

Of course, VR technology is still relatively new, and has only recently become sufficiently cost-effective for most companies to consider using it. But there are a number of other reasons why the adoption of VR technology to date has been relatively slow. These can be summarised as:

* lack of awareness

* difficulties in constructing VR environments

* difficulties combining VR skill with knowledge of the products and processes being modelled

* fear of empowering employees

* conceptual disruption

* lack of technical standardisation and

* health and safety worries.

First, there is very limited awareness of the capabilities of VR systems and their relevance to business issues. Many people still associate VR purely with games and entertainment, and do not see it as a serious business tool. There is still widespread scepticism about the value of VR to business and industry, and this presents a considerable barrier to the suppliers of VR technology who incur heavy costs in educating customers about the benefits of their products.

Second, exploiting VR applications is not simply an issue of making the technology available for people to use. It is relatively easy for non-expert users to familiarise themselves with how to navigate and interact with virtual environments. Learning how to construct a useful virtual environment is much harder -- not something that can be grasped in a short time. Although VR is undoubtedly a powerful medium for communicating ideas effectively, not everyone will find it easy to translate their ideas into an appropriate form to exploit this new medium.

Third, the creation of useful content for virtual environments entails combining expertise in the use of VR systems with a fundamental understanding of the products and processes that are being modelled. Many VR suppliers market their products and services to a wide variety of end-users, and cannot be expected to understand all the subtleties in each organisational setting. If companies are to exploit VR effectively, they need to acquire a range of VR skills and learn sufficient supporting vocabulary. In addition, the construction of virtual environments will often require inputs both from artistically-gifted individuals and from those with an appropriate grasp of the human factors involved. The tendency of VR to involve may people with different skills is of course a strength -- as we have seen above -- but in the short term will be a factor holding back diffusion.

Fourth, it is possible that in some organisational settings, the process of empowering employees and involving more people in the innovation process could actually create conflicts of interest rather than synergies. For instance, our early case study research has found that some marketing professionals may be resistant to the use of highly interactive media, since they like to be able to control the message conveyed to their audience. VR, by contrast, allows the audience several degrees of freedom in how they explore the message. This does not mean that such barriers will not be overcome, but it may be that only the more innovative organisations can exploit the full potential of VR.

Fifth, building virtual worlds often requires people to re-appraise their understanding of their real world -- inviting them to question many of the basic assumptions in their own conceptual models. In the long term, of course, this can be a very positive activity, but it may be disruptive in the short term.

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Sixth, some users argue that the lack of well-defined technical standards for VR has been a major obstacle to developing useful VR models. In particular, some have spoken of considerable difficulties with interfaces between existing CAD and simulation tools and new VR models. These problems are gradually being solved as the central importance of standards is better understood.

Finally -- and this is an issue particularly relevant to immersive VR -- there are some remaining health and safety concerns that relate to simulation sickness and, in particular, to the use of immersive headgear.

Conclusion

Current use of VR shows that it has great potential to enhance the innovation potential of the company: by increasing its capacity to experiment, by involving more people in the innovation process, and by capturing ideas generated in the innovation process. Many well-known companies are already using VR, for example to explore production layouts and new product designs before commitment, and to improve their understanding of complex data. VR can provide a common visual representation that is understood by all, and as such helps communication between different functions within the organisation and between the organisation and external groups -- such as suppliers and customers. But although the prospects for VR look bright, certain barriers to diffusion currently exist -- problems over incompatible standards, high costs in developing "virtual worlds", and difficulties in linking data from CAD models into VR models. For these reasons, amongst others, many of the early investments in VR have been cautious and tentative. Although none of these barriers are insurmountable, it may be that only the more innovative organisations can fully exploit the potential of VR.

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References

Bubley, D. (1994) Virtual Reality: Video Game or Business Tool? London, Financial Times Management Report.

Cugini, J., Piatko, C. and Laskowski, S. (1996) Interactive 3D Visualisation for Document Retrieval, Visualisation and Virtual Reality Group, Information Technology Laboratory, NIST, Gaithersburg. Economics of Innovation and New Technology (1995) Special issue on IT and the Productivity Paradox, 3, 3/4.

Hamel, G. and Prahalad, C. K. (1994) Competing for the Future, Boston, Harvard Business School Press.

Handy, C. (1994) The Empty Raincoat, London: Hutchinson.

Herlsel, S. K. and Jacobson, J. (1994) Virtual Reality Market Place, Westport: Mecklermedia.

Kalawsky, R. S. (1993) The Science of Virtual Reality and Virtual Environments, Wokingham, Addison-Wesley.

MAPS (1995) Strategic Market Report: Virtual Reality 1995, Market Assessment Publications Ltd.

Monnet, B. J. (1995) Virtual Reality: The Technology and its Applications, Information Market Observatory Working Paper, 95, 3, Luxembourg.

Pimentel, K. and Teixeira, K. (1995) Virtual Reality: Through the New Looking Glass, 2nd Edition, New York: Intel/McGraw-Hill.

Roberts, B. (1995) Reality at Last, PC Week, 12, 45.

Stone, R. J. (1996) A Study of the Virtual Reality Market, Summary document prepared for the Department of Trade and Industry Communications and Information Industries Directorate, London, HMSO.

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# Virtual reality and innovation potential.

Swann G. M. P. (1986) Quality Innovation: The Economic Analysis of Rapid Improvements in Electronic Components, London: Pinter.

Swann, G. M. P. (1997) Virtually a Market? Initial Conditions and the Diffusion of Virtual Reality, ESRC Network of Industrial Economists Annual Conference, Heriot-Watt University, Edinburgh.

Swann, G. M. P., Pandit, N. R. and Watts, T. (1997) The Business Payoff from VR Applications: Pilot Case Studies of Space Planning and Training, Report for Department of Trade and Industry, London.

Thompson, J. (1993) Virtual Reality: An International Directory of Research Projects, Westport: Meckler.

Toffler, A. (1970) Future Shock, London: Pan.

UK VR Forum (1998) Web Site: http://www.ukvrforum.org.uk/

Utterback, J. (1994) Mastering the Dynamics of Innovation, Boston, Harvard Business School Press. VR News, Several Issues 1997-1998

RELATED ARTICLE: Applications of Virtual Reality

John Deere, the World's largest producer of agricultural machinery also makes construction equipment. Its construction division, based in Dubuque, Iowa, has been using VR software developed by Division Limited to create virtual prototypes of new earth-moving equipment. Their involvement in VR began when managers discovered that the Ford Motor Company was using VR for vehicle design. They decided to invest in VR as a means to assess key factors in the design of their construction equipment including aspects such as visibility from the cab, and the ability of the operator to reach the controls. The VR system allows them to evaluate different ergonomic options early in the design process ultimately enabling them to create higher quality prototypes. Other companies in the market for construction vehicles, including Caterpillar inc. have also demonstrated an active interest in VR.

Whilst the first example is aimed principally at the evaluation of ergonomic factors, VR systems have equally been used to enable designers and engineers to gain a greater understanding of other factors like the appreciation of the scale of a prototype, including the aesthetics of a design solution, and the ease of assembling and maintaining prospective products. Both McDonnell Douglas and Boeing have used VR systems to enable their engineers to evaluate the maintainability of their aircraft designs before anything has actually been manufactured.

The applications of VR technology are by no means limited to the engineering and design fields. For example, many applications are emerging in which VR is being used by major corporations as a means to promote awareness of their goods and services. Rank Xerox has used Superscape's VRT software as a sales support tool to help its representatives to promote the benefits of its colour printers to potential customers. Traditionally, staff and dealers have produced local information based on PowerPoint presentations. In contrast, virtual reality environments have enabled Rank Xerox to sell a more attractive vision of its printers. In this application, three virtual rooms have been developed, each depicting key product information (including the functions of the equipment, cost, productivity and quality considerations). The VR environments have the potential to enable its representatives to illustrate the advantages of its products in more compelling ways.

RELATED ARTICLE:

* VR has a number of characteristics that can help to develop some of the features that make an organisation innovative.

* As a result, companies need to think strategically about how they may exploit the potential of VR. The most exciting examples are where companies use VR as a generic tool for a variety of purposes, rather than as a one-off and self-contained application.

* VR is currently being used -- or explored -- by a wide range of companies for training, prototype development and space planning. Particularly promising applications are in facilitating communication and in data visualisation.

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* Since VR suppliers cannot be expected to understand all the subtleties of building environments that are appropriate for each organisational setting, there is a clear need for individuals who can combine expertise in VR systems with competence to the company's needs.

* A number of obstacles remain before most companies will be able to exploit the full potential of VR.

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