



**INTRODUCTORY GUIDE
TO VIRTUAL STUDIOS**

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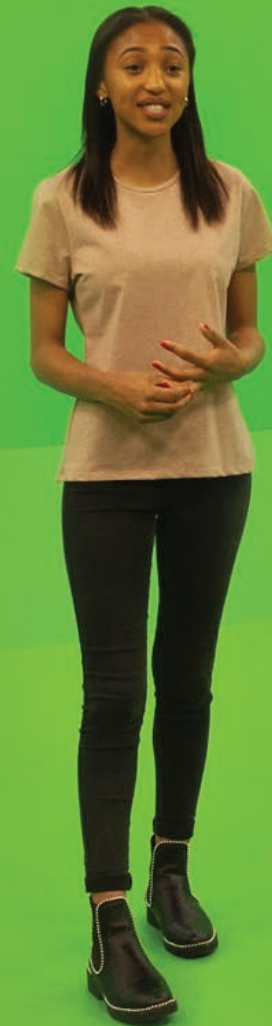
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INTRODUCTION

To understand virtual studios in their current form it is helpful to understand how the needs of content makers helped advance the technology that preceded them. By understanding how we got to where we are today, we will also be able to make some informed predictions of where things are likely to go in the future.

We will look at the types of applications virtual studios are best suited for, and the alternatives.

As each reader is likely to have different levels of knowledge, this document has been structured chronologically so that you can jump forward to a section based on your needs.



PHYSICAL SETS

PHYSICAL SETS: ABOUT

Virtual sets are often judged and compared to their physical counterparts, so it makes sense to start by looking at them first.

Since the early days of cinema, filmmakers have found ways to use artificial backdrops to help make their stories easier to film. It was not always practical to travel to locations depicted in the stories they were telling - especially in harsh or dangerous environments.

As of writing, the majority of television entertainment studio shows continue to use physically built sets. They help to create a unique identity for a show and a visually exciting setting in which the production can take place.



Pros

- Studios allow for protection from changeable weather, as well as controllable and predictable lighting and silent air conditioning (mostly!) - unlike filming outdoors or in buildings not originally designed for filming.
- Soundproofed studios block out outside noises such as building works or traffic that might otherwise ruin important recordings.
- In the modern era, many offer a central location with transportation links, useful for cast, crew, and audiences.
- Filming in a studio with built sets can reduce costs for travel, accommodation and catering compared with location shoots, particularly if you use a local crew.
- Sets allow you to represent fictional places and those otherwise difficult to visit.
- Sets can be stored or kept, being reused for future projects (film and tv nerds enjoy spotting recycled sets from Hollywood films and TV).

Cons

- Sets take time, physical space, and a great deal of manual labour to build so can be expensive the more elaborate they become.
- Larger sets need larger studios which are more expensive to run and to hire.
- The more set you have... the more lighting you need... the more labour you require... the higher the price.
- Storing sets can be expensive and they can sometimes become damaged in transit.

ALTERNATIVES TO FULL-SCALE SETS

ALTERNATIVES TO FULL-SCALE SETS: MODELS

Not every background of every shot needs to be built to scale. Filmmakers found they could create convincing sets, locations, and objects by using small model miniatures to create the illusion of large objects further away.

Whilst the use of miniatures was common for drama and films, their cost meant they were much rarer in television entertainment, which instead formed its own language with sets that did not need to be so 'literal'.



Pros

- Miniatures reduce the amount of space required for convincing 'illusory' environments so they can fit into a studio, allowing filmmakers to benefit from all those advantages outlined in the previous section.
- Unlike locations, models could be stylised to maximise the look and feel of the overall production.
- It is cheaper and quicker to have multiple sets within a studio complex so the team can move swiftly from one to the other, rather than to relocate the whole team over multiple locations.
- Small models are generally cheaper than building big ones!

Cons

- When you get too close to model sets the illusion often falls apart.
- Care needs to be taken to maintain the perspective between the miniature set and real-sized people!

ALTERNATIVES TO FULL-SCALE SETS: GLASS PAINTINGS

Filmmakers used many illusions to fool the audience into what they were seeing.

'Glass' shots allowed for the blending of real sets with elements painted on a sheet of glass. The scene was shot through the glass, obscuring unwanted areas of the set and enhancing the shot with the painted element. Popular in the days of Charlie Chaplin, it was used right through to the 1980s on films such as Star Wars and Indiana Jones.

In the example, Charlie Chaplin can be seen roller skating precariously close to a big drop. You can see how the drop is just a painting.

The elements of design and craft, as well as masks, sometimes known as 'mattes', will recur again later when we get to talk about virtual studios.

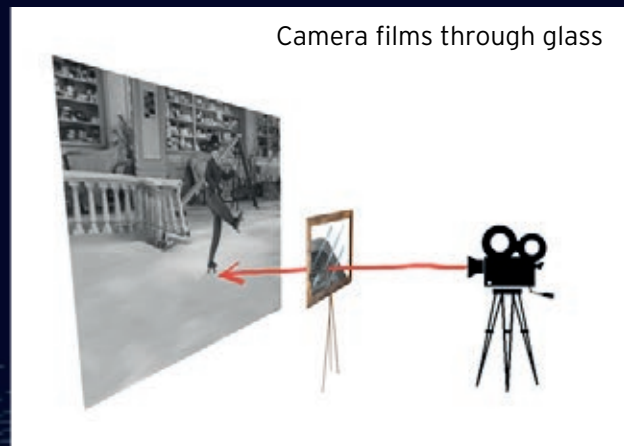
 [Watch video explanation](#)

Pros

- Possible to create a dramatic and impressive scale for the cost of painter, glass, and paint!
- Able to create the illusion of scale in a small space.

Cons

- Need talented artists that can paint photorealistic pictures.
- The camera position cannot be changed as it will destroy the illusion, no good for multicamera setups.
- There can be no movement in the glass shots - they are paintings after all.




ALTERNATIVES TO FULL-SCALE SETS: REAR AND FRONT PROJECTION

A further development, which allowed for movement in the background, was projection.

Projection allows for a composite (combination) of shots filmed at different times. It is most familiar to audiences from countless, unconvincing, driving scenes.

Projection techniques were used as recently as the 1990s on films like Terminator 2.

The combining of different moving picture sources, or 'compositing' as it is usually referred to, is something we'll see later in virtual studios.

 [Watch video explanation](#)



Pros

- Allows you to combine moving pictures.
- Can reduce the risk for your talent, such as the scene in Alfred Hitchcock's North by Northwest when Cary Grant dives forward to avoid being hit by a crop duster aeroplane.
- The illusion is produced 'in camera' meaning that what you see in the camera is what you get. There is no requirement for further technology to achieve the effect.

Cons

- The disparity in colour and sharpness, with projected content often appearing de-saturated (washed out) in comparison to the foreground. This was somewhat overcome with later technology.
- Lots of space can be required for projectors and screens to obtain the right perspective.
- The subtleties between motion in the background and foreground can look odd. This is particularly noticeable when actors driving cars appear to be driving smoothly on a visibly bumpy road.
- The background needs to be filmed beforehand. This can often be expensive and time-consuming as the angles will need to be correct for the projection back in the studio.
- Badly filmed backgrounds can make the 'composite' look very unrealistic.
- You cannot easily replace or 'fix' the background after the sequence has been filmed.
- The effect only works for one camera position. In the above example, the aircraft will always appear to be coming towards the camera, wherever the camera is placed. A new background would need to be shot for a different shot of the foreground actor.

GREEN SCREEN

GREEN SCREEN: ABOUT & HOW IT WORKS

What green screen is, and how it works, is a major part of understanding one of the core elements of a virtual studio.

Green Screen overcomes some of the drawbacks of rear projection. It is an electronic process where a machine 'looks' for a particular colour in a picture (in this case green) and replaces any of this with a different picture. The term 'Green Screen' is a bit of a misnomer, as you could just as easily use a blue screen... or any other pure colour. The colour you use must be different from the parts of the picture that you want to keep. More often than not, we want to keep the actor in the foreground and change the background. One of the main reasons that we chose blue, or green is that human skin doesn't tend to have any blue/green elements; however, men often wear blue suits, so green tends to be used more often. There are other technical reasons to do with green providing a stronger signal, but we don't need to worry about that - suffice to say any colour can be chosen, but it needs to be different to your foreground.

In a traditional film, the green colour is replaced with desired content in post-production, whereas in television it can be achieved live in the studio using what is known as a keyer - a generic description for a piece of hardware or software that enables us to superimpose one TV picture on top of another. The vision mixing desks we have in our studios all have built-in keyers.

Pros

- In the same way, as projected footage, the effect can be produced live in the studio.
- Because you are filming against pure colour, rather than projected footage, the backgrounds can also be shot later and can be composited in post-production.
- The effect can be achieved with just a simple green background. In television, a green screen is used for weather where the presenter can stay in one place in a small studio whilst maps of different areas of the country are shown behind them.

Cons

- Because the background content and foreground are filmed using different cameras at different times, moving either camera can quickly destroy the illusion.
- In the same way as a projection - the effect only works for one camera position. A new background angle would need to be produced for a different foreground shot.

GREEN SCREEN:

OTHER NAMES & HOW A KEYER WORKS

Chromakey - Where 'chroma' means colour and 'key' refers to the process of keying/superimposing one image on top of another.

CSO or Colour Separation Overlay - Using the difference (separation) between colours so the keyer can overlay another image.

These are all different descriptions of the same thing.

HOW A KEYER WORKS

by Michael Lodmore, dock10

A keyer uses three input signals:

Background signal - this is the image that appears behind all the other fill images.

Fill signal - this is the image that appears on top of the background image.

Key signal - this is generated from the fill image by the keyer. Anything in the image that is green is converted to black and everything else is converted to white. This image is used to control which of the background or fill image appears on the final output image. When the key image is black the background image appears on the final output and when the key signal is white it's the fill signal that appears on the final output.

Putting the three images above through our keyer we get this final output signal.

A chroma keyer works in the same way except that the key signal is generated from the fill image.



Background signal



Fill signal



Key signal



Final output signal

COMPUTER GENERATED IMAGES

To understand the next development of the green screen and take a step closer to virtual studios we need to take a diversion into the development of computer graphics!

COMPUTER GENERATED IMAGES: GAME ENGINES, UNITY AND UNREAL

Computers allow for the creation of 3D digital models, like Minecraft or Fortnite. You will no doubt have noticed how the quality of computer game graphics has evolved in leaps and bounds over the years.

This has been brought about by improved hardware capabilities as well as new and better software that can maximise the processing power available to make better games.

'Game Engines' are the software used to build and create video games and they are responsible for drawing ('rendering') graphics, memory management, and much more. 'Unity' and 'Unreal' are game engines. Dock10 uses the 'Unreal Engine' which is made by the same company that developed the game 'Fortnite'. It is also used in Hollywood for work on feature films such as the latest Star Wars films and series.

The latest console games are so powerful that they can 'draw' or 'render' photorealistic graphics so quickly that players can move through these environments in real-time.

In the TV world, this means that instead of using 2D filmed backgrounds, we can now create 3D photo-realistic backgrounds and much like a game, manipulate them in real-time.

We've come a long way from those computer games like 'pong' in the 1970s. The speed and quality of the graphics have continued to improve and improve.

Opposite is actual footage from Unreal Engine 5 Demo.



VIRTUAL STUDIOS

All the previous 'special effects' involved a compromise. The biggest compromise of all was not being able to move the camera (or shoot from different angles) without extensive repositioning and shooting new background footage. Programme makers wanted to shoot on a green screen set just as they would a physical set, recording moving cameras from different angles and directing artists. They wanted to see what the effect looks like there and then and not have to wait until the effect had been composited in post.

Enter the virtual studio!

VIRTUAL STUDIOS: ABOUT

Virtual Studios replace the traditional background with a computer-generated model. In the same way as a computer game works, this makes it possible to move around this model as if it were real. This enables you to change the perspective of the background as you change the camera shot.

Virtual studios have been around since the 1990s and whilst some amazing effects were produced, the graphics often looked very artificial. The computers weren't powerful enough to produce photo-realistic graphics in real-time, so a lower resolution 'proxy' was used with the high-quality image being drawn or 'rendered' by banks of powerful computers after the event. Whilst the finished quality was good, it wasn't possible to be certain of the final output until the rendering had taken place and live broadcasts were not an option.

As we've seen, computers have evolved a great deal since then with improved processing speed and power. This allows for photo-realistic graphics, which more importantly, can now be drawn (rendered) in real-time. So, how do they work?

Both old and new virtual systems are made up of the same components:

- The subject against green screen
- A camera tracking system (so you know the position of the camera and thus what part of the background you need to see)
- A computer-generated background

When the cameras are moved, thanks to the tracking system, the computers know to move the computer environment too, so that when the image is viewed all the elements work together to create a convincing illusion of the subject in the chosen set.

Unlike the virtual studio tech of the past, modern computers can add digital shadows and reflections to make it look as though people are actually situated in their artificial environments.

There are several things you can do with virtual studios that are worth exploring separately.

Pros

- You get all the benefits of shooting in a studio from soundproofing to air conditioning.
- Compared to a physical set, digital sets can be set 'instantly'.
- You can easily switch between complicated sets in a way that would be impossible to do physically, giving content makers much more versatility and variety.
- Large sets don't need large studios, and the size doesn't impact the labour required to put it in.
- Storing sets is cheap and they do not deteriorate over time.
- The 3D computer-generated models have no physical limitations - unlike real-life sets.
- The perspective between the background and foreground is always linked - unlike the previous green screen and painting effect.
- Photorealistic backgrounds can be produced in real-time.
- Live production is possible.
- Because each camera can be tracked individually and backgrounds instantly re-drawn, it is possible to use multiple cameras and cut between them.

Cons

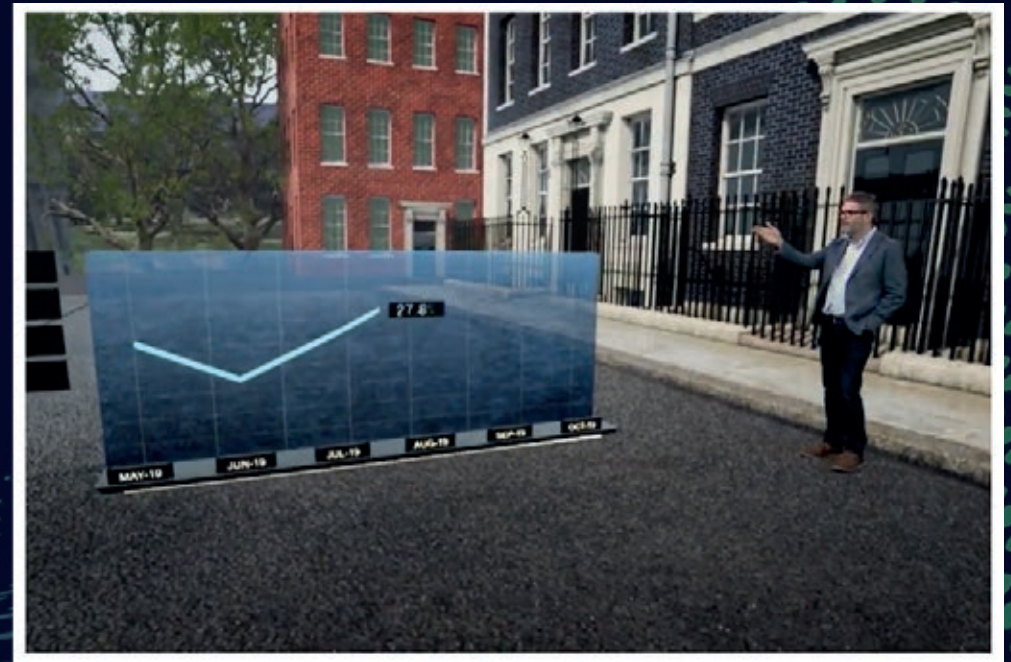
- It takes a lot of disciplines to work together to get a great result.
- Experience in the setup and creation of sets is vital.

VIRTUAL STUDIOS: STATIC AND DYNAMIC MASKS

You can also electronically mask areas of the studio when using a virtual environment. This works in a similar way to the glass shots we explored earlier, effectively painting out parts of the studio or set you don't want people to see and replacing them with another picture - in this case, an extension of your computer-generated background. Again, because this is all computer-generated, it can be re-drawn in real-time and hence used on multiple cameras from different angles.

This means you can give the impression of having sets covering all 4 walls of the studio. When you pan the camera in a circle, you would see a continuation of the virtual environment including items such as a scoreboard or view from a window.

You can take this a step further with Dynamic Masks. These enable you to hide things that can move - such as camera peds etc. This can help to maximise the useable space in the studio and provide wide shots where the crew don't need to hide behind a piece of set or 'camera trap'.



VIRTUAL STUDIOS: HYBRID SETS

It is easy to think of virtual sets as all-encompassing computer-generated sci-fi backgrounds requiring entire studios draped in green - sometimes that's the case, but that's only half of the story.

Virtual sets often work best when 'real' set elements are combined with virtual ones. So, you might have real podiums for a quiz show but the rest of the studio be virtual, offering you the chance to create the illusion of a much bigger space. Green screens are only needed when the artist has to move in front of the background. Some effects are achievable by just using masks - such as using computer-generated video walls to replace LED screens or replacing the lighting grid with a virtual chandelier.

Potentially the show's host could move from a real set to a green screen area, which would feature a virtual set. This could be changed instantly to reflect numerous different backgrounds without a time-consuming reset.



VIRTUAL STUDIOS: VIRTUAL FLYING CAMERAS

It is also possible to transition a shot from a virtual environment to real-life - for example tracking forward from a road through a window into a front room.

In reverse, it is possible to take the viewer in a single, unedited shot, from a physical part of the set out to another area of the digital environment, where the camera operator can move, zoom, focus just as before.



VIRTUAL STUDIOS: PORTAL WINDOWS

This is where physical screens and video walls can be used to show 3D virtual elements so that presenters can see them. It can be combined with AR to dramatic effects - such as having a car drive out of an LED wall in front of the presenter into the studio for example.

Flat videowall or screen



Portal window uses augmented reality to make it appear as if objects come out of the screen



Unlike green screen, the presenter can see the object on the screen



OTHER TYPES OF VIRTUAL STUDIO TECHNOLOGY

OTHER TYPES OF VIRTUAL STUDIO TECHNOLOGY: LED WALLS + UNREAL ENGINE

More common in the feature film world, in this form of virtual studio the green screen is replaced with a video wall. The camera tracking and computer-controlled environment are the same as the green-screen setup. Whilst this technology has some interesting plus points, it is only usable with a single camera and thus somewhat restrictive in the TV environment.



Pros

- LED video wall produces coloured light when it shows the environment. This light will bounce off any subject surrounded by these screens and give some rudimentary reflections.
- Actors and presenters can see the background images and therefore react to them. This can be replicated in green screen virtual studios by using masks with monitors to show talent-relevant content.

Cons

- Unlike a green screen, LED walls have pixels that HD cameras can pick up. These can result in weird effects, so teams need to work hard to get shots that don't destroy the illusion.
- Changing shot size can mean that very large LED walls are required to ensure they aren't in sharp focus. This can mean large studios and expensive screens are required, even for comparatively small scenes.
- Much like a projected background, if you shoot against an LED wall and then want to go back and revise it, it's not easy. Whereas if you have filmed against green screen, you can always revise/change later.

OTHER TYPES OF VIRTUAL STUDIO TECHNOLOGY:

AUGMENTED GRAPHICS

Often abbreviated to AR, augmented reality is where computer-generated elements are superimposed on top of the real world. Combined with a virtual environment it can create something much more immersive. The computer graphics in the foreground can be anything from title cards to three-dimensional charts and images, and moving objects such as cars.

Again, using the camera tracking technology, it is possible to move around these objects as if they were there in real life. The computer redraws the object in real-time from the perspective of whichever camera you choose.

TELEPORTATION

People filmed in one studio against a green screen can be made to appear in a virtual studio at a completely different location. It is possible to do a 2-way interview with a football manager, moments after the game, and have it appear as if they are physically in the studio with hosts - even though they might be hundreds of miles apart.

TALENT TRACKING

In the same way in which cameras have trackers for computers to know where they are in the physical environment, it is possible to place trackers on presenters so that computers 'know' where they are too. This enables presenters to be able to walk around computer-generated objects as if they were physically there. The computer redraws the object from the perspective of the camera dependent on whether it is being obscured by the presenter or not.

OTHER TYPES OF VIRTUAL STUDIO TECHNOLOGY: MOTION CAPTURE

Sometimes referred to as mo-cap, it is where a person can wear a suit containing sensors that track their movement and translate them into a computer model. Those movements can then be used to animate a digital character or an avatar which can then be included in a virtual environment. It can be used for puppetry or to replace traditional animation and allows the 'character' to interact with other people in real-time. You could even interview Wallace and Grommet on the set of their latest film - and they could respond in real-time.





FUTURE

FUTURE:

PLENOPTIC CAMERAS/LIGHT FIELD

Current cameras work by recording the intensity of the light to create flat 2D images. Plenoptic cameras or light field cameras can also record the direction from which the light rays are travelling and can create the 'light field' of a scene - in effect recording 3D information of a scene. These kinds of cameras are already being used on top-end mobile phones for applications such as measuring objects using only the camera.

Because depth information is captured, it becomes possible to do 'depth keying' where you can superimpose subjects based on their relative position to the camera, effectively removing the need for the green screen as well as offering an alternative to talent tracking, so presenters can move around digital elements more naturally.

ARTIFICIAL INTELLIGENCE

AI is already able to upscale footage to higher resolutions, add colour to black and white images, and remap real facial movements onto digital avatars. As it becomes better and quicker at identifying people, we can expect AI-enhanced keying, and motion capture without the need for trackers.

GLOSSARY OF TERMS

VIRTUAL PRODUCTION (VP)

A broad term for anything that uses computer-generated 3D images in real-time during filming. It encompasses green screen-based virtual studios as well as LED volume stages (see below). Virtual productions use camera tracking technology and game engines to allow programme makers to mix live footage with 3D images at once on a set.

LED VOLUME

Virtual productions that use LED volumes have grown in popularity in recent years, with *The Mandalorian* the most famous example. Actors perform on a physical set in a studio in front of a giant array of LED screens which feature images of real-world or computer-generated environments. The set-up is not unlike the projected backgrounds filmmakers have been using since the silent era. The difference is that it's smart. Harnessing a real-time engine, it responds to the movement of the on-set camera by adjusting the perspective, lighting, and other elements within the panels. The technology allows filmmakers to capture effects in-camera and real-time and lends itself best to single camera shoots - such as film, drama and commercials.

VIRTUAL STUDIO

A multicamera studio that uses game engines, camera tracking technology and green screens to place presenters and audiences in realistic 3D sets that can be manipulated in real-time. dock10 employs its virtual studio technology to create virtual sets for BBC Bitesize Daily, Match of the Day and the FIA GT World Championships. Virtual studios are often used for live news and sports programmes. Virtual studios allow productions to create more imaginative sets, can help save money on transportation and storage, are more environmentally friendly and are quicker to set up than real sets. Despite the set being virtual, you can still have multiple camera angles and superimpose additional images.

HYBRID SET

A cross between a traditional and a virtual set. A hybrid set has many of the physical elements that feature in a traditional set, such as desks, chairs and staging - but is enhanced with a virtual backdrop. This allows, say, entertainment shows to make their

physical sets seem much bigger, giving productions a bigger bang for their buck. In essence, a hybrid set is a digital set extension.

VOLUMETRIC CAPTURE

A technology that converts a person, object, or place into 3D digital data and reproduces it as a high-quality 3D image. To do this, many precisely synchronised cameras surround the person or object and capture them from many angles. The recorded video is processed through reconstruction software, which results in a 3D avatar of the performer - a solid, moving model of the performer which can be viewed from all angles. Sky Sports has used the technology to enhance its golf and cricket coverage.

MOCAP

Stands for motion capture, the art of capturing the physical movement of a person and translating it into the action of a computer-generated 3D character on screen to give it greater levels of realism. There are two main types of motion capture technology. Inertial motion capture tracks the positional data of a performer using motion sensors attached to a capture suit. Optical tracking allows cameras to track reflective stickers on a performer's capture suit. Optical tracking is sometimes referred to as an 'outside in' tracking solution as the cameras are placed outside the performance area tracking an object inside.

FACECAP

Refers to the capturing of the physical movements of a person's face and translating it into a digital model. A head mounted camera records facial expressions and / or dialogue to fully capture the intricacies of a performance for a digital character, from blinks to smiles and frowns.

VIRTUAL REALITY (VR)

A computer-generated three-dimensional environment that a user can freely explore, most often via a headset such as the Oculus Quest 2 or HTC Vive. Largely created through gaming software, VR transports the user to another location and often allows them to interact with it.

GLOSSARY OF TERMS CONTINUED

AUGMENTED REALITY (AR)

Augmented reality in television enhances productions by adding 3D computer-generated images, usually to the foreground of a virtual or physical set. It could be a scoreboard, Premier League football table, or an image of an actor or politician. AR can be used in any studio setting, not just a green screen studio. The CGI elements of AR don't interact with their environment but simply enrich it.

UNREAL ENGINE

A powerful game engine, developed by Epic Games, that has established itself as a widely used 3D creation tool that delivers real-time photorealistic graphics. Initially developed for the games industry, it has since been adopted by many other industries. In the TV, film and advertising industries Unreal Engine is now widely used to build the 3D worlds used in virtual productions.

ZERO DENSITY

A control application and chroma keying solution for Unreal Engine that acts as an interface for the broadcast industry to control virtual elements of a production. Virtual elements are built in Unreal Engine, then effectively imported into Zero Density where they can be controlled, customised and automated from a single hub.

MO-SYS

A UK-based company that manufactures advanced and innovative camera robotics and virtual production technologies. The Mo-Sys product range spans remote heads (cameras that can be controlled from a distance), motion control, broadcast robotics, and camera tracking for AR, VR and VP. Not to be confused with MoCap – see above.

STARTRACKER

A camera tracking system from Mo-Sys. The system looks at "stars" – reflective stickers applied to a studio ceiling – which allows StarTracker to report the position and orientation of the studio camera in real-time to the rendering engine. Multiple cameras in the studio can track off the star map. Once calibrated, the system is fully automatic. This is sometimes referred to as an 'inside out' tracking solution; the StarTracker camera is mounted inside the capture area looking for the reflective stickers that are outside the area.

CG AND CGI

CG (computer graphics) and CGI (computer graphics images) are two abbreviations used interchangeably in the TV industry which essentially mean the same thing: images that have been created with the aid of a computer. The images could be anything from an augmented reality scorecard through to a virtual set backdrop.

VIRTUAL STUDIOS DEVELOPER (VSD)

A new-ish role in broadcast production that describes someone whose job it is to design virtual sets. They will be familiar with Unreal Engine and Zero Density. Many VSDs tend to come from the games industry where they have learnt to create computer graphics on Unreal Engine and are now applying their skills to the broadcast sector.

VIRTUAL STUDIOS OPERATOR (VSO)

Another new-ish role in the broadcast sector. A VSO sits in the studio's lighting gallery and is responsible for monitoring the quality of the computer-generated pictures during a live production on a virtual set. They will check the keying and masking, and work alongside the lighting director to make sure that any physical elements or presenting talent fit seamlessly alongside any virtual or augmented elements.

RAY TRACING

A real-time rendering technique used for creating realistic and dynamic lighting in real-time in virtual environments. Ray tracing simulates how light behaves in the real world to produce the realistic and immersive graphics.

XSENS

A company that manufactures motion capture products. Xsens' wearable sensors register the movements of a performance artist, and the tracking data is then used to create digital characters. dock10 uses Xsens' mo-cap sensors to create the AR robot character 'Clogs' for BBC Bitesize Daily.

MVN ANIMATE

Xsens's motion capture software which exports all the real-time tracking data from its sensors to a users' 3D package. MVN Animate offers real-time 3D animation, graphs, data streaming and video.